AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.3.2 ALKANES

SCORE	PERCENTAGE
/226	%

STEMUP

These questions belong to AQA, not to us.

The examination questions, mark schemes and examiner reports in this pack were written and published by AQA. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with AQA and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. AQA has not endorsed, approved or been involved in the production of it. AQA and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

AQA publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at aqa.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Q1.

(a) $C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$

Ignore state symbols

Allow multiples

M1

(b) Zeolite OR aluminosilicate

Allow porous pot / aluminium oxide / alumina / silica / silicon dioxide

M1

Slight/moderate pressure

Slightly above atmospheric – allow 1-5 atmospheres / 100-500kPa

M2

$C_{16}H_{34} \rightarrow C_7H_{16} + C_6H_{12} + C_3H_6$

M3

(c) $Cl\bullet + CH_3CH_2CH_2CH_3 \longrightarrow CH_3CH_2\overset{\bullet}{C}HCH_3 + HCl$

*If incorrect radical or ambiguous radical lose **M1** but can award **M2** for ecf in each equation.*

M1

$CH_3CH_2\overset{\bullet}{C}HCH_3 + Cl_2 \longrightarrow CH_3CH_2CHClCH_3 + Cl\bullet$

Allow equations in either order

Allow dot anywhere on the second carbon

Ignore extra initiation and termination steps

M2

(d) $Cl\bullet$

*Allow Cl or Chlorine in **M1** and **M4***

M1

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

Penalise absence of dot once in the equations

M2

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

Allow dot anywhere on the radical

Apply the list principle in the equations and penalise

M3

$Cl\bullet$ is regenerated (and causes a chain reaction in the decomposition of ozone)

initiation from Cl_2

Allow equations in either order.

Ignore $Cl\bullet$ acts as a catalyst

M4

[10]

STEMUP.CO.UK

Q2.

D

[1]

Q3.

D

[1]

Q4.

(a) (Strength depends on availability of) <u>lone pair on N</u> (atom)

M1

E N (next to ring): (lp) <u>delocalised</u> into ring

M2

(lp) less available (to donate to or to accept a H^+)

M3

F or **G**: N (next to alkyl): (positive) inductive effect/electrons pushed to N

M4

(lp) more available (to donate to or to accept a H^+)

M5

order of increasing base strength **E**<**G**<**F**

*Or **F** is most basic **and E** is least basic*

M6

(b) Intermediate compounds

Product of step 1 $C_6H_5CH_1Cl$

Allow $C_6H_5CH_2Br$

Product of step 2 $C_6H_5CH_2CN$

In steps 2 and 3, only allow marks for reagents/conditions if intermediate compounds are correct or close.

Reagents/conditions

Step 1
Cl_2 & UV

Allow Br_2 & UV

Step 2
KCN alcoholic & aq (both reqd)

Ignore temperature

Step 3
H_2 / Ni or Pt or Pd

Allow $LiAlH_4$ in (dry) ether – (with acid CE, followed by acid allow)

Not $NaBH_4$ and not Sn/HCl or Fe/HCl

STEMUP.CO.UK

2

[11]

Q5.

A

[1]

Q6.

C

[1]

Q7.

C

[1]

Q8.

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

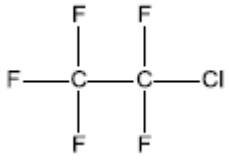
1

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

STEMUP.CO.UK

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]

Q9.

(a) (i) $CH_3Cl + 2Cl_2 \longrightarrow CHCl_3 + 2HCl$

IGNORE *state symbols*

ALLOW *multiples*

1

(ii) (Free-)radical substitution

This answer only

1

(iii) Initiation:

$Cl_2 \longrightarrow 2Cl\bullet$

Penalise absence of dot once only

1

1st Propagation step

$Cl\bullet + CH_2Cl_2 \longrightarrow \bullet CHCl_2 + HCl$

Penalise + and/or – charges every time

1

2nd Propagation step

$\bullet CHCl_2 + Cl_2 \longrightarrow CHCl_3 + Cl\bullet$

ALLOW *• anywhere on $\bullet CHCl_2$ but, if drawn out as a structure, then*

• must be on C

1

Termination

$2\ \bullet CHCl_2 \longrightarrow C_2H_2Cl_4$

Mark independently

ALLOW *$\bullet CH_2Cl + \bullet CCl_3 \longrightarrow C_2H_2Cl_4$*

IGNORE *state symbols throughout*

1

(b) (i) $CClF_3 \longrightarrow \bullet CF_3 + Cl\bullet$

ALLOW *• anywhere on $\bullet CF_3$ unless displayed*

STEMUP.CO.UK

1

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

Equations can be in either order

Penalise absence of • once only

1

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

ALLOW *• anywhere on •ClO*

NOT *•O_3*

1

[9]

Q10.

