Class:12th

Subject: Chemistry

Chapter 9: AROMATIC HYDROCARBONS

🩸Important Keypoints MCQs:

1. Aromatic hydrocarbons include:

(a) Only benzene

(b) Only alkanes

(c) Benzene and all compounds structurally related to benzene ✅

(d) Alkenes and alkynes

2. Monocyclic aromatic hydrocarbons contain:

(a) One benzene ring ✅

(b) Two or more benzene rings

(c) No benzene ring

(d) Only aliphatic chain

3. Polycyclic aromatic hydrocarbons contain:

(a) One benzene ring

(b) Two or more benzene rings ✅

(c) Only alkanes

(d) No benzene rings

4. Who discovered benzene?

(a) Kekule

(b) Michael Faraday ✅

(c) Hoffmann

(d) Dewar

5. In which year was benzene discovered?

(a) 1805

(b) 1825 ✅

(c) 1865

(d) 1905

6. Why is benzene readily attacked by electrophiles?

(a) Because it is saturated

(b) Because its electrons are loosely held and act as a source of electrons ✅

(c) Because it contains no double bonds

(d) Because it is highly reactive like alkenes

7. The main type of reactions observed in benzene is:

(a) Addition reactions

(b) Substitution reactions ✅

(c) Combustion reactions

(d) Polymerization reactions

8. The resonance energy of benzene is:

(a) 100.5 kJ/mole

(b) 120.5 kJ/mole

(c) 150.5 kJ/mole ✅

(d) 200.5 kJ/mole

9. The structure of benzene is a resonance hybrid of:

(a) Only Kekule's structures

(b) Only Dewar's structures

(c) Two Kekule’s and three Dewar’s structures ✅

(d) Three Kekule’s structures

10. Ortho- and para-directing groups include:

(a) CN, CHO, CCl

(b) NH_2, OR, OH ✅

(c) COOH, NO_2

(d) NR_3, NH_3

🩸 Important MCQs:

1. The term aromatic is derived from a Greek word meaning:

(a) Colourless

(b) Fragrant ✅

(c) Bitter

(d) Sweet

2. Aromatic compounds were originally named because many of them were:

(a) Reactive

(b) Acidic

(c) Fragrant ✅

(d) Unsaturated

3. Aromatic compounds generally have a low ratio of:

(a) Carbon to hydrogen

(b) Hydrogen to carbon ✅

(c) Oxygen to carbon

(d) Nitrogen to hydrogen

4. When aromatic compounds of high molecular mass were degraded, they commonly produced:

(a) Methane

(b) Ethene

(c) Benzene or its derivatives ✅

(d) Propane

5. The simplest and parent member of aromatic hydrocarbons is:

(a) Ethene

(b) Methane

(c) Benzene ✅

(d) Toluene

6. Aromatic hydrocarbons include benzene and all compounds:

(a) With double bonds

(b) That are aliphatic

(c) Structurally related to benzene ✅

(d) With sweet smell only

7. Benzene has a structural feature described as:

(a) Linear

(b) Branched

(c) Regular planar hexagonal ✅

(d) Tetrahedral

8. Aromatic hydrocarbons with only one benzene ring are called:

(a) Polycyclic

(b) Aliphatic

(c) Monocyclic aromatic hydrocarbons ✅

(d) Alkanes

9. Benzene and its derivatives belong to the class:

(a) Monocyclic aromatic hydrocarbons ✅

(b) Polycyclic aromatic hydrocarbons

(c) Alkynes

(d) Saturated hydrocarbons

10. Aromatic hydrocarbons containing two or more benzene rings are termed:

(a) Alkanes

(b) Polycyclic aromatic hydrocarbons ✅

(c) Cycloalkanes

(d) Heterocyclic compounds

11. Biphenyl is an example of:

(a) Monocyclic aromatic hydrocarbon

(b) Polycyclic aromatic hydrocarbon with isolated rings ✅

(c) Polycyclic aromatic hydrocarbon with fused rings

(d) Aliphatic hydrocarbon

12. Diphenylmethane belongs to the class where benzene rings are:

(a) Fused

(b) Isolated ✅

(c) Aromatic only

(d) Non-aromatic

13. In fused polycyclic aromatic hydrocarbons, benzene rings share:

(a) Hydrogen atoms

(b) A common carbon–carbon bond ✅

(c) A common nitrogen atom

(d) No connections

14. Naphthalene is an example of:

(a) Isolated ring aromatic compound

(b) Fused ring aromatic compound ✅

(c) Saturated hydrocarbon

(d) Aliphatic compound

15. Which of the following contains fused benzene rings?

(a) Biphenyl

(b) Diphenylmethane

(c) Anthracene ✅

(d) Methane

16. The nomenclature of aromatic hydrocarbons is more complex because:

(a) They have no hydrogen atoms

(b) Substituent positions vary on the ring ✅

(c) They are all aliphatic

(d) They are colourless

17. Monosubstituted benzene derivatives are named by:

(a) Adding suffix “-ene”

