EXAM PAPERS PRACTICE

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Detailed mark scheme

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Level: CIE AS and A Level (9701)
Subject: Chemistry
Topic: CIE Chemistry
Type: Mark Scheme

Chemistry CIE AS & A Level
To be used for all exam preparation for 2025+

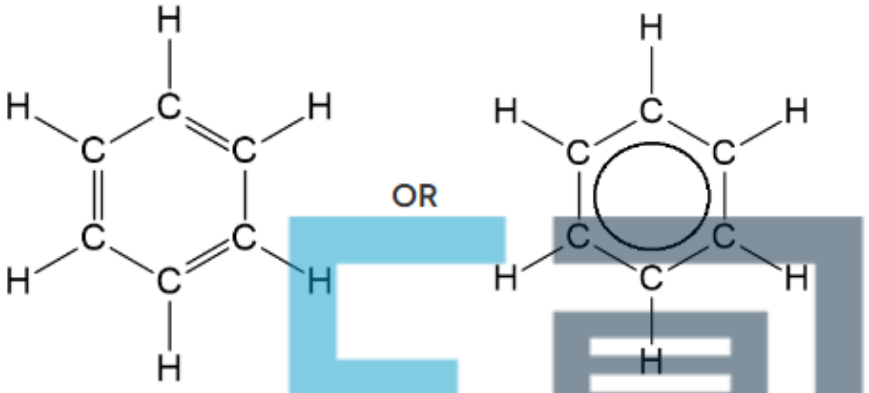
CHEMISTRY AS and A

This to be used by all students studying CIE AS and A level Chemistry (9701) But students of other boards may find it useful

Mark Scheme

Answer 1.

a) The displayed formula of benzene is:



- Correct displayed formula for benzene; [1 mark]

[Total: 1 mark]

- The delocalisation of electrons in benzene is represented by drawing a circle within the hexagon
  - This increases stability
- **Remember:** The fully displayed formula should show all of the atoms and all of the bonds

b) The bond angle in benzene is:

- 120°; [1 mark]

[Total: 1 mark]

- Benzene is a planar regular hexagon with bond angles of 120°
- A molecule with three bonded regions will be planar and have three bond angle of 120°, the same occurs in carbonyls
  - Square planar molecules have four bonded regions and have a bond angle of 90 °
- All the bonds are identical due to the delocalisation of electrons

c) The type of hybridisation of the carbon atoms is:

- sp^2; [1 mark]

[Total: 1 mark]

- Benzene and other aromatic compounds contain sp^2 hybridised carbons
  - Two of their p orbitals have mixed with an s orbital
- This means that each carbon atom in benzene and other aromatic compounds has one p orbital

Answer 2.

a) The IUPAC names for compounds **W**, **X** and **Y** are:

- **W** = 4–chloromethylbenzene; [1 mark]
- **X** = 3–nitrobenzoic acid; [1 mark]
- **Y** = propylbenzene; [1 mark]

[Total: 3 marks]

- The benzene ring is the main functional group in compounds **W** and **Y** so the suffix is -benzene
- In **W** the prefixes chloro- and methyl- are needed
  - The methyl group assumes position 1 and the chloro- group is given a position in relation to this i.e. 4
- In **Y** the prefix propyl- is used to represent the $-CH_2CH_2CH_3$ group
- For compound **Z** the benzene ring has the -COOH group attached, so its suffix is benzoic acid
  - It also has the NO_2 group attached, so the prefix nitro- is needed, and its position is given in relation to the COOH group

b) The IUPAC name for compound **Z** is:

- 2,4–dibromophenol; [1 mark]

[Total: 1 mark]

- This benzene ring contains an -OH group so the main stem is phenol
- Starting from the OH group (on carbon number 1 as this is the dominant functional group) and counting anticlockwise, there are two bromine atoms on carbons 2 and 4; this is the lowest numbered version as in this case counting clockwise would result in numbers of 4 and 6
- So the name is given as 2,4–dibromophenol

c) The bond angle in benzene is:

- 120°; [1 mark]

[Total: 1 mark]

- As each carbon atom is bonded to three other atoms the bond angle will be 120° and the shape will be trigonal planar
- The three areas of electron density arrange themselves as far apart from each other as possible, hence the angle achieved, and there are no lone pairs on the carbons to distort this angle

d)

i) The sp^2 orbitals form σ bonds by:

- Overlapping of sp^2 orbitals; [1 mark]

ii) π bonds are formed by:

- Overlapping of p orbitals; [1 mark]

[Total: 2 marks]

- 3 of the orbitals in each carbon atom are hybridised
- The hybridised orbital is made from 1 s orbital and 2 p orbitals, hence they are called sp^2 hybrids
- Each carbon will overlap its sp^2 hybridised orbital with the sp^2 hybridised orbital of 2 neighbouring carbon atoms and an s orbital of a hydrogen atom
  - These are sigma, σ, bonds and they arrange themselves at 120° to each other in one plane
- Each carbon atom has a fourth electron in a p orbital at right angles to the sp^2 orbitals, so above and below the plane of the rest of the molecule
  - The p orbitals overlap forming a π bond
  - It is these electrons in the p orbitals which become delocalised and can spread around the ring

Answer 3.

a) The names of the compounds **X** and **Y** are:

- compound **X**: 1-chloro-2-methylbenzene; [1 mark]
- compound **Y**: 3,5-dichlorophenylamine; [1 mark]

[Total: 2 marks]

- To name compound **X**, the chloro and methyl group should be named in alphabetical order
- To name compound **Y**, the main group is the amine group, which when bonded to a benzene ring, forms the name phenylamine
  - There are two chloro groups on the benzene ring, in the 3 and 5 position

b) The benzene ring is planar because:

- In C_6H_6 / benzene all the carbon atoms are sp^2 hybridised; [1 mark]
- Forming a triangular planar arrangement
  AND
  (With) bond angles of 120°; [1 mark]

[Total: 2 marks]

- Hybridisation can be used to explain the shape of any molecule and conversely the shape of a molecule can be used to determine the type of hybridisation that has occurred.
  - Tetrahedral arrangement ↔ sp^3 hybridised
  - Triangular planar arrangement ↔ sp^2 hybridised
  - Linear arrangement ↔ sp hybridised

c) The reagents required are:

- step 1 $AlCl_3 + CH_3Cl$
- step 2 $AlCl_3 + Cl_2$

[Total: 2 marks]

- In order for benzene which is very stable to react, an electrophile must be produced
- The delocalised π system is extremely stable and is a region of high electron density
- This can be achieved by using a halogen carrier
  - $AlCl_3 + CH_3Cl \rightarrow CH_3^+ + AlCl_4^-$
  - This will form methylbenzene
  - $AlCl_3 + Cl_2 \rightarrow Cl^+ + AlCl_4^-$
  - This will form compound **Y**

Answer 4.

a) The bond angle in benzene is:

- 120 °; [1 mark]

[Total: 1 mark]

- As each carbon atom is bonded to three other atoms the bond angle will be 120 ° and the shape will be trigonal planar
- The three areas of electron density arrange themselves as far apart from each other as possible, hence the angle achieved, and there are no lone pairs on the carbons to distort this angle

b) Benzene does not tend to react with bromine, but hexene does because:

- Pi / π bond in hexene / C_6H_{12} contains localised electrons / area of high electron density; [1 mark]
- Pi / π bond in hexene / C_6H_{12} induces a partial / delta / δ positive / + and partial / delta / δ negative / - in the bromine / Br_2 molecule; [1 mark]
- Partial / delta / δ positive / + bromine / Br attracted to pi / π bond in hexene / C_6H_{12} leaving a carbocation intermediate; [1 mark]
- The carbocation intermediate attracts the partial / delta / δ negative / – bromine / Br atom; [1 mark]
- In benzene / C_6H_6 there are no localised electrons with areas of high electron density therefore it is unable to polarise the bromine molecule

  OR

  In benzene / C_6H_6 there are delocalised electrons with no areas of high electron density therefore it is unable to polarise the bromine molecule; [1 mark]

[Total: 5 marks]

- Alkenes will undergo electrophilic addition to form haloalkanes when they react with halogen molecules
- The double bond in the alkene is very reactive due to the high electron density
- In order for benzene to react with a halogen molecule, a halogen carrier such as aluminium bromide, $AlBr_3$ must be used

c) The type of reaction that benzene will undergo is:

- Electrophilic substitution; [1 mark]

[Total: 1 mark]

- The nature of benzene is different to other unsaturated compounds such as alkenes, so halogenation via electrophilic addition is not possible as it would involve breaking apart the stabilising ring of delocalised electrons
- Therefore benzene is most likely to undergo electrophilic substitution
- This mechanism restores the delocalisation in the benzene ring