(a) (i) **M1 Initiation**

$Cl_2 \longrightarrow 2Cl\bullet$

Penalise absence of dot once only.

M2 First propagation

$Cl\bullet + CHF_3 \longrightarrow CF_3\bullet + HCl$

Penalise + or − charges <u>every time</u>.

M3 Second propagation

$Cl_2 + CF_3\bullet \longrightarrow CClF_3 + Cl\bullet$

Credit $CF_3\bullet$ with the radical dot above / below / to either side.

M4 Termination (must make C_2F_6)

$2\ CF_3\bullet \longrightarrow C_2F_6$ or CF_3CF_3

Mark independently.

4

(ii) ultra-violet / uv / sun light

OR (very) high temperature

OR 500 °C ≤ T ≤ 1000 °C

OR 773 K ≤ T ≤ 1273 K

1

(b) (i) Cl• **OR** chlorine atom / chlorine (free−) radical / Cl (atom)

Not 'chlorine' alone.

Credit 'Cl' alone on this occasion.

1

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

Or multiples.

Ignore state symbols.

If the correct answer is on the line OR clearly identified below some working, then ignore any working.

1

STEMUP.CO.UK

[7]

Q11.

(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

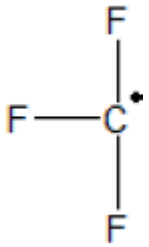
(ii) Ultra-violet / uv / sunlight

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

STEMUP.CO.UK

(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]

Q12.

(a) **Initiation**

$Cl_2 \longrightarrow 2Cl\bullet$

Penalise absence of dot once only.

First propagation

$Cl\bullet + CH_3Cl \longrightarrow \bullet CH_2Cl + HCl$

Credit the dot anywhere on the radical.

Second propagation

$Cl_2 + \bullet CH_2Cl \longrightarrow CH_2Cl_2 + Cl\bullet$

Termination (must make 1,2-dichloroethane)

$2 \bullet CH_2Cl \longrightarrow CH_2ClCH_2Cl$

Penalise $C_2H_4Cl_2$

4

(b) (i) (chlorine free) <u>radical</u>

Ignore formula.

1

(ii) M1 $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$

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

***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.

2

[7]

Q13.

STEMUP.CO.UK

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

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) $CH_3\,CH_3 + \mathbf{5}F_2 \longrightarrow CF_3CHF_2 + \mathbf{5}HF$

$(C_2H_6)(C_2HF_5)$

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]

STEMUP.CO.UK

Q14.

(a) (i) **M1 Initiation**

$Cl_2 \longrightarrow 2Cl\bullet$

Penalise absence of dot once only.

Penalise + or – charges every time

M2 First propagation

$Cl\bullet + CH_2Cl_2 \longrightarrow \bullet CHCl_2 + HCl$

Accept dot anywhere on $CHCl_2$ radical but if the structure is drawn out, the dot must be on the carbon atom. Penalise this error once only

Penalise once only for a line and two dots to show a bond.

M3 Second propagation

$Cl_2 + \bullet CHCl_2 \longrightarrow CHCl_3 + Cl\bullet$

Penalise once only for double headed curly arrows

Mark independently

3

(ii) **M1 Condition**

ultra-violet / uv / sun light

OR high temperature

OR 400°C ≤ T ≤ 900°C

M2 Type of mechanism

(free-) radical substitution (mechanism)

2

(b) (i) $CHCl_3 + Cl_2 \longrightarrow CCl_4 + HCl$

Allow X as alternative to CCl_4 only if X is clearly identified as CCl_4

1

(ii) **M1** Trichloromethane / $CHCl_3$ has a C–H bond

OR

X / CCl_4 / it has no C–H bond

***M1** must refer to presence or absence of the C–H bond in a compound*

M2 The infrared spectrum shows

(absorption / peak for C–H in range) **2850 to 3300** (cm^{-1}) is missing

***M2** answer must refer to / imply the spectrum*

Allow the words "dip" OR "spike" OR "low transmittance" as alternatives for absorption.

