M1. (a) (i) chlorotrifluoromethane

Spelling must be correct but do not penalise "flouro"

Ignore use of 1–

1

(ii) CF_3•

May be drawn out with dot on C

OR if as shown dot may be anywhere

1

(iii) An unpaired/non-bonded/unbonded/free/a single/one/lone electron

NOT "bonded electron" and NOT "paired electron"

NOT "pair of electrons"

NOT "electrons"

Ignore "(free) radical"

1

(b) **M1** Cl• + O_3 → ClO• + O_2

M2 ClO• + O_3 → **2**O_2 + Cl•

Mark independently

Equations could gain credit in either position

The dot can be anywhere on either radical

Penalise the absence of a dot on the first occasion that it is seen and then mark on. Do not make the same penalty in the next equation, but penalise the absence of a dot on the other radical.

Apply the list principle for additional equations

2

(c) (i) (If any factor is changed which affects an equilibrium), the (position of) equilibrium will shift/move so as to oppose the change.

OR

(When a system/reaction in equilibrium is disturbed), the equilibrium shifts/moves in a direction which tends to reduce the disturbance

Must refer to <u>equilibrium</u>

Ignore reference to "system" alone

A variety of wording will be seen here and the key part is the last phrase.

An alternative to shift/move would be the idea of <u>changing/altering the position</u> of equilibrium

1

(ii) **M1** The (forward) reaction/to the right is <u>endothermic</u> or <u>takes in heat</u>

OR The reverse reaction/to the left is <u>exothermic</u> or <u>gives out heat</u>

M2 The <u>equilibrium moves/shifts</u> to <u>oppose the increase in temperature</u>

M2 depends on a correct statement for M1

For M2 accept

The <u>equilibrium moves/shifts</u>

- *to <u>take in heat/lower the temperature</u>*
- *to promote the endothermic reaction and <u>take in heat/ lower the temperature</u>*
- *to oppose the change and <u>take in heat/lower the temperature</u>*

(leading to the formation of more ozone)

2

(d) Any one of

- Pentane <u>does not contain chlorine</u> OR <u>C–Cl</u> (bond)
- Pentane is <u>chlorine-free</u>
- Pentane <u>does not release chlorine</u> (atoms/radicals)

Ignore reference to F OR C–F OR halogen

Ignore "Pentane is not a CFC"

Ignore "Pentane is a hydrocarbon"

Ignore "Pentane only contains C and H"

Ignore "Pentane is C_5H_{12}"

1

[9]

M2. (a) (i) (Free-) radical substitution

Both words needed

1

(ii) UV light/Ultra-violet light/sunlight
OR high temperature/150 °C ≤ T ≤ 500 °C

1

(iii) Propagation (Step)

Ignore "first" or "second"

Accept phonetic spelling

1

(iv) **M1** Termination (Step)

M2 **2**$CH_3CH_2CH_2\bullet \longrightarrow C_6H_{14}$

In M2

C_6H_{14} may be drawn out as $CH_3CH_2CH_2CH_2CH_2CH_3$

The dot may be anywhere around the terminal CH_2 on the radical

Accept $C_3H_7\bullet$ with dot anywhere

Penalise the absence of any radical dot

2

(v) C_3H_8 + **8**$Br_2 \longrightarrow C_3Br_8$ + **8**HBr

Or multiples

1

(b) (i) **M1** Double bonds are

electron-rich

OR electron pair donors

OR centres of electron density.

M2 Bromine becomes polarised/becomes polar

OR forms an induced dipole

OR becomes δ+/δ–

M1 QoL – require <u>one</u> of these terms

Ignore "(very) negative" and "nucleophile" as applied to the double bond.

