M1. (a) (i) (free–) radical substitution

(both words required for the mark)

1

initiation $Cl_2 \rightarrow 2Cl\cdot$

(credit correct half arrows, but penalise double headed arrows)

1

first propagation $CH_3Cl + Cl\cdot \rightarrow \cdot CH_2Cl + HCl$

1

second propagation $\cdot CH_2Cl + Cl_2 \rightarrow CH_2Cl_2 + Cl$

(penalise the absence of dots on radicals once only)

(penalise radical dot on Cl of CH_2Cl once only)

1

(ii) $CH_3Cl + Cl_2 \rightarrow CH_2Cl_2 + HCl$

(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 CCl3

1

M3: 237.0/Mr of CCl_3 = 237.0/118.5 = 2 Therefore C_2Cl_6

(correct answer gains full credit)

1

OR

M1: 237.0 × 10.1/100 and 237 × 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 $C_2H_2Br_4$ (or $CHBr_2CHBr_2$) 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) $CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$ **(1)**

(ii) UV light / sunlight OR <u>high</u> T OR T ≥ 500°C **(1)**
maxT = 1000°C
NOT heat / light
Ignore pressure

2

(b) *Initial step*: $Cl_2 \rightarrow 2Cl^{\cdot}$ **(1)**
Condition could be on first equation arrow

First propagation step: $CHCl_3 + Cl^{\cdot} \rightarrow \dot{C}Cl_3 + HCl$ **(1)**

Second propagation step: $\dot{C}Cl_3 + Cl_2 \rightarrow CCl_4 + Cl\cdot$ **(1)**

A termination step: $\dot{C}Cl_3 + Cl\cdot \rightarrow CCl_4$ **(1)**
OR $2\dot{C}Cl_3 \rightarrow C_2Cl_6$
Not $2Cl\cdot \rightarrow Cl_2$
Ignore additional termination steps

4

[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: $Cl_2 \rightarrow 2Cl\cdot$;

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

1

M3: $C_2H_6 + Cl\cdot \rightarrow CH_3CH_2\cdot + HCl$;

(credit CH_3CH_3 for ethane and C_2H_5- for the ethyl radical)

1

M4: $CH_3CH_2\cdot + Cl_2 \rightarrow C_2H_5Cl + Cl\cdot$;

1

M5: $CH_3CH_2\cdot + CH_3CH_2\cdot \rightarrow C_4H_{10}$;

(penalise the absence of dots once only in this question)
(penalise subsequent ionic reactions as contradictions for each reaction contradicted)

(if <u>neither</u> M3 nor M4 scored, allow $CH_3CH_2\cdot + Cl\cdot \rightarrow C_2H_5Cl$ for one mark)

1

[5]

M5. (a) (i) UV light OR sunlight OR T $\geq$ 450°C **(1)**
NOT high T

(ii) (free) radical substitution **(1)**

(iii) CCl_4 **(1)** OR named

3

(b) (i) $CH_3Cl + KCN \rightarrow CH_3CN + KCl$ **(1)**
CN^- Cl^-

(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

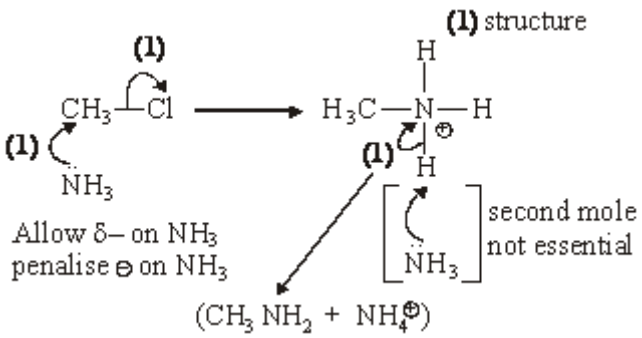
(c) CH_3COOH OR ethanoic acid **(1)**

1

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

(ii) methylamine **(1)** only

(iii) S_N1 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°C $\geq$ T $\geq$ 450 °C

(Ignore reference to temperature if included with uv light)

(Penalise "high temperature" for M2)

1

(iii) $2\dot{C}H_3 \rightarrow C_2H_6$

(OR CH_3CH_3 as alternative to C_2H_6)

1

(iv) $CH_3Br + Br_2 \rightarrow CH_2Br_2 + HBr$

1

(b) (i) Electron pair donor

OR species with an electron pair able to form a covalent bond.

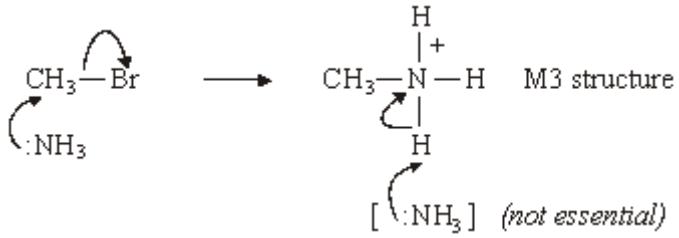
1

(ii) Methylamine

(Credit "aminomethane")

1

(iii)



1

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 $CH_3\overset{+}{N}H_3$

(Ignore partial charges on haloalkane but penalise if incorrect)

(Accept $CH_3\overset{+}{N}H_3$ 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

[11]

M7. (a) $F_2 \rightarrow 2F\bullet$

1

$CH_4 + F\bullet \rightarrow \bullet CH_3 + HF$

1

$\bullet CH_3 + F_2 \rightarrow CH_3F + F\bullet$

1

$\bullet CH_3 + F\bullet \rightarrow CH_3F$

1

OR $2\bullet CH_3 \rightarrow C_2H_6$

(allow credit on this occasion for $2F\bullet \rightarrow F_2$)
(penalise incorrect symbol Fl, once only)
(penalise absence of radical dot once only)

(b) $CH_3F + 3F_2 \rightarrow CF_4 + 3HF$

1

[5]