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Level: CIE AS and A Level (9701)
Subject: Chemistry
Topic: CIE Chemistry
Type: Topic Question

Chemistry CIE AS & A Level
To be used for all exam preparation for 2025+

CHEMISTRY AS and A

This to be used by all students studying CIE AS and A level Chemistry (9701) But students of other boards may find it useful

Question 1.

(a) The structure of a halogenoalkane containing bromine is shown in Fig. 1.1.

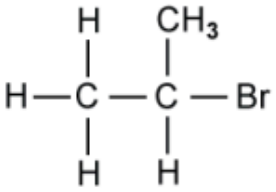


Fig. 1.1

i) Name the compound shown in Fig. 1.1.

[1]

ii) State the class of halogenoalkane to which this compound belongs.

[1]

(2 marks)

(b) State the colour of the precipitate formed in the reaction between the halogenoalkane in Fig. 1.1 in part **(a)** and acidified silver nitrate, $AgNO_3$.

(1 mark)

(c) The compound drawn in Fig. 1.1 in part **(a)** is reacted with alcoholic potassium cyanide, KCN. The reaction is heated under reflux.

Draw the product of this nucleophilic substitution reaction.

(1 mark)

(d) The halogenoalkane drawn in Fig. 1.2 contains a chlorine atom instead of a bromine atom. This halogenoalkane is reacted under the same conditions outlined in part **(c)**.

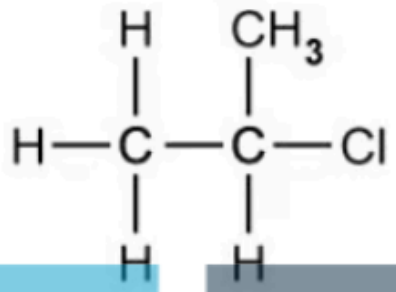


Fig. 1.2

The reaction for a halogenoalkane containing bromine would be faster than if the compound in Fig. 1.2 was used. Briefly explain why this reaction would be faster.

(2 marks)

Question 2.

(a) Fig. 2.1 shows the reaction profile for the production of propene.

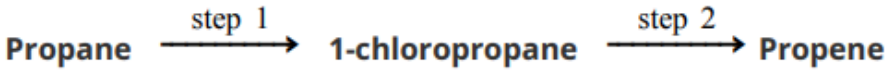


Fig. 2.1

i) State the conditions required for step 1.

[2]

ii) Name the mechanism for step 1.

[1]

(3 marks)

The mechanism for step 1 in part **(a)** involves three different steps, initiation, propagation and termination.

Initiation:
$Cl_2 \rightarrow 2Cl\bullet$

Propagation:
Equation 1
Equation 2

Termination:
$Cl\bullet + CH_3CH_2CH_2\bullet$

The two propagation steps are missing. Write both of the equations that are required for this step.

(b) **(2 marks)**

(c) i) Name the mechanism for step 2.

[1]

ii) State the reagent and necessary conditions for step 2.

[3]

(4 marks)

Question 3.

(a) Many of the reactions of halogenoalkanes involve a nucleophile attacking the carbon attached to the halogen atom. The nucleophile replaces the halogen atom in a nucleophilic substitution reaction.

The mechanism for the reaction is determined by the structure of the halogenoalkane. Primary and tertiary halogenoalkanes react via different reaction mechanisms.

i) State what is meant by the term tertiary halogenoalkane.

[1]

ii) Tertiary halogenoalkanes react via an S_N1 mechanism, whereas primary halogenoalkanes react via an S_N2 mechanism.

Explain what the numbers 1 and 2 refer to in S_N1 and S_N2.

[1]

(2 marks)

(b) 2-bromo-2-methylpropane reacts with hydroxide ions via an S_N1 mechanism.

i) The incomplete reaction mechanism for the reaction is shown in Fig. 3.1
Complete the reaction mechanism shown in Fig. 3.1 clearly showing any partial charges, full charges and the transfer of electrons.