Ignore references to other absorptions.

2

(c) **M1 a statement about bond breakage / formation of Cl•**

C–Cl / carbon-chlorine bond breakage occurs

OR Cl• / chlorine (free) radical forms

OR correct equation $CHClF_2 \longrightarrow Cl\bullet + \bullet CHF_2$

STEMUP.CO.UK

*Penalise **M1**, if Cl• is formed from Cl_2 as the only reaction or an additional reaction*

Do not penalise an incorrect equation using $CHClF_2$ if correct reference is made to Cl• formation or C–Cl / carbon-chlorine bond breakage

M2 Cl• + O_3 ⟶ ClO• + O_2

M3 ClO• + O_3 ⟶ Cl• + $2O_2$

***M2** and **M3** either order*

Penalise absence of dot once only.

Accept dot anywhere on ClO radical

M4 $CHClF_2$ / chlorine-containing compounds/ CFCs damage / react with / decrease the ozone layer

OR

this overall decomposition occurs; $2O_3$ ⟶ $3O_2$

OR

without an ozone layer or with a decreased ozone layer, uv radiation is not being "filtered" / prevented from passing through the atmosphere or there is a concern about an increase in skin cancer etc.

OR

Cl• catalyses the decomposition of ozone / a single Cl• causes (chain) reaction / decomposition of many ozone molecules / ozone layer

*Award **M4** for the general idea behind the EU justification for banning the use of CFCs as refrigerants*

*Penalise **M4** if overall ozone decomposition equation is incorrect*

Ignore "greenhouse effect", "global warming" etc.

4

(d) (i)

All bonds must be drawn out

1

(ii) 2,3,3,3-tetrafluoropropene / it does not contain chlorine (atoms) / C–Cl (bonds)

Ignore "chlorine molecules"

OR

It does not produce Cl• / does not produce chlorine (free) radical(s)

OR

chlorodifluoromethane does contain chlorine / does produce Cl• / does produce chlorine (free) radical(s)

OR

C–F is too strong and does not break / create radicals

OR

C–F is stronger than C–Cl

1

[14]

Q15.

(a) (i) $CH_4 + \mathbf{3}F_2 \longrightarrow CHF_3 + \mathbf{3}HF$

1

STEMUP.CO.UK

(ii) **M1 Initiation**

$F_2 \longrightarrow 2F\bullet$

M2 First propagation

$F\bullet + CHF_3 \longrightarrow \bullet CF_3 + HF$

M3 Second propagation

$F_2 + \bullet CF_3 \longrightarrow CF_4 + F\bullet$

M4 Termination (must make C_2F_6)

$\mathbf{2}\bullet CF_3 \longrightarrow C_2F_6$ or CF_3CF_3

Penalise absence of dot once only.

Radical dot on $\bullet CF_3$ can be anywhere but if the structure is drawn out, the dot must be on the carbon atom. Penalise this error once only.

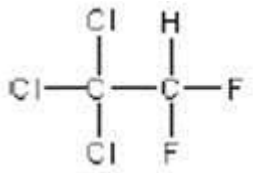
Penalise once only for a line and two dots to show a bond.

Penalise each of ''Fl" and lower case F, once only in this clip

4

(b) (i) Displayed formula

e.g.



<u>All bonds</u> must be drawn out.

Ignore bond angles. Penalise "sticks"

1

(ii) **M1** <u>C–Cl</u> bond OR <u>carbon-chlorine</u> bond

M2 <u>chlorine atom</u> OR <u>chlorine (free) radical</u>

M3 $\mathbf{2}O_3 \longrightarrow \mathbf{3}O_2$

M1 NOT carbon-halogen

Penalise incorrect spelling of chlorine <u>once only</u> in this clip

M2 ignore formulae

Ignore Cl_2 or $Cl\bullet$ or $ClO\bullet$ balanced on <u>both</u> sides of the equation

Ignore other equations leading to the overall equation

3

[9]

Q16.

STEMUP.CO.UK

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

Both words needed

1

(ii) UV light/Ultra-violet light/sunlight
OR <u>high</u> 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 <u>electron pair donors</u>

OR centres of <u>electron density</u>.