Penalise M2 for ion formation from bromine

For M2, do not credit dipole formation <u>solely</u> as a consequence of electronegativity

2

(ii) <u>Electrophilic addition</u>

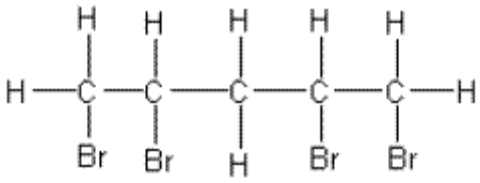
Both words needed

Accept phonetic spelling

1

(iii) Structure for 1,2,4,5-tetrabromopentane, for example $BrCH_2CHBrCH_2CHBrCH_2Br$

OR



Must be clear that they have drawn 1,2,4,5-tetrabromopentane and does NOT need to be displayed

Credit use of "sticks" for each C-H bond

1

(c) +

M1 Structure of CH_3CHCH_3

M2 (Secondary) Carbocation OR (secondary) carbonium ions

Mark independently

For M1 the positive charge must be on the central carbon atom

Penalise bond to positive charge

Penalise answers which show more than the correct carbocation e.g. the mechanism, unless the intermediate is clearly identified

Credit use of "sticks" for each C-H bond

For M2, penalise "primary" or "tertiary"

2

[12]

M3. (a) (i) (free–)radical substitution

(both words required for the mark)

1

(ii) uv light OR sunlight OR high temperature OR 150 °C to 500 °C

1

(iii) Propagation

(ignore "chain", "first", "second" in front of the word propagation)

1

(iv) Termination

1

$\bullet CH_2CH_3 + Br\bullet \longrightarrow CH_3CH_2Br$
OR $2\bullet CH_2CH_3 \longrightarrow C_4H_{10}$

(penalise if radical dot is obviously on CH_3, but not otherwise)

(penalise $C_2H_5\bullet$)

(credit $2Br\bullet \longrightarrow Br_2$)

(ignore "chain" in front of the word termination)

1

(b) (i) Fractional distillation OR fractionation

(credit gas–liquid chromatography, GLC)

1

(ii) $CH_3CH_3 + 6Br_2 \longrightarrow C_2Br_6 + 6HBr$

(credit C_2H_6 for ethane)

1

(c) Correct structure for CF_2BrCF_2Br drawn out

(penalise "Fl" for fluorine)

1

(d) (i) 2–bromo–2–chloro–1,1,1–trifluoroethane
OR 1–bromo–1–chloro–2,2,2–trifluoroethane

(insist on all numbers, but do not penalise failure to use alphabet)

(accept "flourine" and "cloro" in this instance)

1

(ii) 197.4 only

(ignore units)

1

(iii) (57/197.4 × 100) = 28.9% OR 28.88%

(credit the correct answer independently in part (d)(iii), even if (d)(ii) is blank or incorrectly calculated, but mark consequential on part (d)(ii), if part (d)(ii) is incorrectly calculated, accepting answers to 3sf or 4sf only)

(penalise 29% if it appears alone, but not if it follows a correct answer)

(do not insist on the % sign being given)

(the percentage sign is not essential here, but penalise the use of units e.g. grams)

1

[11]

M4. (a) **M1** (Free-) **radical substitution**

Both words needed

1

M2 $Cl_2 \rightarrow 2Cl\bullet$

1

M3 $Cl\bullet + CH_4 \rightarrow \bullet CH_3 + HCl$

1

M4 $Cl_2 + \bullet CH^3 \rightarrow CH_3Cl + Cl\bullet$

1

M5 $CH_4 + 3Cl_2 \rightarrow CHCl_3 + 3HCl$

Penalise the absence of a radical dot once only

***Ignore termination steps except, if and only if both** M3 and M4 do not score, then accept for one mark*
$Cl\bullet + \bullet CH_3 \rightarrow CH_3Cl$

1

(b) **M1** UV (light)/ sunlight / light / UV radiation

M2 C–Cl or carbon-chlorine bond breakage

OR
homolysis of C–Cl
OR
equation to show a chlorine-containing organic compound forming two radicals

For M1 and M2, ignore use of Cl_2, but credit UV and C–Cl bond breakage if seen

1

M3 $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$

1

M4 $ClO\bullet + O_3 \rightarrow Cl\bullet + 2O_2$

Ignore other equations
Penalise the absence of a radical dot once only
Accept radical dot anywhere on either radical.