(b) Alphabetical order

(c) Prefixing benzene with substituent name ✅

(d) Using Roman numerals

18. Methylbenzene is commonly known as:

(a) Phenol

(b) Benzoic acid

(c) Aniline

(d) Toluene ✅

19. Hydroxybenzene is also called:

(a) Phenol ✅

(b) Benzaldehyde

(c) Nitrobenzene

(d) Toluene

20. Removal of one hydrogen atom from benzene gives:

(a) Vinyl group

(b) Aryl oxide

(c) Phenyl group ✅

(d) Alkyl group

21. The correct symbol for the phenyl group is:

(a) C_2H_5-

(b) Ph− or C_6H_5- ✅

(c) C_6H_6-

(d) $C_5H_{11}-$

22. Substituted phenyl groups are called:

(a) Vinyl groups

(b) Aryl groups ✅

(c) Carbonyl groups

(d) Alkyl groups

23. The three isomers of disubstituted benzene are:

(a) Cis, trans, iso

(b) Ortho, meta, para ✅

(c) Alpha, beta, gamma

(d) Primary, secondary, tertiary

24. The highest-priority group in aromatic nomenclature is:

(a) NH_2

(b) OH

(c) CH_3

(d) COOH ✅

25. If substituents are not in the priority list, they are named in:

(a) Molecular mass order

(b) Alphabetical order ✅

(c) IUPAC numbering

(d) Order of reactivity

26. Benzene was discovered by Michael Faraday in:

(a) 1925

(b) 1825 ✅

(c) 1725

(d) 1855

27. Benzene was first discovered in the gas produced by:

(a) Fractional distillation

(b) Cracking of petroleum

(c) Destructive distillation of vegetable oil ✅

(d) Steam distillation

28. The molecular mass of benzene determined by vapour density method is:

(a) 58

(b) 78 ✅

(c) 92

(d) 108

29. The molecular formula of benzene is:

(a) C_6H_{12}

(b) C_6H_{10}

(c) C_6H_6 ✅

(d) C_5H_6

30. The molecular formula C_6H_6 indicates that benzene is:

(a) A saturated compound

(b) A highly unsaturated compound ✅

(c) An alkane

(d) An alkyne

31. Benzene does not decolorize alkaline $KMnO_4$ because it:

(a) Has no double bonds

(b) Is fully saturated

(c) Is stable and resistant to oxidation ✅

(d) Is an alkyne

32. Benzene gives addition reactions with hydrogen and halogens, showing the presence of:

(a) One double bond

(b) Two double bonds

(c) Three double bonds ✅

(d) No double bonds

33. Benzene gives substitution reactions with conc. HNO_3 and conc. H_2SO_4, indicating:

(a) Alkyne character

(b) Saturated character ✅

(c) Aliphatic nature

(d) High oxidation

34. Benzene forms only one monosubstituted product because:

(a) It has only one carbon atom

(b) All positions on the ring are equivalent ✅

(c) It has no hydrogens

(d) It reacts very slowly

35. Kekule proposed a structure for benzene in:

(a) 1765

(b) 1865 ✅

(c) 1965

(d) 1815

36. According to Kekule, benzene contains:

(a) Six double bonds

(b) Three alternating double bonds ✅

(c) One triple bond

(d) No double bonds

37. X-ray studies show that all carbon and hydrogen atoms in benzene are:

(a) Linear

(b) Tetrahedral

(c) In the same plane ✅

(d) Randomly arranged

38. The C–C bond length in benzene is:

(a) 1.20 Å

(b) 1.54 Å

(c) 1.397 Å ✅

(d) 1.09 Å

39. Modern theory states that each carbon in benzene is:

(a) sp hybridized

(b) sp^2 hybridized ✅

(c) sp^3 hybridized

(d) Unhybridized

40. The stability of benzene is mainly due to:

(a) Single bonds only

(b) Presence of hydrogen atoms

(c) Extensive delocalization of electrons ✅

(d) High reactivity

41. In alkanes, the C–C bond length is:

(a) 1.20 Å

(b) 1.34 Å

(c) 1.54 Å ✅

(d) 1.397 Å

42. In alkenes, the C=C bond length is:

(a) 1.54 Å

(b) 1.34 Å ✅

(c) 1.20 Å

(d) 1.397 Å

43. In alkynes, the C≡C bond length is:

(a) 1.54 Å

(b) 1.34 Å

(c) 1.20 Å ✅

(d) 1.397 Å

44. In benzene, the C–C bond length is:

(a) 1.54 Å

(b) 1.34 Å

(c) 1.20 Å

(d) 1.397 Å ✅

45. The C–C bond length in benzene is:

(a) Equal to alkanes

(b) Equal to alkenes

(c) Intermediate between alkanes and alkenes ✅

(d) Equal to alkynes

46. Benzene and other aromatic hydrocarbons are mainly obtained from:

(a) Natural gas

(b) Coal and petroleum ✅

(c) Air

(d) Wood

47. Benzene can be prepared by dehydrogenation of:

(a) Cyclohexane ✅

(b) Propane

(c) Acetylene

(d) Ethylene

48. Benzene is formed by passing acetylene over organo-nickel catalyst at:

(a) 25°C

(b) 50°C

(c) 70°C ✅

(d) 100°C

49. n-Hexane vapours give benzene when passed over catalysts at:

(a) 100°C

(b) 300°C

(c) 500°C ✅

(d) 700°C

50. Laboratory preparation of benzene includes:

(a) Heating sodium benzoate with soda lime ✅

(b) Heating sodium chloride

(c) Heating methane

(d) Distilling ethanol

51. Benzene is less reactive towards electrophiles because:

(a) It has no double bonds

(b) Its delocalized electrons are highly stable ✅

(c) It has no hydrogen atoms

(d) It is aliphatic

52. Halogenation of benzene requires:

(a) Only halogen

(b) Iron or ferric halide catalyst ✅

(c) Sunlight only

(d) Heat only

53. The actual halogenating agent in benzene halogenation is:

(a) Halogen molecule

(b) Halogen radical

(c) Halogenonium ion (X^+) ✅

(d) Halide ion

54. Addition reactions in benzene are not favorable because:

(a) Benzene has no double bonds

(b) They destroy the stability of benzene ring ✅

(c) They produce halides

(d) They produce alcohols

55. Nitration of benzene is carried out using:

(a) Conc. HCl

(b) Conc. HNO_3 + conc. H_2SO_4 ✅

(c) Br_2 and $FeBr_3$

(d) NaOH

56. In nitration, the actual electrophile is:

(a) NO_2^+ ✅

(b) NO_2^-

(c) N_2O

(d) HNO_3

57. Sulphonation of benzene gives:

(a) Benzene nitrate

(b) Benzene sulphonic acid ✅

(c) Benzoic acid

(d) Phenol

58. The electrophile in sulphonation using conc. H_2SO_4 is:

(a) SO_3 ✅

(b) HSO_4^-

(c) H^+

(d) O_3

59. Friedel-Crafts alkylation requires:

(a) Alkyl halide and $AlCl_3$ ✅

(b) Alkyl alcohol and H_2SO_4

(c) Alkyne and Pt

(d) Alkene and Br_2

60. Friedel-Crafts acylation introduces:

(a) Alkyl group

(b) Acyl group (R–CO) ✅

(c) Halogen

(d) Nitro group

61. Reduction of benzene produces:

(a) Cyclohexane ✅

(b) Cyclohexene

(c) Benzene oxide

(d) Phenol

62. Addition of chlorine to benzene under sunlight gives:

(a) Chlorobenzene

(b) Hexachlorobenzene ✅

(c) Benzyl chloride

(d) Nitrobenzene

63. Combustion of benzene produces:

(a) CO_2 and H_2O ✅

(b) CO only

(c) CH_4 and O_2

(d) C_2H_6 and H_2

64. Benzene is not oxidized by $KMnO_4$ because:

(a) It is saturated

(b) Its ring is highly stable ✅

(c) It has no hydrogen

(d) It has triple bonds

65. Side chain oxidation of alkylbenzenes gives:

(a) Alcohols

(b) Aldehydes

(c) Carboxylic acids ✅

(d) Ketones

66. Regardless of the length of the alkyl group, oxidation of alkylbenzene produces:

(a) Alcohol

(b) Benzoic acid ✅

(c) Phenol

(d) Nitrobenzene

67. In electrophilic substitution, benzene gives only one monosubstituted product because:

(a) It has six identical positions ✅

(b) It is aliphatic

(c) It reacts slowly

(d) It has no hydrogens

68. The three possible isomers for disubstituted benzene are:

(a) Alpha, beta, gamma

(b) Ortho, meta, para ✅

(c) Cis, trans, iso

(d) Primary, secondary, tertiary

69. The directive effect of a substituent in monosubstituted benzene determines:

(a) The strength of the ring

(b) The position of new incoming groups ✅

(c) The molecular mass

(d) The melting point

70. Ortho- and para-directing groups in benzene:

(a) Withdraw electrons from the ring

(b) Release electrons to the ring ✅

(c) Decrease reactivity

(d) Always form meta products

71. Alkanes are relatively unreactive due to:

(a) Polar nature of bonds

(b) Inertness of σ-bonds ✅

(c) Availability of electrons

(d) Weak C–H bonds

72. Alkanes mainly undergo:

(a) Electrophilic addition

(b) Free radical substitution ✅

(c) Electrophilic substitution

(d) Polymerization

73. Alkenes are highly reactive because:

(a) They have strong σ-bonds

(b) They have weak π-bonds and electrons available for electrophiles ✅

(c) They are saturated

(d) They resist oxidation

74. Benzene is stable due to:

(a) Its saturated nature

(b) Extensive delocalization of π-electrons ✅

(c) Strong C–H bonds only

(d) Free radical reactions

75. Unlike alkenes, benzene:

(a) Undergoes polymerization easily

(b) Requires mild conditions for addition reactions

(c) Undergoes electrophilic substitution instead of free radical reactions ✅

(d) Is highly reactive in oxidation

🩸 Important Short Questions:

1. Define the term "Aromatic".

Answer:

👉 The term aromatic is derived from the Greek word ‘aroma’ meaning fragrant and is used for a special class of organic compounds.

2. Why were some compounds initially called aromatic?

Answer:

👉 Because many of them were fragrant, although some were later found to be odourless.

3. Do all aromatic compounds have a characteristic odour?

Answer:

👉 No, many aromatic compounds are odourless, and some fragrant compounds are not aromatic.

4. What common unit is present in almost all aromatic compounds?

Answer:

👉 A six-carbon unit like that of benzene is present in almost all aromatic compounds.

5. Which compound is considered the simplest aromatic hydrocarbon?

Answer:

👉 Benzene is recognized as the simplest and parent member of aromatic hydrocarbons.

6. Name the two main classes of aromatic hydrocarbons based on the number of benzene rings.

Answer:

👉 (a) Monocyclic Aromatic Hydrocarbons

👉 (b) Polycyclic Aromatic Hydrocarbons

7. Define Monocyclic Aromatic Hydrocarbons with an example.

Answer:

👉 Aromatic hydrocarbons containing one benzene ring in their molecule are called Monocyclic Aromatic Hydrocarbons, e.g., benzene.

8. Define Polycyclic Aromatic Hydrocarbons with an example.

Answer:

👉 Aromatic hydrocarbons containing two or more benzene rings in their molecules are called Polycyclic Aromatic Hydrocarbons, e.g., naphthalene.

9. Name the two types of polycyclic aromatic hydrocarbons based on ring arrangement.

Answer:

👉 (i) Benzene rings isolated from each other, e.g., biphenyl, diphenylmethane

👉 (ii) Benzene rings fused together, e.g., naphthalene, anthracene

10. Give examples of fused polycyclic aromatic hydrocarbons.

Answer:

👉 Examples include naphthalene, phenanthrene, and anthracene.

11. How are mono-substituted benzene derivatives named?

Answer:

👉 Mono-substituted benzene derivatives are named by prefixing benzene with the name of the substituent as a single word, e.g., methylbenzene, chlorobenzene.