M2 Bromine <u>becomes polarised/becomes polar</u>

OR forms an <u>induced dipole</u>

OR <u>becomes δ+/δ–</u>

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

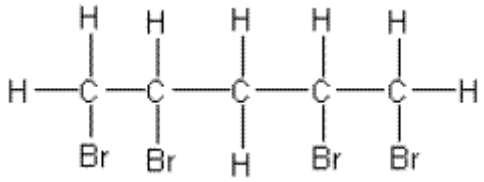
1

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

STEMUP.CO.UK

$BrCH_2CHBrCH_2CHBrCH_2Br$

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]

Q17.

(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 <u>electron</u>

NOT "bonded electron" and NOT "paired electron"

NOT "pair of electrons"

NOT "electron<u>s</u>"

Ignore "(free) radical"

1

(b) **M1** $Cl• + O_3 \rightarrow ClO• + O_2$

STEMUP.CO.UK

M2 $ClO\bullet + O_3 \rightarrow \mathbf{2}O_2 + Cl\bullet$

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 equilibrium

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 changing/altering the position of equilibrium

1

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

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

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

M2 depends on a correct statement for M1

For M2 accept

The equilibrium moves/shifts

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

(leading to the formation of more ozone)

2

(d) Any one of

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

Ignore reference to F OR C–F OR halogen

STEMUP.CO.UK

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]

Q18.

(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 $Cl_2 + \bullet CH_3 \rightarrow CH_2Cl + Cl\bullet$

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 <u>both</u> 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 <u>C–Cl</u> or <u>carbon-chlorine</u> bond breakage
OR
homolysis of <u>C–Cl</u>
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 **<u>one</u>** from

- Combination $2O_3 \rightarrow 3O_2$
- <u>Stated</u> that Cl• / chlorine atom is regenerated / not used up
- <u>Stated</u> that the Cl• / chlorine atom is unaffected

STEMUP.CO.UK

by the process.

1

For M5 accept Cl• on <u>both sides</u> of the equation

M6 <u>Stated</u> 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 <u>only</u> 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 <u>only</u> 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]

Q19.

(a) <u>Functional group</u> (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*)

M2 <u>silver mirror</u>

OR

<u>black solid/precipitate</u>
(NOT silver precipitate)

M3 (stays) colourless
or no change or no reaction

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 <u>Red solid/precipitate</u>
(*Credit orange or brown <u>solid</u>*)

M3 (stays) blue
or no change or no reaction

Mark on from an incomplete/incorrect attempt at the correct

STEMUP.CO.UK

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 the last carbon.

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 = 44.06352 (for propane)
M_r = 43.98982 (for carbon dioxide)

Mark independently

M1 a correct value for both of these M_r values.

M2 a statement or idea that two peaks appear (in the mass spectrum)

OR

STEMUP.CO.UK

two molecular ions are seen (in the mass spectrum).

2

[12]

Q20.

(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)

STEMUP.CO.UK

(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]

Q21.

(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)

STEMUP.CO.UK

2

[10]

Q22.

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]

Q23.

(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 $2F\bullet \rightarrow F_2$)

STEMUP.CO.UK

(penalise incorrect symbol Fl, once only)
(penalise absence of radical dot once only)

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

1

[5]

Q24.

(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

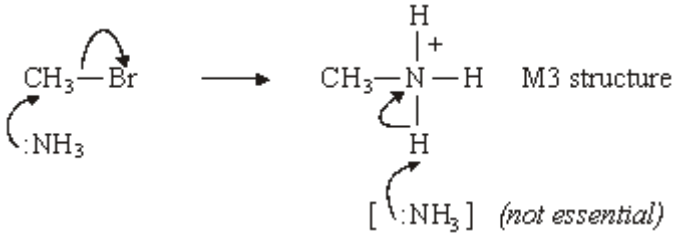
(b) (i) Electron pair donor
OR species with an electron pair able to form a covalent bond.

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)

STEMUP.CO.UK

(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]

Q25.

(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

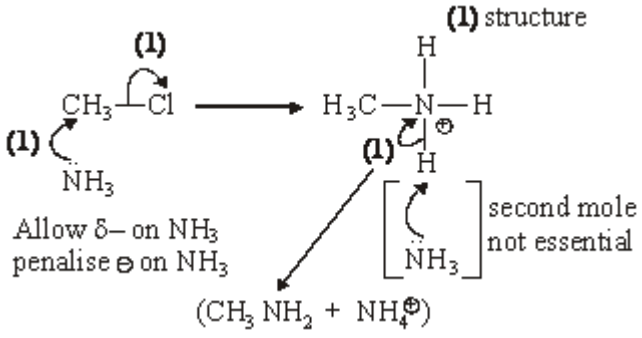
(c) CH_3COOH OR ethanoic acid **(1)**

1

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

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

(iii) S_N1 scores full marks



6

[13]

Q26.

