



# **A-Level Chemistry**

## **Ozone Depletion**

### **Question Paper**

**Time available: 64 minutes**

**Marks available: 60 marks**

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1.

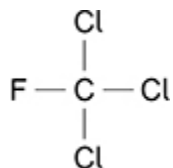
CFCs were used as refrigerants and in aerosols.

The scientists Rowland and Molina published research in 1974 to show that CFCs are responsible for the destruction of ozone molecules in the upper atmosphere.

A few years later, other scientists discovered that the concentration of ozone in the upper atmosphere was decreasing.

In 1987 there was an agreement by many countries to restrict the use of CFCs.

(a) The molecule CFC-11 was commonly used as a refrigerant.



Use IUPAC rules to name CFC-11

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(1)

(b) A molecule of CFC-11 breaks down in the upper atmosphere to form a chlorine free radical.

Give the equation for this reaction.

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(1)

- (c) A typical refrigerator contained 0.50 kg of CFC-11 ( $M_r = 137.5$ ).

One molecule of CFC-11 causes the destruction of approximately 100 000 molecules of ozone.

Use these data to estimate the number of molecules of ozone that can be destroyed by 0.50 kg of CFC-11

Give your answer in standard form.

The Avogadro constant,  $L = 6.022 \times 10^{23} \text{ mol}^{-1}$

Number of molecules of ozone \_\_\_\_\_

**(2)**

- (d) State the benefit to life on Earth of ozone in the upper atmosphere.

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**(1)**

- (e) Suggest **one** reason why the use of CFCs was not restricted until several years after Rowland and Molina published their research.

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**(1)**

(f) CFC-11 is a greenhouse gas that can contribute to global warming.

State and explain how CFC-11 is able to contribute to global warming.

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(2)  
(Total 8 marks)

**2.**

This question is about the ozone layer in the upper atmosphere.

(a) State why the ozone layer is beneficial for living organisms.

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(1)

(b) State how chlorofluorocarbons (CFCs) form chlorine atoms in the upper atmosphere.

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(1)

(c) Give equations to show how chlorine atoms catalyse the decomposition of ozone.

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(2)

- (d) Hydrochlorofluorocarbons (HCFCs) have been used in place of CFCs. In the mechanism to make an HCFC from a fluoroalkane, two incomplete steps are shown.

Complete each step in the mechanism.

Give the name of the type of step shown by both these equations.



Type of step \_\_\_\_\_

(3)

(Total 7 marks)

3.

Halogenoalkanes such as 1,1,2-trichloro-1,2,2-trifluoroethane were used as coolants in refrigerators until the late 1980s. Their use was then banned and alternative coolants were used instead.

- (a) Draw the displayed formula of 1,1,2-trichloro-1,2,2-trifluoroethane.

(1)

- (b) 1,1,2-Trichloro-1,2,2-trifluoroethane was banned for use as a refrigerant because it damaged the ozone layer.

Write **three** equations to show how this compound is involved in damaging the ozone layer.

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(3)

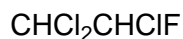
- (c) State the role of chlorine atoms in the reactions in part (b).

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(1)

(d) Inevitably, some coolant escapes from refrigerators.

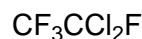
Deduce which of the following coolants, **A**, **B** or **C**, would cause least environmental damage to the atmosphere.



**A**



**B**



**C**

Coolant \_\_\_\_\_

(1)

(e) Give the IUPAC name of compound **B** in part (d).

\_\_\_\_\_

(1)

(f) The boiling point of iodomethane ( $\text{CH}_3\text{I}$ ) is higher than that of fluoromethane ( $\text{CH}_3\text{F}$ ) even though the electronegativity of iodine is less than that of fluorine.

Explain why iodomethane has the higher boiling point by considering the forces that act between  $\text{CH}_3\text{I}$  molecules and comparing these forces with the forces between the  $\text{CH}_3\text{F}$  molecules.

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\_\_\_\_\_  
\_\_\_\_\_

(3)

(Total 10 marks)

4.

$\text{CCl}_4$  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

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Equation 2

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(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)

5.

Refrigerants are substances used to cool refrigerators and freezers. Until recently, many of the compounds used as refrigerants were chlorofluorocarbons (CFCs), but these are now known to form chlorine radicals. CFCs have been phased out in many countries by international agreement.

- (a) Write **two** equations to show how chlorine radicals react with ozone molecules in the upper atmosphere.

1. \_\_\_\_\_

2. \_\_\_\_\_

(2)

- (b) Chloropentafluoroethane is a CFC that has been used as a refrigerant.

Draw its displayed formula.

(1)

- (c) 1,1,1-trifluoroethane ( $\text{CF}_3\text{CH}_3$ ) is one of the molecules that has been used as a refrigerant in place of CFCs.

Explain why 1,1,1-trifluoroethane does not lead to the depletion of the ozone in the upper atmosphere.

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(1)

- (d) One of the steps in the synthesis of 1,1,1-trifluoroethane ( $\text{CF}_3\text{CH}_3$ ) is the reaction of 1,1-difluoroethane ( $\text{CHF}_2\text{CH}_3$ ) with fluorine in a free-radical substitution reaction.

Write **two** equations to represent the propagation steps in this conversion of  $\text{CHF}_2\text{CH}_3$  into  $\text{CF}_3\text{CH}_3$

Propagation step 1

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Propagation step 2

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(2)



- (e) A refrigerator contains 1.41 kg of 1,1,1-trifluoroethane ( $\text{CF}_3\text{CH}_3$ ).

Calculate the number of molecules of 1,1,1-trifluoroethane in the refrigerator.

Give your answer to an appropriate number of significant figures.

(The Avogadro constant  $L = 6.022 \times 10^{23} \text{ mol}^{-1}$ )

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(2)

- (f) There are growing concerns about the use of 1,1,1-trifluoroethane as a refrigerant as it is a greenhouse gas that absorbs some of Earth's infrared radiation.

Give **one** reason why bonds in molecules such as carbon dioxide and 1,1,1-trifluoroethane absorb infrared radiation.

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(1)

(Total 9 marks)

**6.**

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  $\text{CHF}_3$  with  $\text{Br}_2$

Initiation step

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First propagation step

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Second propagation step

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A termination step

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(4)

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

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(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 ( $\text{Br}\cdot$ ) 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

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Equation 2

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Explanation

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(3)

(Total 10 marks)

7.

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.

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(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

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First propagation step

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Second propagation step

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

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**(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.

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**(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  $\text{CCl}_3\text{CF}_2\text{Cl}$

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**(1)**

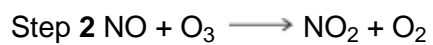
- (c) Nitrogen monoxide (NO) catalyses the decomposition of ozone into oxygen.

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

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**(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)