A-Level Chemistry

Ozone Depletion

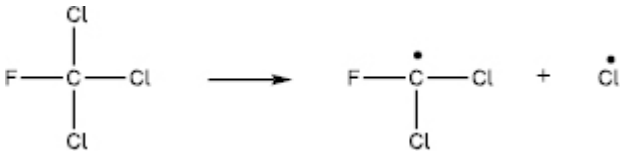
Mark Scheme

Time available: 64 minutes
Marks available: 60 marks

1. (a) trichlorofluoromethane

1

(b)



$CCl_3F \rightarrow \bullet CCl_2F + \bullet Cl$

radical dot anywhere on each radical

1

(c) **M1** amount of CFC-11 = $\frac{500}{137.5}$ (= 3.64) mol

*Allow ECF from **M1** to **M2***

1

M2 molecules of O_3 = 3.64 x 100,000 x 6.022 x 10^{23} = 2.19 x 10^{29}

Allow answers in range 2 x 10^{29} to 2.20 x 10^{29} (1sf is acceptable as this is an estimate)

1

(d) Absorbs (harmful) ultraviolet / uv (light / radiation)

Protects us from (harmful) uv

Ignore other wavelengths / types of light

1

(e) One of these reasons:

- lack of evidence that ozone was being depleted
- lack of alternatives to CFCs
- commercial interest to continue to use CFCs
- hard to obtain international agreement

1

(f) **M1** absorbs infrared radiation

***M1** idea of IR being taken in*

1

M2 molecule has polar bonds

***M2** accept polar molecule*

1

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2. (a) Absorbs/prevents harmful uv

Allow reduced risk of skin cancer from uv

1

(b) C-Cl bonds broken (homolytically)

Could show in an equation showing the bond

1

(c) $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$

M1

$ClO\bullet + O_3 \rightarrow Cl\bullet + 2O_2$

M2

(d) $Cl\bullet + CH_2F_2 \rightarrow$

Penalise missing dot once only

M1

$\rightarrow CHClF_2 + Cl\bullet$

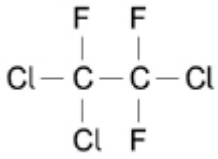
M2

Propagation

M3

[7]

3. (a)



1

(b) Initiation: $CCl_2FCF_2Cl \longrightarrow Cl\bullet + CCl_2FCF_2.$

Allow initiation equations where more than one Cl• is formed

1

$Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$

1

$ClO\bullet + O_3 \longrightarrow 2O_2 + Cl\bullet$

1

(c) Acts as a catalyst

1

(d) B

1

(e) 1,1,1,2-tetrafluoroethane

1

(f) Iodine is bigger than fluorine so the van der Waals forces between CH_3I molecules are stronger than those between CH_3F molecules

1

The dipole-dipole forces between CH_3F molecules are stronger than those between CH_3I molecules

Or vice versa

1

The van der Waals forces are stronger than the dipole-dipole forces so these dominate

1

[10]

4. (a) UV light

1

$CCl_4 \longrightarrow CCl_3\bullet + \bullet Cl$

1

(b) $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$

1

$ClO\bullet + O_3 \longrightarrow Cl\bullet + 2O_2$

1

(c) M_r of CF_3Cl = 104.5

Moles freon = $1.78 \times 10^{-4} \times 10^3 / 104.5 = 1.70 \times 10^{-3}$

1

Number of molecules = $1.70 \times 10^{-3} \times 6.02 \times 10^{23} = 1.02 \times 10^{21}$

1

Molecules in 500 cm^3 = $(1.02 \times 10^{21} \times 500 \times 10^{-6}) / 100$
$= 5.10 \times 10^{15}$

Allow answer in the range 5.10–5.13 × 10^{15}
Answer must be given to this precision

1

[7]

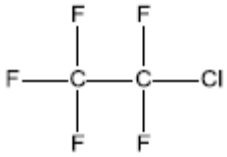
5. (a) M1 $\bullet Cl + O_3 \longrightarrow \bullet ClO + O_2$

1

M2 $\bullet ClO + O_3 \longrightarrow \bullet Cl + 2O_2$

1

M1 and M2 could be in either order
Credit the dot anywhere on the radical
Penalise absence of dot once only
Individual multiples acceptable but both need to be doubled if two marks are to be awarded
Ignore state symbols

(b) 

Must be displayed formula

1

(c) Does not contain Cl or does not release Cl (atoms/radicals)
or no C-Cl bonds
or C-F bond(s) strong / does not break / no F (atom/radicals) released