(a) (i) $CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$ **(1)**

(ii) UV light / sunlight OR high T OR T ≥ 500°C **(1)**

STEMUP.CO.UK

maxT = 1000°C
NOT heat / light
Ignore pressure

2

(b) *Initial step*: $Cl_2 \rightarrow 2Cl^{\bullet}$ **(1)**

Condition could be on first equation arrow

First propagation step: $CHCl_3 + Cl^{\bullet} \rightarrow \dot{C}Cl_3 + HCl$ **(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]

Q27.

C

[1]

Q28.

Penalise missing • once only

(i) $Cl_2 \rightarrow 2\ Cl\bullet$ **(1)**

(ii) $CH_2Cl_2 + Cl_2 \rightarrow CHCl_3 + HCl$ **(1)**

(iii) $CH_2Cl_2 + Cl\bullet \rightarrow CHCl_2\bullet + HCl$ **(1)**
$CHCl_2\bullet + Cl_2 \rightarrow CHCl_3 + Cl\bullet$ **(1)**

Can reverse order

(iv) Effect on rate: increases **(1)** **If decrease given C.E zero marks**
Explanation: <u>more Cl•</u> radicals formed **(1)**

<u>More Cl</u> atoms, more Cl—Cl or Cl_2 bonds broken, more Cl_2 have

E_A, increased rate of Cl• production

[6]

Q29.

(a) *Condition:* U.V. light or sunlight or 450°C or <u>high</u> temp **(1)**
Explanation: U.V. light etc. provides energy to break(Cl-Cl) bond **(1)**

Do not accept reference to E_a or wrong bond or 'to make Cl

STEMUP.CO.UK

radicals'

2

(b) (i) (Free) radical substitution **(1)**

(ii) *Step 1:* initiation **(1)**
Step 2: propagation **(1)**
Step 3: termination **(1)**

Any order
Don't be too harsh on spelling

4

(c) (i) *Equation 1:* $CH_3 + Cl\bullet \rightarrow CH_2Cl\bullet + HCl$ **(1)**
Equation 2: $CH_2Cl\bullet + Cl_2 \rightarrow CH_2Cl_2 + Cl\bullet$ **(1)**

or $CH_2Cl\bullet + Cl\bullet \rightarrow CH_2Cl_2$
Mark equ independently
any order

(ii) $CH_2Cl\bullet + CH_3\bullet \rightarrow CH_3CH_2Cl$ **(1)**
or $CH_3CH_2\bullet + Cl_2 \rightarrow CH_3CH_2Cl + Cl\bullet$
or $CH_3CH_2\bullet + Cl\bullet \rightarrow CH_3CH_2Cl$

Equ must have CH_3CH_2Cl as product
Accept C_2H_5Cl
Penalise absence of • once only

3

[9]

Q30.

B

[1]

Q31.

D

[1]

Q32.

B

[1]

STEMUP.CO.UK

Q1.

(a) The equation was an easy starter and 90.1% of the students gained the mark.

(b) Most students were able to give a correct catalyst and the correct equation. However, the pressure condition was not answered well. Low or high pressure were common wrong answers and there were some contradictions. Although temperature was not required, it was sometimes given.

(c) Only the better students scored both marks, but nearly two-thirds of the students scored one out of two. Common errors were to give the ambiguous radical, C_4H_9. or $.C_4H_9$, or to show poor placement of the dot on carbon number 2.

(d) This four mark question was answered well and 40.2% of candidates gained full marks. The chlorine radical was well known although F and other radicals from the CFC were seen. A few students thought that Cl came from Cl_2 rather than from the CFC and this was penalised. There were a few missing dots in the equations. Mark point 4 was usually gained, although some candidates wrote about Cl acting as a catalyst and not being used up, without stating that it was regenerated/reformed.

Q2.

This was an extremely accessible question (96.7% correct).

Q3.

This was answered well with a high proportion of the students (68.8%) scoring the mark.

Q4.

