A-Level Chemistry

Free Radical Substitution

Question Paper

Time available: 59 minutes
Marks available: 54 marks

1. Haloalkanes are used as refrigerants, solvents and anaesthetics.

(a) Trichloromethane ($CHCl_3$) is a haloalkane that can be formed by heating a mixture of chloromethane (CH_3Cl) and chlorine.

(i) Write an overall equation for the formation of trichloromethane by the reaction of chloromethane with chlorine.

_____

(1)

(ii) Name the mechanism for this formation of trichloromethane.

_____

(1)

(iii) Dichloromethane (CH_2Cl_2) is an intermediate in this formation of trichloromethane.

Write an equation for each of the following steps in the mechanism for the reaction of dichloromethane with chlorine.

Initiation step

_____

First propagation step

_____

Second propagation step

_____

A termination step leading to the formation of a compound with formula $C_2H_2Cl_4$

_____

(4)

(b) Chlorotrifluoromethane ($CClF_3$) is used as a refrigerant, but is being phased out due to concerns about ozone depletion in the upper atmosphere.
In the upper atmosphere, $CClF_3$ decomposes in the presence of UV light forming a reactive intermediate that catalyses the decomposition of ozone.

(i) Write an equation to show how $CClF_3$ decomposes to form the reactive intermediate.

_____

(1)

(ii) Write two equations to show how this reactive intermediate is involved in catalysing the decomposition of ozone.

1. _____

2. _____

(2)

(Total 9 marks)

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

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

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

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

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

Initiation step

_____

First propagation step

_____

Second propagation step

_____

A termination step

_____

(4)

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

_____

(1)

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

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

$$CBrF_3 \longrightarrow \underline{\qquad\qquad} + Br^{\bullet}$$

(1)

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

Suggest **one** reason for this.

_____

_____

_____

(1)

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

$$2O_3 \longrightarrow 3O_2$$

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

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

Equation 1

_____

Equation 2

_____

Explanation _____

_____

_____

(3)

(Total 10 marks)

3. This question is about 2-bromopropane.

(a) Define the term electronegativity.

Explain the polarity of the C–Br bond in 2-bromopropane.

Electronegativity _____

_____

_____

Explanation _____

_____

_____

(3)

(b) Outline the mechanism for the reaction of 2-bromopropane with an **excess of ammonia**.

(4)

(c) Draw the skeletal formula of the main organic species formed in the reaction between a **large excess of 2-bromopropane** and ammonia.

Give a use for the organic product.

Skeletal formula

Use _____

(2)

(Total 9 marks)

4. Bromoethane reacts with potassium cyanide to form compound D.

$$CH_3CH_2Br + KCN \rightarrow CH_3CH_2CN + KBr$$

Compound **D**

(a) Outline the mechanism for this reaction.

(2)

(b) Give the IUPAC name of **D**.

_____

(1)

(c) Calculate the percentage atom economy for the formation of **D** in this reaction.

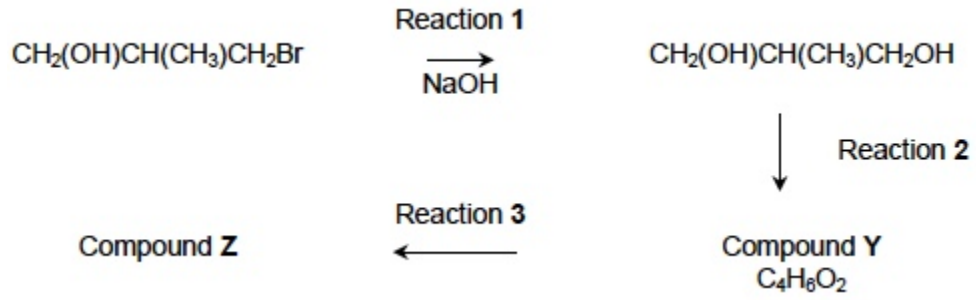
Give your answer to the appropriate number of significant figures.

% atom economy _____

(2)

(Total 5 marks)

5. Halogenoalkanes are useful compounds in synthesis. A reaction pathway is shown.



(a) Give the IUPAC name for $CH_2(OH)CH(CH_3)CH_2Br$

(1)

(b) Reaction **1** occurs via a nucleophilic substitution mechanism.

Explain why the halogenoalkane is attacked by the nucleophile in this reaction.

(3)

(c) The infrared spectrum of Compound **Y** shows a significant absorption in the range 1680–1750 cm^{-1}

Draw the displayed formula of Compound **Y**.

(1)

(d) Compound **Z** has the empirical formula C_3H_4NO

Give the structure of Compound **Z**.

Suggest the reagent for Reaction **3**.

Structure

Reagent for Reaction **3** _____

(2)

(Total 7 marks)

6. 2-Methylpropan-1-ol can be prepared by reacting 1-bromo-2-methylpropane with dilute aqueous sodium hydroxide.

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

Name of mechanism _____

Mechanism

(3)

(b) When 2.0 cm^3 of 1-bromo-2-methylpropane (M_r = 136.9) were reacted with an excess of sodium hydroxide, 895 mg of 2-methylpropan-1-ol (Mr = 74.0) were obtained.

The density of 1-bromo-2-methylpropane is 1.26 g cm^{-3}

Calculate the percentage yield for this reaction.

Percentage yield _____

(3)

(c) When 1-bromo-2-methylpropane reacts with hot, concentrated ethanolic potassium hydroxide rather than dilute aqueous sodium hydroxide, a different product is formed.

Name this organic product and name the mechanism for this reaction.

Name of organic product _____

Name of mechanism _____

(2)

(Total 8 marks)

7. 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)