[3]

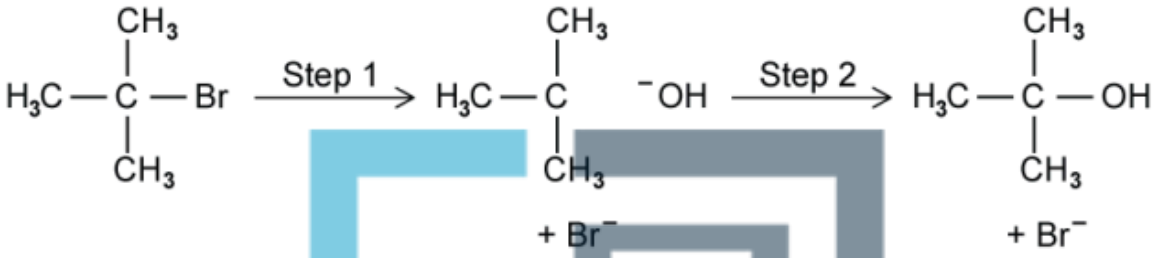


Fig. 3.1

ii) Identify which, step 1 or step 2, is the rate-determining step.

[1]

(4 marks)

(c) An ethanolic solution of excess ammonia (NH_3 in ethanol) is heated under pressure with 2-bromo-2-methylpropane.

i) Draw the structure of the resulting organic product.

[1]

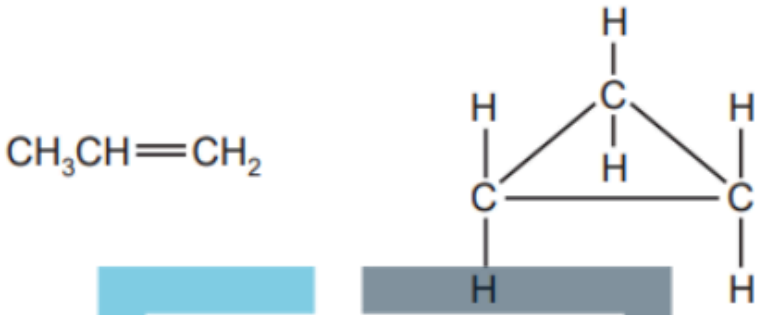
ii) State the name of the functional group of the organic product.

[2]

(3 marks)

Question 4.

(a) The molecular formula C_3H_6 represents the compounds propene and cyclopropane are shown in Fig. 1.1.



propene cyclopropane

Fig. 1.1

What is the H–C–H bond angle at the terminal $=CH_2$ group in propene?

(1 mark)

(b) Under suitable conditions, propene and cyclopropane each react with chlorine.

i) With propene, 1,2-dichloropropane, $CH_3CHClCH_2Cl$ is formed.
State fully what type of reaction this is.

[1]

ii) When cyclopropane reacts with chlorine, **three** different compounds with the molecular formula $C_3H_4Cl_2$ can be formed.
Draw displayed structures of each of **these** three compounds.

[3]

(4 marks)

(c) Ethane reacts with chlorine according to the following equation.

$$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$$

i) State the conditions needed for this reaction.

[1]

ii) State the type of reaction occurring here.

[1]

(2 marks)

(d) i) One of the steps during the reaction in **(c)** is the following process.

$$Cl\bullet + CH_3CH_3 \rightarrow HCl + CH_3CH_2\bullet$$

Table 1.1

Bond	Bond enthalpy / kJ mol^{-1}
C–H	410
H–Cl	431
H–I	299

Use the data in Table 1.1 to calculate the enthalpy change, ΔH, of this step.

Show your working.

[1]

ΔH = ... kJ mol^{-1}

ii) Use the data in Table 1.1 to calculate the enthalpy change, ΔH, of the similar reaction:

$I\bullet + CH_3CH_3 \rightarrow HI + CH_3CH_2\bullet$

Show your working.

