

- M1.** (a) (i) (free-) radical substitution
(both words required for the mark) 1
- initiation $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$
(credit correct half arrows, but penalise double headed arrows) 1
- first propagation $\text{CH}_3\text{Cl} + \text{Cl}\cdot \rightarrow \cdot\text{CH}_2\text{Cl} + \text{HCl}$ 1
- second propagation $\cdot\text{CH}_2\text{Cl} + \text{Cl}_2 \rightarrow \text{CH}_2\text{Cl}_2 + \text{Cl}$
(penalise the absence of dots on radicals once only)
(penalise radical dot on Cl of CH_2Cl once only) 1
- (ii) $\text{CH}_3\text{Cl} + \text{Cl}_2 \rightarrow \text{CH}_2\text{Cl}_2 + \text{HCl}$
(penalise if any radicals appear in this equation) 1
- (b) **M1:** mol C = $10.1/12.0$ and mol Cl = $89.9/35.5$ 1
- M2:** Ratio 0.842 : 2.53 OR 1: 3 OR CCl_3 1
- M3:** $237.0/\text{Mr of } \text{CCl}_3 = 237.0/118.5 = 2$ Therefore C_2Cl_6
(correct answer gains full credit) 1
- OR
- M1:** $237.0 \times 10.1/100$ and $237 \times 89.9/100$ 1
- M2:** Ratio $23.9/12.0 : 213/35.5$ OR 2 : 6 1
- M3:** C_2Cl_6
(correct answer gains full credit) 1
- (c) any two from CHBr_3 or CBr_4 or $\text{C}_2\text{H}_2\text{Br}_4$ (or $\text{CHBr}_2\text{CHBr}_2$) or C_2Br_6 (or CBr_3CBr_3)
(ignore HBr or H_2)
(ignore equations and ignore names when given in addition)

to formulae)
(penalise names alone)

2

[10]

M2.C

[1]

- M3.** (a) (i) $\text{CHCl}_3 + \text{Cl}_2 \rightarrow \text{CCl}_4 + \text{HCl}$ (1)
(ii) UV light / sunlight OR high T OR $T \geq 500^\circ\text{C}$ (1)
max T = 1000°C
NOT heat / light
Ignore pressure

2

- (b) *Initial step:* $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$ (1)
Condition could be on first equation arrow

First propagation step: $\text{CHCl}_3 + \text{Cl}\cdot \rightarrow \dot{\text{C}}\text{Cl}_3 + \text{HCl}$ (1)

Second propagation step: $\dot{\text{C}}\text{Cl}_3 + \text{Cl}_2 \rightarrow \text{CCl}_4 + \text{Cl}\cdot$ (1)

A termination step: $\dot{\text{C}}\text{Cl}_3 + \text{Cl}\cdot \rightarrow \text{CCl}_4$ (1)

OR $2\dot{\text{C}}\text{Cl}_3 \rightarrow \text{C}_2\text{Cl}_6$

Not $2\text{Cl}\cdot \rightarrow \text{Cl}_2$

Ignore additional termination steps

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[6]

M4. M1: uv light/sunlight

OR

T = 450 °C to 1000 °C;

(do not credit "high temperature")

(ignore references to pressure or catalyst)

(penalise M1 if aqueous chlorine OR chlorine water)

(credit M1 if the condition appears over the arrow of the initiation step)

1

M2: $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$;

(credit correct half arrows, but penalise (once in the question) the use of double headed arrows)

1

M3: $\text{C}_2\text{H}_6 + \text{Cl}\cdot \rightarrow \text{CH}_3\text{CH}_2\cdot + \text{HCl}$;

(credit CH_3CH_3 for ethane and $\text{C}_2\text{H}_5\cdot$ for the ethyl radical)

1

M4: $\text{CH}_3\text{CH}_2\cdot + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_5\text{Cl} + \text{Cl}\cdot$;

1

M5: $\text{CH}_3\text{CH}_2\cdot + \text{CH}_3\text{CH}_2\cdot \rightarrow \text{C}_4\text{H}_{10}$;

(penalise the absence of dots once only in this question)

(penalise subsequent ionic reactions as contradictions for each reaction contradicted)

(if neither M3 nor M4 scored, allow $\text{CH}_3\text{CH}_2\cdot + \text{Cl}\cdot \rightarrow \text{C}_2\text{H}_5\text{Cl}$ for one mark)