(a) The full range of marks was seen and included some excellent answers. Other responses did not contain accurate descriptions of the effect of the attached groups on the availability of the lone pair on the nitrogen atom. The idea that, for nitrogen atoms directly attached to the benzene ring, the lone pair was delocalised into the ring was often poorly explained. The (positive) inductive effect of alkyl groups was much better described.

(b) Some excellent answers were seen, but overall this was not answered well. The fact that about 8% of students made no attempt at this part of the question perhaps indicated that a small number of students were short of time. Some students, confused by the presence of a benzene ring, started with nitration. This rarely led to any marks. For those who chose the correct route, the two intermediates were often correctly identified. The use of chlorine or bromine in UV in the first step was usually well known but use of the reagent KCN in a mixed aqueous/alcoholic solvent was less often correct in the next step. The expected reducing agent/condition for the final step was hydrogen with a nickel or platinum catalyst. $LiAlH_4$ in dry ether is not required knowledge for this specification, but was an acceptable answer.

Q8.

Free radical reactions

In (a) the two equations showing how chlorine radicals destroy ozone were quite well

STEMUP.CO.UK

known. Many students in (b) could draw the correct displayed formula of chloropentafluoroethane. Many students in (c) could explain why 1,1,1-trifluoroethane did not lead to ozone depletion. The simplest answer was that it contains no chlorine, but credit was given for students who stated that the C-F bonds were strong and so fluorine radicals were not released. Students in (d) found the two propagation steps to convert CHF_2CH_3 into CF_3CH_3 more challenging, but a pleasing number could do this. The most common mistake was to remove a Hydrogen atom from the wrong Carbon atom in the first step. Students found (e) - the calculation for the number of molecules - challenging. Some had little idea where to start while many others failed to convert kg to g and/or give their final answer to the correct number of significant figures. Few students knew (f) that molecules with vibrating polar bonds absorb IR radiation.

Q9.

This question was generally answered well throughout.

The commonest mistakes seen were for the propagation steps in the mechanism where CH_3Cl was used instead of CH_2Cl_2 and for dots to be missing from radicals in parts (b)(i) and (b)(ii).

Q10.

Part (a) required a free-radical substitution mechanism for molecules with two different halogens and it discriminated well. In common with previous questions involving a similar mechanism, the second propagation step proved to be the most demanding part of this question. The remainder of the question was relatively high scoring.

Q11.

This discriminated well with 85% scoring at least two marks in part (a)i and 70% all four marks. In part (b)ii, only 35% were able to draw a correct displayed formula for the trifluoromethyl radical; many answers giving a correct structure but including a positive charge or a lone pairs of electrons on carbon. Many good answers were seen in part (b)ii in which the two carbon-halogen bonds were compared correctly. By contrast part (b)iii proved quite demanding with only 46% gaining all three marks. Errors in the formulas of species and in balancing equations were common, whilst the idea of the bromine atom being regenerated was well understood.

Q12.

The free-radical substitution mechanism always discriminates well and this was no exception. Almost three-quarters of all students scored 2 marks but fewer than 10% scored 4 marks. It was important in the termination step to show clearly that the product is 1,2-dichloroethane.

Some good responses were seen in part (b) perhaps because this is straight from the specification, although only half of all students scored both marks in part (b)(ii).

Q13.

Part (a)(ii) of this question discriminated extremely well, although the termination step caused problems for those who were determined to produce difluoromethane. Phonetic spelling was allowed in part (b), but other incorrect spelling, such as “flouro”, was penalised. Students were required to cancel through any additional species on both sides of the equation for credit to be awarded in part (c)(i) and 51% scored this mark. Only one answer was acceptable for the more demanding part (c)(ii) and 18% were successful.

STEMUP.CO.UK

Q14.

Part (a) involved familiar chemistry and despite this, some students struggled to score many marks, making the usual mistakes. Identification of CCl_4 as the unknown **X** was accessed by many in part (b) and equations were generally done well. The explanation of the infrared spectrum usually yielded some credit but only the best students linked together the fact that there is an absorption missing in the range 2850 – 3300 cm^{-1} with the idea either that $CHCl_3$ has a C–H bond that would give rise to that absorption or that CCl_4 does not.

In part (c), too many students referred to Cl_2 as the source of chlorine atoms in the upper atmosphere rather than referring to the breakage of the C–Cl bond in $CHClF_2$. Most students attempted to write the correct equations for the catalytic decomposition of ozone and understood the significance of this process. Part (d) was generally answered well.

