

Q1. CCl₄ is an effective fire extinguisher but it is no longer used because of its toxicity and its role in the depletion of the ozone layer. In the upper atmosphere, a bond in CCl₄ breaks and reactive species are formed.

- (a) Identify the condition that causes a bond in CCl₄ to break in the upper atmosphere. Deduce an equation for the formation of the reactive species.

Condition

Equation

.....

(2)

- (b) One of the reactive species formed from CCl₄ acts as a catalyst in the decomposition of ozone.

Write **two** equations to show how this species acts as a catalyst.

Equation 1

.....

Equation 2

.....

(2)

- (c) A small amount of the freon CF₃Cl with a mass of 1.78×10^{-4} kg escaped from a refrigerator, into a room of volume 100 m³. Assuming that the freon is evenly distributed throughout the air in the room, calculate the number of freon molecules in a volume of 500 cm³.

Give your answer to the appropriate number of significant figures.

The Avogadro constant = 6.02×10^{23} mol⁻¹.

Number of molecules =

(3)

(Total 7 marks)

Q2. The refrigerant R410A, used in air conditioners, is a mixture of two fluoroalkanes, pentafluoroethane and difluoromethane.

- (a) (i) The mechanism for the reaction of fluorine with either an alkane or a fluoroalkane is similar to that for the reaction of chlorine with methane.

Name the type of mechanism for the reaction of chlorine with methane.

.....

(1)

- (ii) Write equations for the following steps in the mechanism for the reaction of fluorine with fluoromethane (CH_3F) to form difluoromethane (CH_2F_2).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step leading to the formation of 1,2-difluoroethane.

.....

(4)

- (iii) Write an overall equation for the reaction of fluorine with ethane to form pentafluoroethane (CF_3CHF_2) by this mechanism.

.....

(1)

- (b) The refrigerant R112A ($\text{CCl}_3\text{CF}_2\text{Cl}$) has been banned because of concerns about ozone depletion.

Give the IUPAC name for $\text{CCl}_3\text{CF}_2\text{Cl}$

.....

(1)

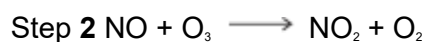
- (c) Nitrogen monoxide (NO) catalyses the decomposition of ozone into oxygen.

- (i) Write the overall equation for this decomposition.

.....

(1)

- (ii) Use the overall equation to deduce Step 3 in the following mechanism that shows how nitrogen monoxide catalyses this decomposition.



Step 3

(1)

(Total 9 marks)

Q3. Chlorine can be used to make chlorinated alkanes such as dichloromethane.

- (a) Write an equation for each of the following steps in the mechanism for the reaction of chloromethane (CH_3Cl) with chlorine to form dichloromethane (CH_2Cl_2).

Initiation step

.....

First propagation step

.....

Second propagation step

.....
The termination step that forms a compound with empirical formula CH₂Cl.
.....

(4)

- (b) When chlorinated alkanes enter the upper atmosphere, carbon-chlorine bonds are broken. This process produces a reactive intermediate that catalyses the decomposition of ozone. The overall equation for this decomposition is



- (i) Name the type of reactive intermediate that acts as a catalyst in this reaction.

.....

(1)

- (ii) Write **two** equations to show how this intermediate is involved as a catalyst in the decomposition of ozone.

Equation 1.....

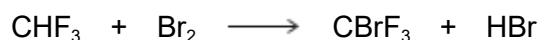
Equation 2.....

(2)

(Total 7 marks)

Q4. 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.



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 CHF₃ with Br₂

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.



.....

(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.

.....

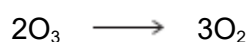
.....

.....

(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



Write **two** equations to show how bromine atoms (Br^\bullet) 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)

Q5. Trifluoromethane (CHF_3) can be used to make the refrigerant chlorotrifluoromethane (CClF_3).

(a) Chlorotrifluoromethane is formed when trifluoromethane reacts with chlorine.



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 Cl_2

Initiation step

.....

First propagation step

.....

Second propagation step

.....

Termination step to form hexafluoroethane

.....

(4)

(ii) Give **one** essential condition for this reaction.

.....

(1)

(b) In some refrigeration systems, CHF_3 has replaced CClF_3 because of concerns about ozone depletion.

(i) Identify the species formed from CClF_3 that is responsible for the catalytic decomposition of ozone in the upper atmosphere.

.....

(1)

(ii) Write an overall equation to represent the decomposition of ozone into oxygen.

.....

(1)

(Total 7 marks)