[1]

ΔH = ... kJ mol^{-1}

iii) Hence suggest why it is not possible to make iodoethane by reacting together iodine and ethane.

[1]

(3 marks)

(e) Complete the following equations of some possible steps in the formation of chloroethane.

$Cl_2 \rightarrow$ .....

$Cl\bullet + CH_3CH_3 \rightarrow HCl + CH_3CH_2\bullet$

$CH_3CH_2\bullet$ + ... → ..... + ...

..... + ... → CH_3CH_2Cl

(3 marks)

Question 5.

(a) This question concerns halogenoalkanes.

1-chloropropane can react to form organic products as shown in the reaction scheme in Fig. 2.1.

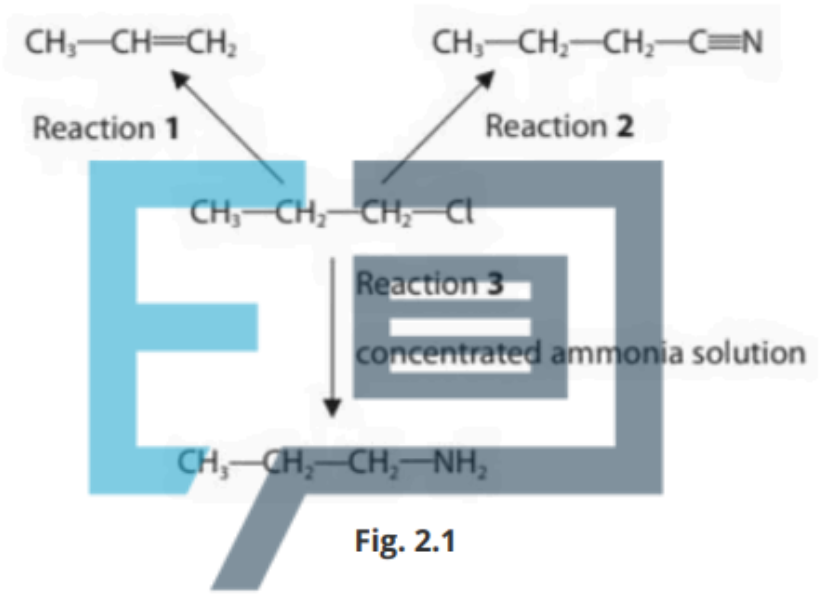


Fig. 2.1

i) State the reagent and conditions used in Reaction 1.

[2]

ii) Identify a suitable reagent for Reaction 2 and include a reason why this is a particularly useful type of reaction in organic chemistry.

[2]

Reagent .....

Reason .....

iii) State the conditions which are used in Reaction 3.

[2]

iv) Write the structural formula of the product that will be formed if 1-chloropropane is refluxed with aqueous sodium hydroxide solution.

[1]

(7 marks)

(b) 2-chloro-2-methylpropane can be reacted with aqueous alkali to form 2-methylpropan-2-ol.

The equation for this reaction is

$$(CH_3)_3CCl + OH^- \rightarrow (CH_3)_3COH + Cl^-$$

The graph in Fig 2.2 shows how the concentration of 2-chloro-2-methylpropane changes with time during an investigation of this reaction.