Q15.

Candidates found this question quite demanding, with, for example, only 31% scoring the mark in part (a)(i). In part (a)(ii) candidates sometimes lost marks because they used curly half-arrows incorrectly or they became confused in the propagation steps. Notwithstanding these problems, this mechanism provided a good opportunity for almost all candidates to show what they could do. Part (b)(i) was very high-scoring whereas part (b)(ii) proved a bigger challenge with full marks from only 18% of candidates and 24% scoring no marks.

Q16.

Candidates had little difficulty with all of part (a), although incorrect equations showing hydrogen as a product were seen in part (a)(v). Part (b)(i) required a clear explanation that the electron density of the double bond induced a dipole in the bromine molecule. The remainder of this question was relatively high scoring.

Q17.

This question was not as high scoring as might have been expected. Candidates were unfamiliar with the equations that show how chlorine atoms catalyse the decomposition of ozone, even though these are in the specification. The ability to articulate a correct argument using Le Chatelier's principle in part (c)(ii) was well done, although candidates should be urged to refer to the "equilibrium" rather than the "system".

Q18.

The stem of this question was about the development of compounds used as anaesthetics. Part (a) was an example of free-radical substitution. Candidates have difficulty with this mechanism beyond its name and the initiation step and this proved to be the case here with only 45% of the candidates gaining more than two marks. Part 10(b) was chemistry new to this unit. The question was about the probable impact of chlorine-containing compounds on the ozone layer in the upper atmosphere. Only a minority scored all 6 marks, with only 45% able to score at least 2 marks. Rather too many candidates made imprecise statements or did not know the content of the Specification sufficiently well to allow them to access this question. Part (c) required an appreciation of the difference, in terms of bonds and atoms present, between *desflurane* and *halothane.* Almost 75% of the candidates were able to gain at least half of the marks.

Q19.

Recognising functional group isomerism in part (a) proved difficult for many candidates whereas testing for an aldehyde was generally done well in part (b). The free-radical

STEMUP.CO.UK

substitution in part (d) produced a wide range of marks and only the best candidates scored full marks. The use of precise M_r values in part (e) was new and only 38% scored any marks.

Q20.

This was a high scoring question with many scores of eight or more marks. In part (a) candidates were penalised if the radical dot was shown to be on the CH_3 group, rather than as given in the question. In part (b) many equations gave hydrogen as the product rather than hydrogen bromide, suggesting that candidates had difficulty applying the information to a novel situation. Parts (c) and (d) (i) were frequently correct, although the failure to number all of the substituents on the two carbon atoms of halothane was penalised. In part (d) (ii), many candidates had problems using the data to calculate a correct relative molecular mass and the answer of 197.4 was the only response accepted. In part (d) (iii), consequential credit was awarded, with correct answers to either 3 or 4 significant figures being accepted.

Q21.

This question usually yielded at least half marks for most candidates. In part (a), the word “substitution” was occasionally omitted. Weaker candidates struggled to present correct propagation steps, but could complete both the initiation step and the overall equation. Centres should encourage candidates to place the unpaired electron on a carbon atom when writing the formula for a free-radical intermediate.

Part (b) caused few problems for many candidates, although several could get no further than a correct empirical formula and then manipulated the numbers to produce an incorrect molecular formula.

In part (c) most candidates could get $CHBr_3$, but a second formula proved elusive for some, with HBr a common incorrect answer.

Q22.

This was probably the best answered question on the paper, with many candidates scoring at least three out of the five marks and many scoring full marks. The mark missed most frequently was the second propagation step. Candidates should be advised strongly not to write curly arrows in radical substitution reactions, because too many mistakes are made, even when they try (correctly) to use half-headed arrows. They should also be advised that they will lose credit if they write a correct mechanism and then contradict this mechanism with one which includes ionic species.

Q23.

This was the first occasion that fluorine had been used in a question of this type and it was good to see that the majority of candidates were able to apply their knowledge and score at least three of the five marks. The symbol “FI” was penalised once only and the improbable recombination of two fluorine atoms into a fluorine molecule was given credit as a termination step, since it represented logical thinking by the candidate. The most difficult part of the question proved to be part (b) and unbalanced equations or equations with hydrogen or haloalkanes other than tetrafluoromethane were common.

Q24.

