

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

**M3** Actual  $\Delta H^\circ$  hydrogenation of benzene is  
 $152 \text{ kJ mol}^{-1}$  (less exothermic)  
or  $152 \text{ kJ mol}^{-1}$  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

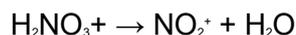
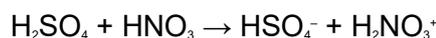
Conc  $H_2SO_4$   
*this one mark can be gained in equation* 1



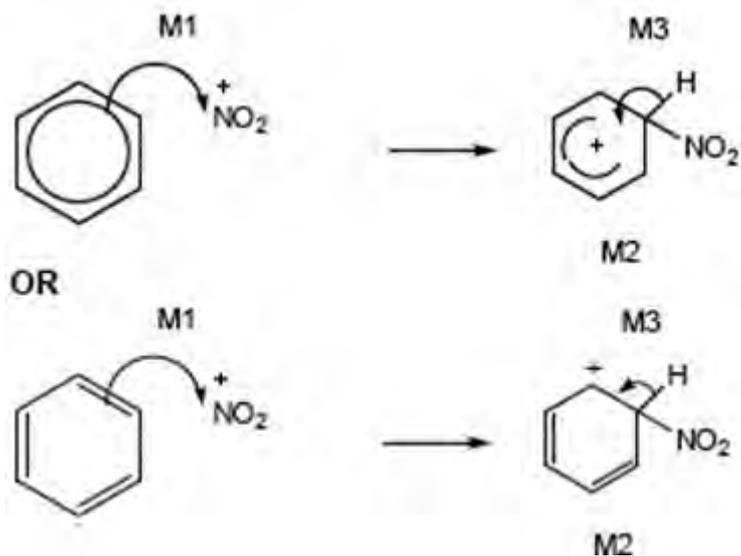
**OR**



**OR via two equations**



*Allow + anywhere on  $NO_2^+$*



*M1 arrow from within hexagon to N or + on N*

*Allow  $\text{NO}_2^+$  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*

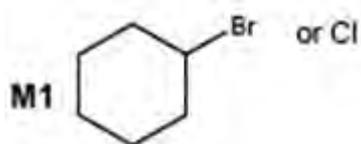
*allow M3 arrow independent of M2 structure*

*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<sup>+</sup>)

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*  
 *$\text{C}_6\text{H}_{14}$  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  $\text{CH}_2$  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  $\delta^+/\delta^-$   
*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

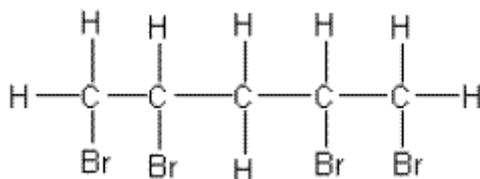
*Both words needed*

*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  $\text{CH}_3\text{CHCH}_3$

**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<sub>2</sub> (provides the pale green colour)

*M1 requires the formula*

**M2** NaOH reacts with the acid(s)/the HCl/the HClO/H<sup>+</sup>

*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** Cl<sub>2</sub> + 2e<sup>-</sup> → 2Cl<sup>-</sup>

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*

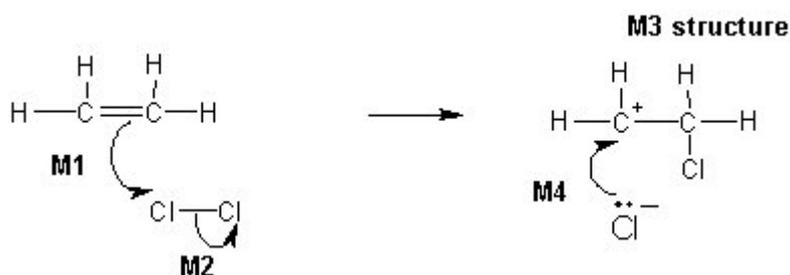
*Ignore "disappears"*

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 Br<sub>2</sub> 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

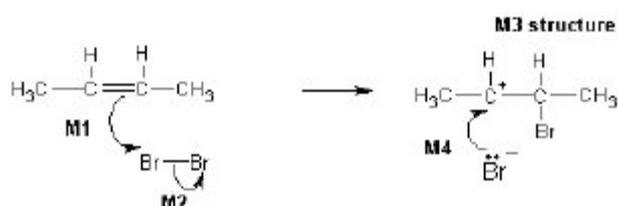
1

(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

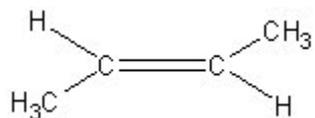
**M2** With atoms/bonds/groups arranged differently in space  
**OR**  
atoms/bonds/groups have different spatial

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]