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 $\Delta H^{\ominus}$ hydrogenation of C_6H_6 is 3(–120)

= –360 kJ mol^{-1}

Allow in words e.g. expected $\Delta H^{\ominus}$ hydrog is three times the $\Delta H^{\ominus}$ hydrog of cyclohexene

1

M3 Actual $\Delta H^{\ominus}$ 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

$2\ H_2SO_4 + HNO_3 \rightarrow 2\ HSO_4^- + NO_2^+ + H_3O^+$

OR

$H_2SO_4 + HNO_3 \rightarrow HSO_4^- + NO_2^+ + H_2O$

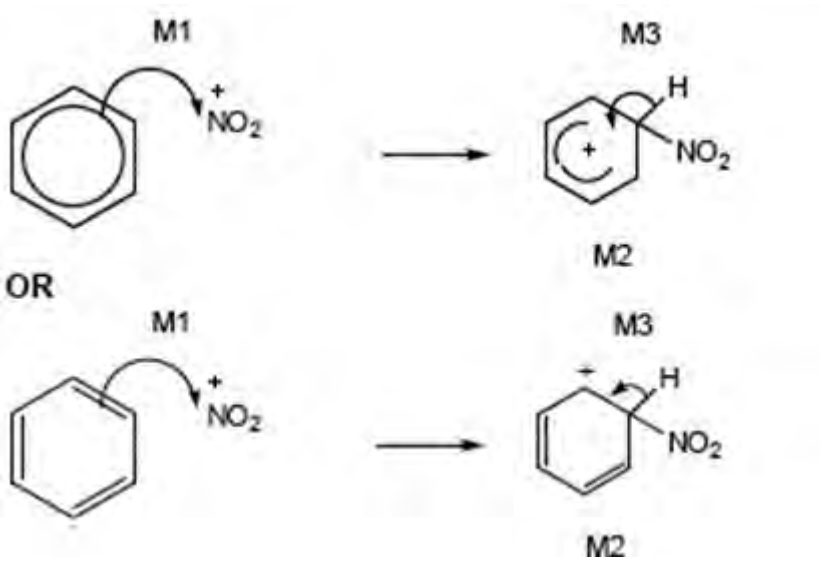
OR via two equations

$H_2SO_4 + HNO_3 \rightarrow HSO_4^- + H_2NO_3^+$

$H_2NO_3+ \rightarrow NO_2^+ + H_2O$

Allow + anywhere on NO_2^+

1



M1 arrow from within hexagon to N or + on N

Allow NO_2^+ 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

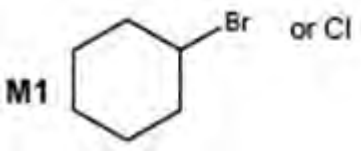
allow M3 arrow independent of M2 structure

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 °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 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

consequence of electronegativity

2

(ii) Electrophilic addition

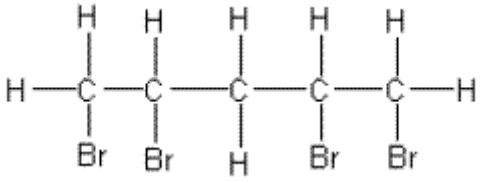
Both words needed

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]

M5. (a) **M1** Cl_2 (provides the pale green colour)

M1 <u>requires the formula</u>

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 <u>requires a correct answer in M2</u>
Equilibrium shifts (from left) <u>to right</u> ***OR*** wtte

3

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

Penalise M1 if "electron pair donor"

M2 $Cl_2 + 2e^- \rightarrow 2Cl^-$

For M3 and M4, **i**odide 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
<u>Iodide ions</u> are <u>larger</u>/have more (electron) shells/levels than chloride ions (or converse for chloride ion) OR <u>electron(s) to be lost/outer shell/level</u> is <u>further</u> from the nucleus (or converse for chloride ion) OR greater/more shielding

For M3 insist on "<u>iodide ions</u>"

M4 Strength of attraction for <u>electron(s) being lost</u>
<u>Electron(s) lost</u> from an iodide ion is <u>less strongly held by the nucleus</u> 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

(c) **M1** $\mathbf{2}Cl_2 + \mathbf{2}H_2O \rightarrow \mathbf{4}HCl + O_2$

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

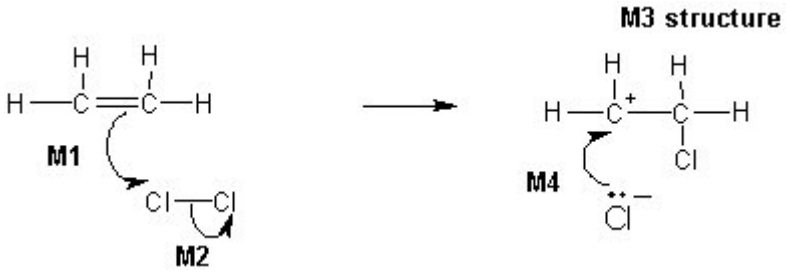
Ignore "disappears"

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 Br_2 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

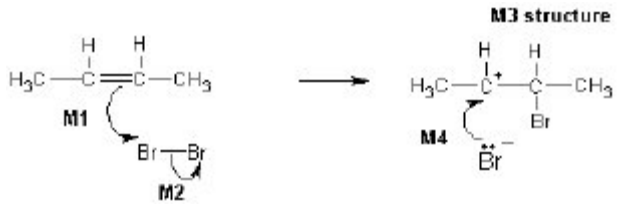
1

(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

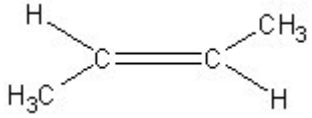
M2 With atoms/bonds/groups arranged differently in space
OR
atoms/bonds/groups have different spatial

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]