Part (a) of this question was well answered by many candidates, with due credit given to those who chose to include half arrows in part (a)(iii); this is not necessary, but is correct

STEMUP.CO.UK

chemistry and will receive credit. The most common error in part (a)(i) was to fail to include the word “substitution” and too often in part (a)(iv) errors were encountered due to incorrectly balanced equations, incorrect products or the use of an incorrect formula. The idea of an electron pair donor and a correct name for methylamine was known by a large number of candidates in parts (b)(i) and (ii). Most candidates had a go at part (b)(iii), sometimes scoring only the mark for the C-Br bond breakage. Even some of the best candidates incorrectly included a negative charge on the ammonia molecule.

Q25.

This question was well answered by many candidates, although in part (a)(ii) the word “substitution” was often missed and weaker candidates had problems recognising that tetrachloromethane would form as the main product when a large excess of chlorine is used. In part (b)(i) marks were lost through equations not being balanced or through errors in the formula of ethanenitrile. In part (b)(iii) the idea from the specification that the “carbon-halogen bond enthalpy influences the rate of hydrolysis” was known and applied in this context by many candidates. Rather too many answers lacked precision and stated simply that “bromomethane has weaker bonds” without indicating the relative strengths of the C-Br and C-Cl bonds. Part (c) was generally answered correctly. In part (d)(i) the demand was for the candidates to appreciate the polar nature of the C-Cl bond, rather than the more vague response that “chloromethane is polar”. In (d)(ii), many candidates were able to name methylamine correctly and attempts at the mechanism in (d)(iii) were generally good. The main problems with many mechanisms arose from the inclusion either of a negative charge on the ammonia molecule or curly arrows going the wrong way on the methylammonium ion, which often lacked a positive charge. Notwithstanding these difficulties most candidates scored at least two marks.

Q26.

Many candidates found parts (a) and (b) difficult. It was obvious from their answers that the conversion from methane to chloromethane had been learned, but the application of this idea to trichloromethane proved difficult. Even when candidates were able to start with a correct formula for trichloromethane, equations were confused, typically with radicals appearing in the overall equation and incorrect products and intermediates throughout both of parts (a) and (b).

Q28.

Parts (i) and (ii) were generally well answered, although equations in (i) showing the reaction of chlorine with substances such as methane, and equations in (ii) which contained such species as $Cl\cdot$, HCl, Cl_2 and H_2, were not uncommon. There were rather more errors in (iii), where equations showing the mono-chlorination of methane, or which contained such species as CH_2Cl_3, $CH_2Cl\cdot$ and $CH_2Cl_2\cdot$ were quite common. It was not uncommon to see an equation for a termination step offered as the second propagation step. Almost all candidates predicted an increase in rate in (iv), however, the explanations offered frequently lacked precision. Many vague references were seen to increased numbers of radicals, radicals being formed faster, there being more kinetic energy available or that the activation energy being altered by the more intense light. The better candidates correctly attributed the change in rate to an increased rate of production/concentration of chlorine radicals.

Q29.

Part (a) was generally well answered, with most candidates quoting ultraviolet light as the required condition. References to high temperature or sunlight were less common but earned credit, whereas vague references to light or to heat were not accepted. In many

STEMUP.CO.UK

cases, acceptable explanations in terms of the need to break the Cl-Cl bond were given but inaccurate explanations in terms of the activation energy of the reaction, C-H bond cleavage, or of heterolytic fission of the Cl-Cl bond were seen. Part (b) was also generally well done, however, some candidates quoted the mechanism as being ‘free radical’ but omitted to specify ‘substitution’. A few references to ‘nucleophilic’ or ‘electrophilic’ mechanisms were also seen. The names quote in part (b)(ii) were almost always acceptable, however, there were some odd misspellings of some of the steps. A few candidates gave incorrect responses, such as ‘substitution’ or ‘reduction’. Although the better candidates coped well with part (c), the overall level of success was lower than that in the earlier parts of the question. In (c)(i), it was not uncommon to see equations omitting CH_3Cl as a reactant or CH_2Cl_2 as a product. Also, it was not unusual for the dots to be omitted from the formulae of radicals, for equations to show species carrying charges or for species such as HCl• or CH_3Cl• to be shown. A termination equation showing the formation of CH_2Cl_2 was accepted for Equation 2. Most candidates gave an acceptable equation to represent the formation, either by termination or as part of a propagation step, of CH_3CH_2Cl.

STEMUP.CO.UK