12. Give examples of monosubstituted benzene derivatives with special names.

Answer:

👉 Examples include toluene (methylbenzene), phenol (hydroxybenzene), aniline (amino-benzene), benzoic acid, benzaldehyde.

13. What is a phenyl group and how is it symbolized?

Answer:

👉 When a hydrogen atom is removed from benzene, it forms a phenyl group, symbolized as C_6H_5- or Ph−. Substituted phenyl groups are called aryl groups.

14. What are the three isomeric forms of disubstituted benzene?

Answer:

👉 The second substituent can give three isomers: ortho (1,2), meta (1,3), and para (1,4).

15. How are substituents numbered in disubstituted benzene when groups have different priorities?

Answer:

👉 The higher priority substituent is given position 1, and other groups are numbered to give the lowest possible numbers. If groups are not in the priority list, they are named in alphabetical order.

16. Who discovered benzene and when?

Answer:

👉 Benzene was discovered by Michael Faraday in 1825 in the gas produced by the destructive distillation of vegetable oil. Twenty years later, Hoffmann found it in coal-tar.

17. What is the molecular formula of benzene?

Answer:

👉 The molecular formula of benzene is C_6H_6, determined from its empirical formula and molecular mass.

18. Why are straight-chain structures ruled out for benzene?

Answer:

👉 Straight-chain structures are ruled out because benzene is stable to $KMnO_4$, gives only one monosubstitution product, and its molecular formula does not match any open-chain hydrocarbons.

19. Who proposed the cyclic structure of benzene and when?

Answer:

👉 Kekule proposed the cyclic regular hexagonal structure of benzene in 1865.

20. How did Kekule support his structure of benzene?

Answer:

👉 Kekule supported his structure because benzene gives three disubstituted products, adds three hydrogen molecules, and adds three chlorine molecules, indicating alternating single and double bonds.

21. What did X-ray studies reveal about benzene?

Answer:

👉 X-ray studies confirmed that all carbon and hydrogen atoms are in the same plane, angles are 120°, and C-C and C-H bond lengths are 1.397 Å and 1.09 Å, respectively.

22. What is the hybridization of carbon atoms in benzene?

Answer:

👉 Each carbon in benzene is sp^2 hybridized, forming three σ-bonds (two with carbons, one with hydrogen), while unhybridized 2p orbitals form a delocalized π-electron cloud.

23. Why is benzene unusually stable?

Answer:

👉 Benzene's stability is due to the extensive delocalization of π-electrons, making it more stable than hypothetical 1,3,5-cyclohexatriene by 150.5 kJ/mol (resonance energy).

24. What is meant by resonance in benzene?

Answer:

👉 Resonance is the delocalization of p-electrons over the benzene ring, represented by multiple resonance structures. This increases the chemical stability of benzene.

25. How are C-C bond lengths in benzene different from alkanes, alkenes, and alkynes?

Answer:

👉 All C-C bond lengths in benzene are equal (1.397 Å), which is intermediate between single bonds in alkanes (1.54 Å) and double bonds in alkenes (1.34 Å).

26. Why are benzene's electrons less reactive towards electrophiles compared to alkenes?

Answer:

👉 Benzene has highly stable, delocalized electrons, which are not readily available for nucleophilic or weak electrophilic attack.

27. What is required for halogenation of benzene?

Answer:

👉 Halogenation requires a halogen (Cl_2 or Br_2) and a catalyst like $FeCl_3$ or $FeBr_3$ to form a powerful electrophile.

28. What is the actual halogenating agent in benzene halogenation?

Answer:

👉 The halogen cation (X^+), also called halogenonium ion, is the actual electrophile attacking benzene.

29. What is nitration of benzene?

Answer:

👉 Nitration is the introduction of a NO_2 group into benzene by heating it with concentrated HNO_3 and H_2SO_4 to generate the nitronium ion (NO_2^+).

30. What is sulphonation of benzene?

Answer:

👉 Sulphonation is the introduction of a $-SO_3H$ group into benzene by heating it with fuming or concentrated H_2SO_4, where SO_3 acts as the electrophile.

31. What are Friedel-Crafts reactions?

Answer:

👉 Alkylation and acylation of benzene in the presence of a catalyst $AlCl_3$ are called Friedel-Crafts reactions.

32. How can benzene be reduced?

Answer:

👉 Benzene can be reduced to cyclohexane by heating with hydrogen in presence of Pt (or Ni) catalyst at high temperature.