1

M5 Any **one** from

- Combination $2O_3 \rightarrow 3O_2$
- Stated that Cl• / chlorine atom is regenerated / not used up
- Stated that the Cl• / chlorine atom is unaffected by the process.

1

For M5 accept Cl• on both sides of the equation

M6 Stated that the role of the Cl• / chlorine atom is to find an alternative route ***OR*** lower E_a / activation energy

1

(c) **M1** Halothane contains C–Cl / Cl
OR
Desflurane does not contain C–Cl bonds / Cl
OR
Desflurane contains C–F / F as the only halogen

Mark independently.
For M1, credit the idea that desflurane contains C–F bonds that are difficult to break OR that halothane contains C–Cl bonds which are easy to break.

1

M2 Desflurane / molecules that have fluorine as the only halogen, cause no damage / do not deplete / do not react with the ozone (layer)
OR
Halothane / chlorine-containing molecules, damage / deplete / react with the ozone (layer)

1

[13]

M5. (a) Functional group (isomerism)

1

(b)

M1 Tollens' (reagent) (*Credit ammoniacal silver nitrate* **OR** *a description of making Tollens'*) (*Ignore either $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3*)	**M1** Fehling's (solution) or Benedict's solution (*Ignore $Cu^{2+}(aq)$ or $CuSO_4$ on their own, but mark on to M2 and M3*)
M2 silver mirror **OR** black solid/precipitate *(NOT silver precipitate)*	**M2** Red solid/precipitate (*Credit orange or brown solid*)
M3 (stays) colourless or no change or no reaction	**M3** (stays) blue or no change or no reaction

Mark on from an incomplete/incorrect attempt at the correct reagent, penalising M1

No reagent, CE=0

Allow the following alternatives
M1 *(acidified) potassium dichromate(VI) (solution)*
M2 *(turns) green*
M3 *(stays) orange/no change*
OR
M1 *(acidified) potassium manganate(VII) (solution)*
M2 *(turns) colourless*
M3 *(stays) purple/no change*

For M3
Ignore "nothing (happens)"
Ignore "no observation"

3

(c) (Both have) C=O ***OR*** a carbonyl (group)

1

(d) (i) (Free-) radical substitution ONLY

Penalise "(free) radical mechanism"

1

(ii) **Initiation**

$Cl_2 \rightarrow 2Cl\bullet$

Penalise absence of dot once only.

First propagation

$Cl\bullet + CH_3CH_2CH_3 \rightarrow \bullet CH_2CH_2CH_3 + HCl$

OR C_3H_8

Penalise incorrect position of dot on propyl radical once only.

Penalise $C_3H_7\bullet$ once only

Second propagation

$Cl_2 + \bullet CH_2CH_2CH_3 \rightarrow CH_3CH_2CH_2Cl + Cl\bullet$

OR

C_3H_7Cl

Accept $CH_3CH_2CH_2\bullet$ with the radical dot above/below/to the side of <u>the last carbon</u>.

Termination (must make C_6H_{14})

$2\ \bullet CH_2CH_2CH_3 \rightarrow C_6H_{14}$ or $CH_3CH_2CH_2CH_2CH_2CH_3$

Use of the secondary free radical might gain 3 of the four marks

4

(e) M_r = <u>44.06352</u> (for propane)

M_r = <u>43.98982</u> (for carbon dioxide)

Mark independently

M1 a correct value for <u>both</u> of these <u>M_r values</u>.

M2 a statement or idea that <u>two peaks</u> appear (in the mass spectrum)

OR

<u>two molecular ions</u> are seen (in the mass spectrum).

2

[12]