

M1. (a) **M1** Benzene is more stable than cyclohexatriene
more stable than cyclohexatriene must be stated or implied
If benzene more stable than cyclohexene, then penalise M1
but mark on
If benzene less stable: can score M2 only 1

M2 Expected ΔH° hydrogenation of C_6H_6 is $3(-120)$
 $= -360 \text{ kJ mol}^{-1}$
Allow in words e.g. expected ΔH° hydrog is three times the
 ΔH° hydrog of cyclohexene 1

M3 Actual ΔH° hydrogenation of benzene is
 152 kJ mol^{-1} (less exothermic)
or 152 kJ mol^{-1} different from expected
Ignore energy needed 1

M4 Because of delocalisation or electrons spread out or resonance 1

(b) **No mark for name of mechanism**

Conc HNO_3
If either or both conc missing, allow one; 1

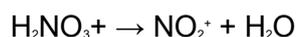
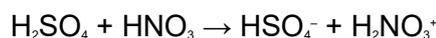
Conc H_2SO_4
this one mark can be gained in equation 1



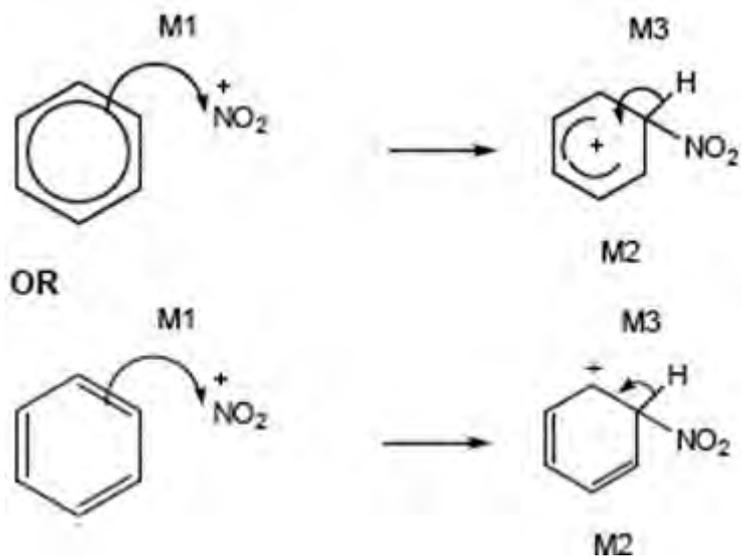
OR



OR via two equations



Allow + anywhere on NO_2^+



M1 arrow from within hexagon to N or + on N

Allow NO₂⁺ in mechanism

horseshoe must not extend beyond C2 to C6 but can be smaller

+ not too close to C1

M3 arrow into hexagon unless Kekule

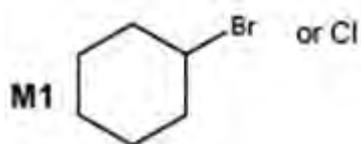
allow M3 arrow independent of M2 structure

ignore base removing H in M3

+ on H in intermediate loses M2 not M3

3

(c) **If intermediate compound V is wrong or not shown, max 4 for 8(c)**



or chlorocyclohexane or bromocyclohexane

1

Reaction 3

M2 HBr

1

M3 Electrophilic addition

Allow M2 and M3 independent of each other

1

Reaction 4

M4 Ammonia if wrong do not gain M5

1

Allow M4 and M6 independent of each other

M5 Excess ammonia or sealed in a tube or under pressure

1

If CE e.g. acid conditions, lose M4 and M5

M6 Nucleophilic substitution

1

(d) Lone or electron pair on N

No marks if reference to "lone pair on N" missing

1

Delocalised or spread into ring in U

1

Less available (to accept protons) or less able to donate (to H⁺)

1

[19]

M2.D

[1]

M3.D

[1]

M4. (a) (i) (Free-) radical substitution

Both words needed

1

(ii) UV light/Ultra-violet light/sunlight
OR high temperature/ $150\text{ }^{\circ}\text{C} \leq T \leq 500\text{ }^{\circ}\text{C}$ 1

(iii) Propagation (Step)
Ignore "first" or "second"
Accept phonetic spelling 1

(iv) **M1** Termination (Step)
M2 $2\text{CH}_3\text{CH}_2\text{CH}_2\cdot \longrightarrow \text{C}_6\text{H}_{14}$
In M2
 C_6H_{14} may be drawn out as $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
The dot may be anywhere around the terminal CH_2 on the radical
Accept $\text{C}_3\text{H}_7\cdot$ with dot anywhere
Penalise the absence of any radical dot 2

(v) $\text{C}_3\text{H}_8 + 8\text{Br}_2 \longrightarrow \text{C}_3\text{Br}_8 + 8\text{HBr}$
Or multiples 1

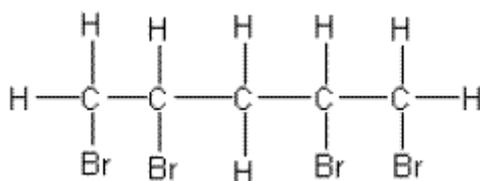
(b) (i) **M1** Double bonds are
electron-rich
OR electron pair donors
OR centres of electron density.
M2 Bromine becomes polarised/becomes polar
OR forms an induced dipole
OR becomes δ^+/δ^-
M1 QoL – require one of these terms
Ignore "(very) negative" and "nucleophile" as applied to the double bond.
Penalise M2 for ion formation from bromine
For M2, do not credit dipole formation solely as a