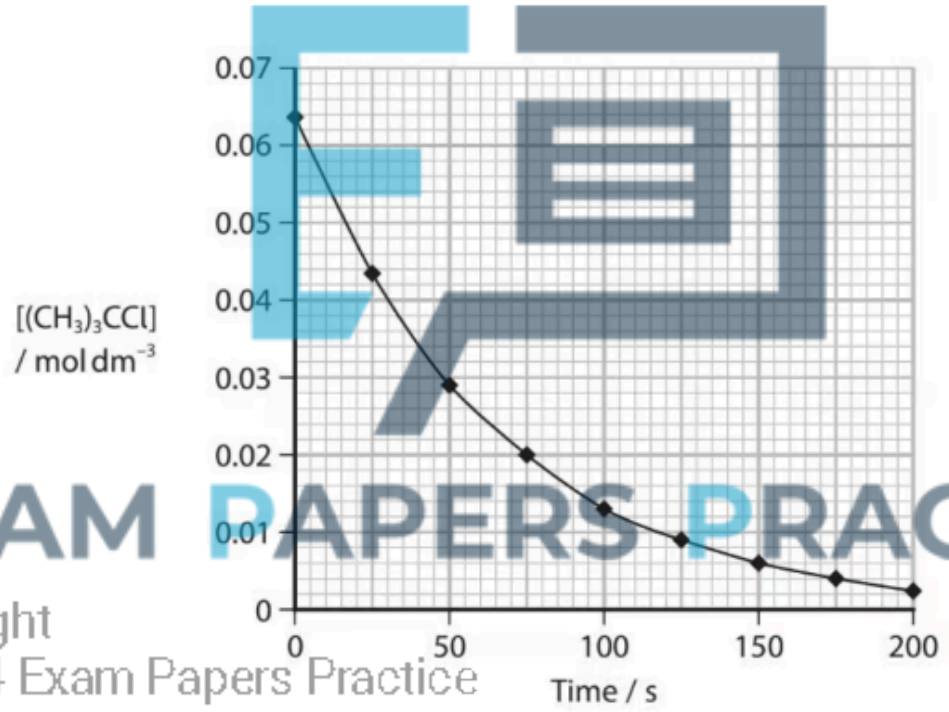


Fig. 2.2

Calculate the rate of reaction at 50 s. Show your working on the graph.
Include units with your final answer.

Rate of reaction at 50 s = ...

(3 marks)

(c) What is the classification of the mechanism for the reaction of 2-chloro-2-methylpropane with aqueous alkali?

(1 mark)

(d) The letters **X**, **Y** and **Z** refer to three different halogenoalkanes:

X	1-bromobutane
Y	1-iodobutane
Z	1-chlorobutane

1 cm^3 of each of these halogenoalkanes was added to separate test tubes containing 5 cm^3 of ethanol and 5 cm^3 of aqueous silver nitrate solution in a water bath at 50 °C.

i) State the visible change in the reaction of an ethanol/silver nitrate solution with halogenoalkane **X**.
Include the **formula** of the compound responsible for this observation.

[2]

ii) The three halogenoalkanes were placed in order of **decreasing** rate of reaction.
State the order, starting with the halogenoalkane that reacted the fastest

[1]

(3 marks)

(e) 2-bromo-2-methylpropane can be prepared from the addition of hydrogen bromide, HBr, to 2-methylpropene.

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

(4 marks)

Question 6.

(a) One method of making 1-bromobutane in the laboratory is described below.

Step 1 Place 35 g of powdered potassium bromide, 30 cm^3 of water, and 25 cm^3 of butan-1-ol, in a 250 cm^3 two necked flask fitted with a tap funnel and reflux condenser.

Step 2 Concentrated sulfuric acid (25 cm^3) is then placed in the tap funnel and added drop by drop to the reagents in the flask, keeping the contents well shaken and cooled occasionally in an ice-water bath.

The overall reaction may be considered to take place in two stages. In the first stage, the inorganic reagents react together to form HBr. In the second stage, the organic reagent reacts with the HBr that is formed in the first stage.

Write an equation for each of these stages.

Stage 1 .....

Stage 2 .....

(2 marks)

(b) 1-bromobutane can be prepared using different reagents and conditions.

State **two** different ways that 1-bromobutane can be prepared.
In each case, include the reagents and conditions that are necessary

(2 marks)

(c) i) Complete the following reaction scheme shown in Fig. 3.1 which starts with 1-bromobutane.

In each empty box, write the structural formula of the organic compound that would be formed.