33. How does benzene undergo side chain oxidation?

Answer:

👉 Alkyl benzenes are oxidized by acidified $KMnO_4$ or $K_2Cr_2O_7$, converting the alkyl group to COOH, while the benzene ring remains intact.

34. How many monosubstituted products are formed when benzene undergoes electrophilic substitution?

Answer:

👉 Only one monosubstituted product is formed because all six positions in the benzene ring are equivalent.

35. What are ortho/para-directing groups in benzene?

Answer:

👉 Groups like $-CH_3$ release electrons to the ring and facilitate substitution at ortho and para positions, increasing benzene’s reactivity towards electrophiles.

36. What are aromatic hydrocarbons?

Answer:

👉 Aromatic hydrocarbons include benzene and all compounds structurally related to benzene.

37. What are monocyclic aromatic hydrocarbons?

Answer:

👉 Aromatic hydrocarbons containing one benzene ring in their molecules are called monocyclic aromatic hydrocarbons.

38. What are polycyclic aromatic hydrocarbons?

Answer:

👉 Aromatic hydrocarbons containing two or more benzene rings in their molecules are called polycyclic aromatic hydrocarbons.

39. Who discovered benzene and when?

Answer:

👉 Michael Faraday discovered benzene in 1825.

40. Why is benzene readily attacked by electrophiles?

Answer:

👉 The electrons in benzene are loosely held, and the ring acts as a source of electrons, making it susceptible to electrophilic attack in the presence of a catalyst.

41. What type of reactions are mainly observed in benzene?

Answer:

👉 Electrophilic substitution reactions are the main reactions because they produce resonance-stabilized benzene derivatives.

42. What is the resonance energy of benzene?

Answer:

👉 The resonance energy of benzene is 150.5 kJ/mole.

43. How is the structure of benzene represented?

Answer:

👉 The structure of benzene is a resonance hybrid of two Kekule's structures and three Dewar's structures.

44. What are ortho- and para-directing groups?

Answer:

👉 Groups like NH_2, NHR, OR, SH, OCOR, X, OH increase electron density in the ring and facilitate substitution at ortho and para positions.

45. What are meta-directing groups?

Answer:

👉 Groups like CN, CHO, NH_3, NR_3, CCl hinder further substitution in the benzene nucleus and are called meta-directing groups.

🩸 EXERCISE

Q1. Fill in the blanks:

(i) The term aromatic was derived from Greek word ______ meaning fragrant. **Answer**: aroma ✅

(ii) Aromatic hydrocarbons include benzene and all those compounds which are ______ related to benzene.

Answer: structurally ✅

(iii) ______ is recognized as the simplest member of the class of Aromatic Hydrocarbons.

Answer: Benzene ✅

(iv) Benzene has ______ structure.

Answer: planar hexagonal ✅

(v) The removal of hydrogen atom from aromatic hydrocarbons gives a radical. The radicals are called ______.
Answer: aryl radicals ✅

(vi) Benzene was discovered by Michael Faraday in ______.
Answer: 1825 ✅

(vii) The unhybridized 2pz orbitals in benzene partially overlap to form a ______ of electron cloud. **Answer**: delocalized sheath ✅

(viii) The introduction of halogen group in benzene ring is called ______. **Answer**: halogenation ✅

(ix) The molecular formula of C_6H_6 indicates that it is highly ______ compound. **Answer**: unsaturated ✅

(x) On oxidation in the presence of V_2O_5 benzene gives ______.

Answer: benzoic acid ✅

Q2. Indicate True or False:

(i) Benzene is more reactive than alkene and less reactive than alkane. **Answer**: False ✅

(ii) Benzene has a pentagonal structure. **Answer**: False ✅

(iii) The C-C bond length in benzene molecule is 1.397 Å. **Answer**: True ✅

(iv) The state of hybridization of carbon in benzene molecule is sp^3. **Answer**: False ✅

(v) There are six sigma bonds in benzene molecule. **Answer**: True ✅

(vi) Halogenonium ion produced in electrophilic substitution reactions is a powerful electrophile. **Answer**: True ✅

(vii) In electrophilic substitution reactions, addition products are favourable. **Answer**: False ✅

(viii) Sulphonation is carried out when benzene is heated with conc. HNO_3. **Answer**: False ✅

(ix) In ozonolysis benzene directly gives glyoxal. **Answer**: True ✅

(x) Benzene has five resonance contributing structures.