1

(d) M1 $CHF_2CH_3 + \bullet F \longrightarrow \bullet CF_2CH_3 + HF$

1

M2 $\bullet CF_2CH_3 + F_2 \longrightarrow CF_3CH_3 + \bullet F$

1

M1 and M2 could be in either order

Credit the dot anywhere on the radical

Penalise absence of dot once only

(e) M1 moles CF_3CH_3 = 1410/84(.0) (=16.8, 16.79 mol)

1

M2 molecules = M1 × $6.022 \times 10^{23} = 1.01 \times 10^{25}$ (3sf only)

1

Correct answer scores both marks

Allow M2 for M1 × Avogadro with answer to 3 sf (but must have attempted to calculate moles for M1)

Ignore incorrect units

(f) (bonds) vibrate/stretch/bend OR (as bonds) are polar

NOT polar molecules; 'they' = bonds

1

[9]

6. (a) (i) **Initiation**

$Br_2 \longrightarrow 2Br\bullet$

First propagation

$Br\bullet + CHF_3 \longrightarrow \bullet CF_3 + HBr$

Second propagation

$Br_2 + \bullet CF_3 \longrightarrow CBrF_3 + Br\bullet$

Termination

$2\bullet CF_3 \longrightarrow C_2F_6$ ***OR*** CF_3CF_3

OR

$2Br\bullet \longrightarrow Br_2$

OR

$Br\bullet + \bullet CF_3 \longrightarrow CBrF_3$

Penalise absence of dot once only

Credit the dot anywhere on the radical

4

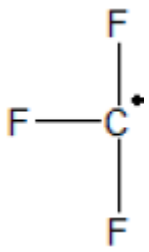
(ii) Ultra-violet / uv / sunlight

OR

T > 100°C OR high temperature

1

(b) (i)



Displayed formula required with the radical dot on carbon

1

(ii) (The) C–Br (bond) breaks more readily / is weaker than (the) C–Cl (bond) (or converse)

OR

The C–Br bond enthalpy / bond strength is less than that for C–Cl (or converse)

*Requires **a comparison** between the two bonds*

Give credit for an answer that suggests that the UV frequency / energy may favour C–Br bond breakage rather than C–Cl bond breakage

Ignore correct references either to size, polarity or electronegativity

Credit correct answers that refer to, for example "the bond between carbon and bromine requires less energy to break than the bond between carbon and chlorine"

1

(iii) **M1**

$Br\bullet + O_3 \longrightarrow BrO\bullet + O_2$

M2

$BrO\bullet + O_3 \longrightarrow Br\bullet + 2O_2$

***M1** and **M2** could be in either order*

Credit the dot anywhere on the radical

Penalise absence of dot once only

Penalise the use of multiples once only

M3 One of the following

They / it / the bromine (atom)

- does not appear in the overall equation
- is regenerated
- is unchanged <u>at the end</u>
- has <u>not been used up</u>
- provides an alternative route / mechanism

3

[10]

7. (a) (i) (Free-) <u>radical substitution</u>

Both underlined words are required

Penalise a correct answer if contradicted by an additional answer

1

(ii) **Initiation**

$F_2 \longrightarrow 2F\bullet$

Penalise absence of dot once only

First propagation

$F\bullet + CH_3F \longrightarrow \bullet CH_2F + HF$

Penalise + or − charges every time

Second propagation

$F_2 + \bullet CH_2F \longrightarrow CH_2F_2 + F\bullet$

Accept dot anywhere on CH_2F radical

Mark independently

Termination (must make 1,2-difluoroethane)

$2 \bullet CH_2F \longrightarrow \underline{CH_2FCH_2F}$

Use of half-headed arrows must be correct to score, but if not correct then penalise once only in this clip

4

(iii) $CH_3CH_3 + \mathbf{5}F_2 \longrightarrow CF_3CHF_2 + \mathbf{5}HF$

(C_2H_6) (C_2HF_5)

1

(b) 1,1,1,2-tetrachloro-2,2-difluoroethane

Accept phonetic spelling eg "fluro, cloro"

Penalise "flouro" and "floro", since ***QoL***

OR

1,2,2,2-tetrachloro-1,1-difluoroethane

Ignore commas and hyphens

1

(c) (i) $\mathbf{2}O_3 \longrightarrow \mathbf{3}O_2$

ONLY this equation or a multiple

Ignore NO over the arrow

Other species must be cancelled

1

(ii) $O + NO_2 \longrightarrow NO + O_2$

ONLY this answer and NOT multiples

Ignore any radical dot on the O atom

1

[9]