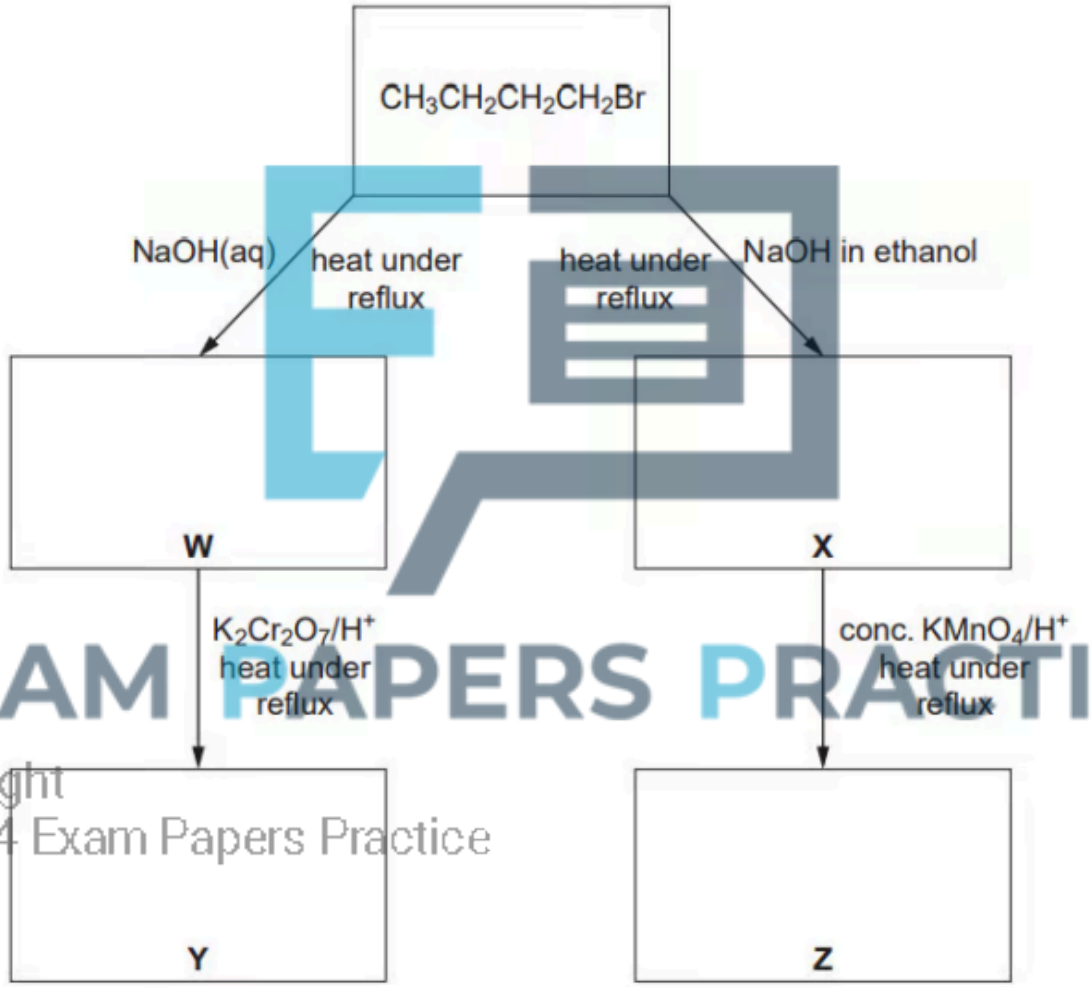


Fig. 3.1

ii) State the name of the type of reaction that occurs when **X** is produced from 1-bromobutane.

(5 marks)

(d) Compound **W** can also be formed from 1-bromobutane by heating it under reflux with aqueous silver nitrate. This causes the hydrolysis of 1-bromobutane.

Suggest why the rate of the formation of compound **W** is slower using this method than heating under reflux with aqueous sodium hydroxide.

(2 marks)

Question 7.

(a) This is a question about the hydrolysis of halogenoalkanes.