1

[5]

M5. (a) (i) UV light OR sunlight OR $T \geq 450^\circ\text{C}$ (1)
NOT high T

(ii) (free) radical substitution (1)

(iii) CCl_4 (1) OR named

3



(ii) nucleophilic substitution (1)

(iii) C–Br bond is weaker (than C–Cl bond)
OR C–Br bond enthalpy is less than C–Cl (1)
Ignore electronegativity

3

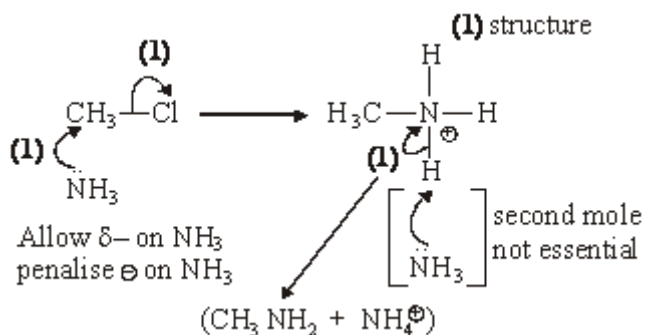
(c) CH_3COOH OR ethanoic acid (1)

1

(d) (i) $\overset{\delta+}{\text{C}}-\overset{\delta-}{\text{Cl}}$ OR C–Cl is polar (1) OR C atom is electron deficient / $\delta+$

(ii) methylamine (1) only

(iii) $\text{S}_{\text{N}}1$ scores full marks



6

[13]

M6. (a) (i) (Free) radical substitution
(Both words needed)

1

(ii) M1 initiation ONLY 1

M2 ultra-violet light OR sunlight OR $1000^{\circ}\text{C} \geq T \geq 450^{\circ}\text{C}$
(Ignore reference to temperature if included with uv light)
(Penalise "high temperature" for M2) 1

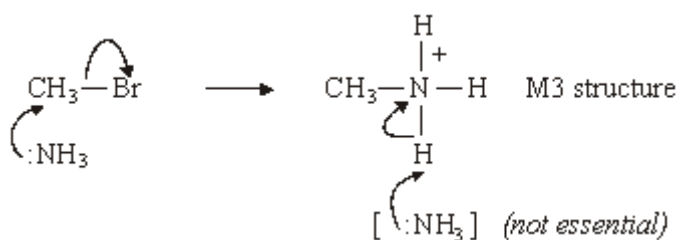
(iii) $2\dot{\text{C}}\text{H}_3 \rightarrow \text{C}_2\text{H}_6$
(OR $\text{CH}_3\dot{\text{C}}\text{H}_3$ as alternative to C_2H_6) 1

(iv) $\text{CH}_3\text{Br} + \text{Br}_2 \rightarrow \text{CH}_2\text{Br}_2 + \text{HBr}$ 1

(b) (i) Electron pair donor
OR species with an electron pair able to form a covalent bond. 1

(ii) Methylamine
(Credit "aminomethane") 1

(iii)



M1 arrow to show breakage of C – Br bond 1

M2 arrow from lone pair on N of NH_3 to form bond with C 1

M4 arrow from bond of N – H to N atom of $\text{CH}_3\overset{+}{\text{N}}\text{H}_3$
(Ignore partial charges on haloalkane but penalise if incorrect)

(Accept $\text{CH}_3\overset{+}{\text{N}}\text{H}_3$ for M3)

(Full credit for carbocation mechanism; M1 for C – Br bond breakage and M2 for lone pair attack on carbocation)

(Second mole of ammonia not essential to mechanism for full credit)

1

- M7.** (a) $F_2 \rightarrow 2F\cdot$ 1
- $CH_4 + F\cdot \rightarrow \cdot CH_3 + HF$ 1
- $\cdot CH_3 + F_2 \rightarrow CH_3F + F\cdot$ 1
- $\cdot CH_3 + F\cdot \rightarrow CH_3F$ 1
- OR $2\cdot CH_3 \rightarrow C_2H_6$
- (allow credit on this occasion for $2F\cdot \rightarrow F_2$)*
- (penalise incorrect symbol FI, once only)*
- (penalise absence of radical dot once only)*
- (b) $CH_3F + 3F_2 \rightarrow CF_4 + 3HF$ 1