

**Q1.**  $\text{CCl}_4$  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  $\text{CCl}_4$  breaks and reactive species are formed.

- (a) Identify the condition that causes a bond in  $\text{CCl}_4$  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  $\text{CCl}_4$  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  $\text{CF}_3\text{Cl}$  with a mass of  $1.78 \times 10^{-4}$  kg escaped from a refrigerator, into a room of volume  $100 \text{ m}^3$ . Assuming that the freon is evenly distributed throughout the air in the room, calculate the number of freon molecules in a volume of  $500 \text{ cm}^3$ .

Give your answer to the appropriate number of significant figures.

The Avogadro constant =  $6.02 \times 10^{23} \text{ mol}^{-1}$ .

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 ( $\text{CH}_3\text{F}$ ) to form difluoromethane ( $\text{CH}_2\text{F}_2$ ).

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 ( $\text{CF}_3\text{CHF}_2$ ) 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)

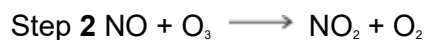
- (c) Nitrogen monoxide (NO) catalyses the decomposition of ozone into oxygen.

- (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 ( $\text{CH}_3\text{Cl}$ ) with chlorine to form dichloromethane ( $\text{CH}_2\text{Cl}_2$ ).

Initiation step

.....

First propagation step

.....

Second propagation step

.....  
The termination step that forms a compound with empirical formula CH<sub>2</sub>Cl.  
.....

(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.

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(1)

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

Equation 1.....

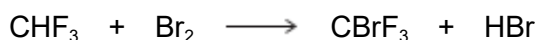
Equation 2.....

(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 CHF<sub>3</sub> with Br<sub>2</sub>

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  $\text{CBrF}_3$  may produce bromine atoms in the upper atmosphere.



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(1)

(ii) In the upper atmosphere, it is more likely for  $\text{CBrF}_3$  to produce bromine atoms than it is for  $\text{CClF}_3$  to produce chlorine atoms.

Suggest **one** reason for this.

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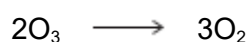
.....

.....

(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 ( $\text{Br}^\bullet$ ) 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 ( $\text{CHF}_3$ ) can be used to make the refrigerant chlorotrifluoromethane ( $\text{CClF}_3$ ).

(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  $\text{CHF}_3$  with  $\text{Cl}_2$

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,  $\text{CHF}_3$  has replaced  $\text{CClF}_3$  because of concerns about ozone depletion.

(i) Identify the species formed from  $\text{CClF}_3$  that is responsible for the catalytic decomposition of ozone in the upper atmosphere.

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(1)

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

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(1)

(Total 7 marks)