Devise an experiment, giving outline details only, that would enable the relative rates of hydrolysis of halogenoalkanes to be compared.

(5 marks)

(b) Explain the trend in the rates of hydrolysis of 1-chlorobutane, 1-bromobutane and 1-iodobutane.

(2 marks)

(c) The product of the hydrolysis of 2-bromobutane is butan-2-ol. Both molecules are chiral.

State what is meant by the term **chiral**, using three-dimensional diagrams of the enantiomers of butan-2-ol to illustrate your answer.

(3 marks)

(d) Compare and contrast the mechanism of hydrolysis, using aqueous sodium hydroxide, of the primary halogenoalkane, RCH_2X, with that of the tertiary halogenoalkane, R_3CX. Include diagrams of any intermediate or transition state.

Curly arrows are not required.

(6 marks)

Question 8.

(a) Give the structures of the four structural isomers of C_4H_9Br **and** identify each as primary, secondary or tertiary.

(4 marks)

(b) Name the isomer of C_4H_9Br that contains a chiral centre and draw the three-dimensional structures of the two optical isomers.

name .....

structures

(3 marks)

(c) Aqueous silver nitrate solution was added to separate tubes containing chloroethane, bromoethane and iodoethane. The tubes were heated in a water bath.

A yellow precipitate appeared first in the tube containing iodoethane, followed by a cream precipitate in the tube containing bromoethane and finally a white precipitate appeared in the tube containing chloroethane.

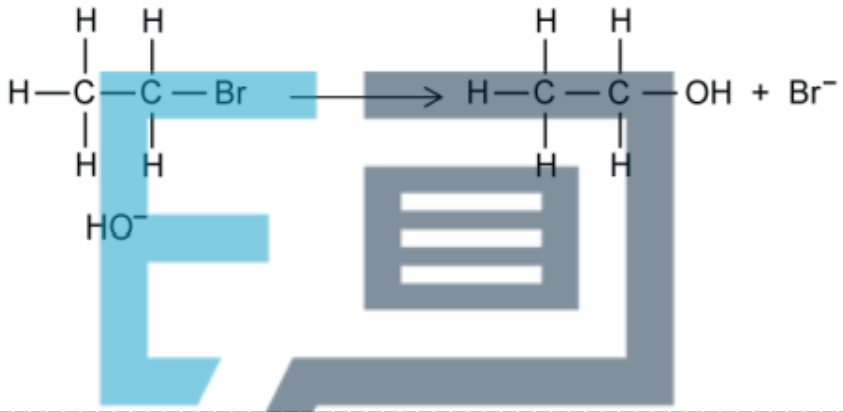
Explain these observations.

(2 marks)

(d) i) Give the full name of the mechanism for the reaction between aqueous sodium hydroxide and bromoethane.

[2]

ii) Complete the diagram below to represent this mechanism. Include all necessary curly arrows, partial charges and lone pairs.



[2]

(4 marks)

(e) Primary and teriary halgenoalkanes have different reaction mechanisms when they react with aqueous sodium hydroxide.

i) State the name that is given to the reaction mechanism when aqueous sodium hydroxide is reacted with the following types of halogenoalkane.

primary halogenoalkane .....

tertiary haologenolkane .....

[2]

ii) Tertiary halogenoalkanes form a tertiary carbocation as an intermediate during this reaction. Explain why tertiary carbocations are more stable than primary carbocations.

[3]

(5 marks)

Question 9.

(a) This question is about halogenoalkanes.

A student investigates the rate of reaction of six halogenoalkanes using the following method.

1. Mix ethanol with six drops of halogenoalkane.
2. Warm the mixture in a water bath at 50 °C.
3. Add silver nitrate solution.
4. Record the time taken for the precipitate to form.

Table 1.1 shows the student's results.