(ii) Electrophilic addition*Both words needed**Accept phonetic spelling*

1

(iii) Structure for 1,2,4,5-tetrabromopentane, for example
 $\text{BrCH}_2\text{CHBrCH}_2\text{CHBrCH}_2\text{Br}$

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]

M5. (a) **M1** Cl₂ (provides the pale green colour)

M1 requires the formula

M2 NaOH reacts with the acid(s)/the HCl/the HClO/H⁺

Ignore "reacts with the products"

Ignore "reacts with chloride ion"

Ignore "reacts with chlorine"

M3 requires a correct answer in M2

Equilibrium shifts (from left) to right **OR** wtte

3

(b) **M1** A reducing agent is an electron donor OR (readily) loses/ gives away electrons

Penalise M1 if "electron pair donor"

M2 Cl₂ + 2e⁻ → 2Cl⁻

For M3 and M4, iodide ions are stronger reducing agents than chloride ions, because

Ignore state symbols in M2 Accept no charge on the electron

Credit the electrons being lost on the RHS

M3 Relative size of ions/atomic radius/ionic radius

Iodide ions are larger/have more (electron) shells/levels than chloride ions (or converse for chloride ion) OR electron(s) to be lost/outer shell/level is further from the nucleus (or converse for chloride ion) OR greater/more shielding

For M3 insist on "iodide ions"

M4 Strength of attraction for electron(s) being lost

Electron(s) lost from an iodide ion is less strongly held by the nucleus compared with that lost from a chloride ion

M3 and M4 must be comparative and should refer to electrons.

(assume argument refers to iodide ions but accept converse argument for chloride ions)

4



Or multiples

M2 silver chloride ONLY

M2 requires a name

M3 The solid/precipitate would dissolve

OR is soluble

OR (It) forms a (colourless) solution

Mark M3 independently

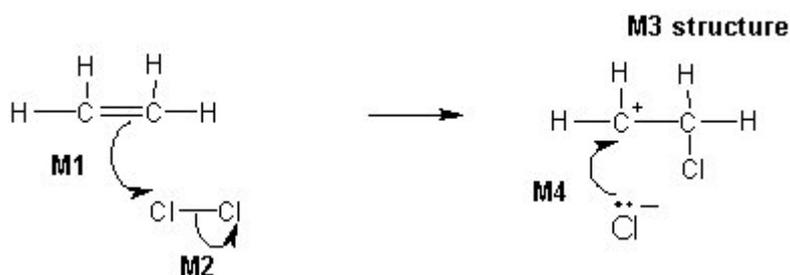
Ignore "disappears"

3

(d) Electrophilic addition

1

Mechanism:



M2 Penalise partial charges if wrong way around, otherwise ignore

*Max 3 marks **for the mechanism** for wrong reactant and/or "sticks" (wrong reactant could be HBr or Br₂ or incorrect alkene)*

M1 must show an arrow from the double bond towards one of the Cl atoms on a Cl-Cl molecule.

M2 must show the breaking of the Cl-Cl bond.

M3 is for the structure of the carbocation with Cl substituent.

M4 must show an arrow from the lone pair of electrons on a negatively charged chloride ion towards the positively charged carbon atom.

4

[15]

M6. (a) Contains a C=C **OR** a double bond

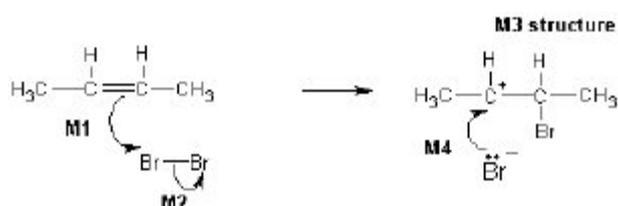
1

(b) **Electrophilic addition**

Both words needed

1

Mechanism:



Ignore partial negative charge on the double bond.

M2 Penalise partial charges on bromine if wrong way and penalise formal charges

Penalise once only in any part of the mechanism for a line and two dots to show a bond.

M1 Must show an arrow from the double bond towards one of the Br atoms on a Br-Br molecule.

Deduct 1 mark for sticks.

M2 Must show the breaking of the Br-Br bond.

M3 Is for the structure of the secondary carbocation with Br substituent.

M4 Must show an arrow from the lone pair of electrons on a negatively charged bromide ion towards the positively charged carbon atom.

Deduct 1 mark for wrong reactant, but mark consequentially. If HBr, mark the mechanism consequentially and deduct one mark

If but-1-ene, mark the mechanism consequentially and deduct one mark.

If both HBr and but-1-ene, mark the mechanism consequentially and deduct ONLY one mark.

4

(c) (i) **M1** Compounds with the same structural formula

Penalise M1 if "same structure"

Ignore references to "same molecular formula" or "same empirical formula"

1

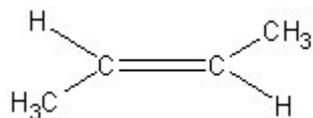
M2 With atoms/bonds/groups arranged differently in space
OR
atoms/bonds/groups have different spatial

arrangements/ different orientation.

Mark independently.

1

(ii)



Award credit provided it is obvious that the candidate is drawing the trans isomer.

Do not penalise poor C–C bonds

Trigonal planar structure not essential

1

[9]