Table 1.1

Halogenoalkane	Time taken for the precipitate to form (s) at 50 °C
$CH_3CH_2CH_2CH_2CH_2Cl$	265
$CH_3CH_2CH_2CH_2CH_2Br$	152
$CH_3CH_2CH_2CH_2CH_2I$	65
$CH_3CH_2CH_2CHBrCH_3$	88
$(CH_3)_2CHCHClCH_3$	190
$CH_3CH_2C(CH_3)_2Cl$	88

i) Suggest how the student could improve the method.

[3]

ii) Other than precipitation, state what type of reaction is occurring in this method.

[1]

(4 marks)

(b) Using Table 1.1, describe and explain **two** factors that influence the rate of this type of reaction in halogenoalkanes.

(4 marks)

(c) A fresh sample of aqueous 1-bromopentane reacts with an aqueous solution of sodium hydroxide.

i) Fully identify the mechanism for this reaction and state the number of steps in the mechanism.

[1]

ii) One of the products contains bromine. Name this product.

[1]

iii) The reaction conditions are changed resulting in the formation of three products, including the product identified in part **(c)(ii)**.

Suggest the change that is made to the conditions.

[1]

(3 marks)

(d) 1-chloropentane was prepared in the laboratory by the reaction of an alcohol and thionyl chloride, $SOCl_2$.

Two additional products are also produced in this reaction.

i) Give the equation, including state symbols, for the preparation of 1-chloropentane.

[2]

ii) Explain **one** safety precaution necessary for carrying out this reaction. Justify your answer.

[2]

(4 marks)

Question 10.

(a) This question is about the reactions of halogenoalkanes.

2-bromo-2-methylpropane is refluxed with ethanolic potassium hydroxide, KOH. The result is a mixture of products containing roughly a 4 : 1 ratio of alkene to alcohol.

Complete Table 2.1 to name the organic products and identify the mechanisms involved.

Table 2.1

Organic product	Name	Mechanism involved
Alkene		
Alcohol		

(2 marks)

(b) Suggest why there is a mixture of an alkene and an alcohol produced in the reaction outlined in part **(a)**.

(2 marks)

(c) An iodoalkane is prepared by the reaction of red phosphorus, P, with iodine, I_2, to produce phosphorus(III) iodide, PI_3. This then is reacted with an alcohol to produce the iodoalkane and phosphorous acid, H_3PO_3.

Give the equation for the reaction between butan-2-ol and phosphorus(III) iodide.

(2 marks)

(d) During a series of reactions to produce a bromoalkane, a 50 : 50 mix of sulfuric acid and water is reacted with potassium bromide to produce hydrogen bromide. The mixture is kept very cool.

Explain why sulfuric acid can not be used in the preparation of an iodoalkane

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(1 mark)

Question 11.

(a) Compound **G** is a chloroalkane that can undergo two different reactions as outlined in Fig. 3.1.

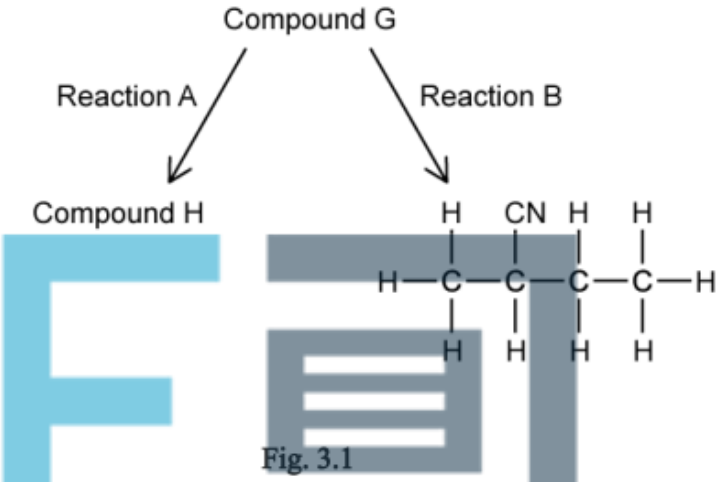


Fig. 3.1

Compound **H** is an alkene which does not exhibit geometric isomerism.

Draw the skeletal structures of compounds **G** and **H**.

(2 marks)

(b) State the reagents and conditions that will be required for reaction **A** in Fig. 3.1.

(2 marks)

(c) Name and draw the mechanism for reaction **B** in Fig 3.1. Include all charges, partial charges, lone pairs and curly arrows.

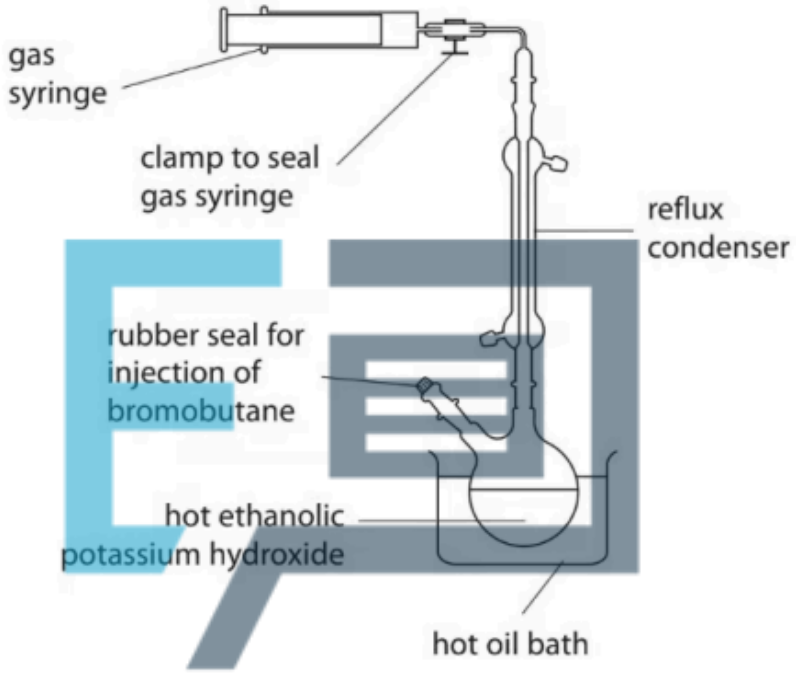
(4 marks)

Question 12.

(a) Bromobutanes react with hot ethanolic potassium hydroxide solution to produce gaseous butenes.

$$C_4H_9Br + OH^- \rightarrow C_4H_8 + Br^- + H_2O$$

Apparatus



Procedure

- 0.0080 mol of liquid 1-bromobutane was injected into a round bottom flask containing hot ethanolic potassium hydroxide.
- After the reaction, the syringe was sealed using a clamp.
- The syringe was then removed from the apparatus and allowed to cool to 25°C.

Result

- The final volume of but-1-ene collected was 22.0 cm^3.

State the purpose of the condenser.

_____

(1 mark)

(b) Describe a chemical test and the expected observation to identify the functional group of the gas in the syringe.

(3 marks)

(c) Calculate the percentage of 1-bromobutane which was converted to but-1-ene.

(2 marks)

(d) Before cooling, the volume of but-1-ene in the gas syringe was 24.0 cm^3.

Assuming a constant pressure and that no but-1-ene is lost from the gas syringe during cooling, calculate the temperature of the gas in the syringe.

Temperature = ...

(2 marks)

(e) i) Another compound formed from 1-bromobutane under these conditions is butan-1-ol.

Fully identify the type of reaction taking place to form butan-1-ol.

[1]

ii) Draw the mechanism for the reaction of 1-bromobutane with hydroxide ions to form butan-1-ol. Include all charges, partial charges, lone pairs and curly arrows.

[3]

iii) Describe a chemical test and the expected observation(s) to confirm the presence of the functional group in butan-1-ol.

[2]

(6 marks)

(f) Isomeric alkene molecules are formed in the elimination reaction of 2-bromobutane.

Draw the displayed formulae of the isomers formed during this reaction.

(3 marks)