Answer: True ✅

🩸 Q3. Multiple choice questions. Encircle the correct answer:

(i) The benzene molecule contains

(a) Three double bonds ✅

(b) Two double bonds

(c) One double bond

(d) Delocalized-electron charge

(ii) Aromatic hydrocarbons are the derivatives of

(a) normal series of paraffins

(b) alkene

(c) benzene ✅

(d) cyclohexane

(iii) Which of the following acid can be used as a catalyst in Friedel-Crafts reactions?

(a) $AlCl_3$ ✅

(b) HNO_3

(c) $BeCl_2$

(d) NaCl

(iv) Benzene cannot undergo

(a) substitution reactions

(b) addition reactions ✅

(c) oxidation reactions

(d) elimination reactions

(v) Amongst the following, the compound that can be most readily sulphonated is

(a) toluene ✅

(b) benzene

(c) nitrobenzene

(d) chlorobenzene

vi) During nitration of benzene, the active nitrating agent is

(a) NO_3

(b) NO_2^+ ✅

(c) NO_2^-

(d) HNO_3

(vii) Which compound is the most reactive one:

(a) benzene

(b) ethene ✅

(c) ethane

(d) ethyne

(viii) The electrophile in aromatic sulphonation is:

(a) H_2SO_4

(b) HSO_4

(c) SO_3

(d) SO_3^+ ✅

(ix) Aromatic compounds burn with sooty flame because:

(a) They have high percentage of hydrogen.

(b) They have a ring structure.

(c) They have high percentage of carbon ✅

(d) They resist reaction with air.

(x) The conversion of n-hexane into benzene by heating in the presence of Pt is called:

(a) Isomerization

(b) Aromatization ✅

(c) Dealkylation

(d) Rearrangement

🌟 Q.4. What are aromatic hydrocarbons? How are they classified?

❖ Introduction:

Aromatic hydrocarbons are an important class of organic compounds known for their special ring structure and unique stability. The most famous aromatic compound is benzene, which serves as the parent structure for many other aromatic compounds.

📘 Definition of Aromatic Hydrocarbons

👉 Aromatic hydrocarbons are those organic compounds that contain one or more benzene rings in their structure or have properties similar to benzene.

They possess delocalized π-electrons, which provide them extra stability called aromaticity.

✨ General Characteristics of Aromatic Hydrocarbons

- Burn with a sooty flame due to high carbon percentage.
- Undergo electrophilic substitution reactions rather than addition reactions.
- Have a planar cyclic structure.
- Are more stable because of resonance (delocalization).
- Benzene is the simplest aromatic hydrocarbon.

📚 Classification of Aromatic Hydrocarbons

1. Monocyclic Aromatic Hydrocarbons

- These aromatic hydrocarbons contain one benzene ring in their molecules.

Examples: Benzene, Toluene, Phenol, Aniline

Explanation: Derived from benzene by replacing hydrogen atoms with other substituents.

2. Polycyclic Aromatic Hydrocarbons (PAHs)

These contain two or more fused benzene rings.

Examples: Naphthalene, Anthracene, Phenanthrene

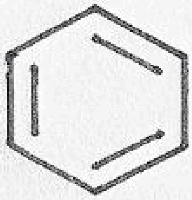
Explanation: Benzene rings share common carbon atoms, forming larger aromatic systems.

✦ **Digram:**

Diagram (Labelled for clarity)

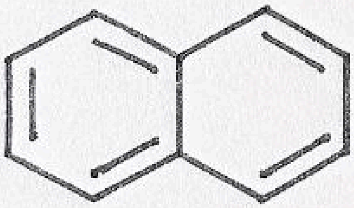
Monocyclic Aromatic:

- Benzene – One ring

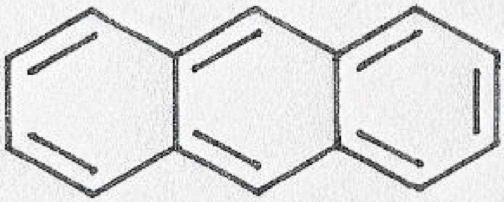


Polycyclic Aromatic:

- Naphthalene – Two rings



- Anthracene – Three rings



📝 **Conclusion**:

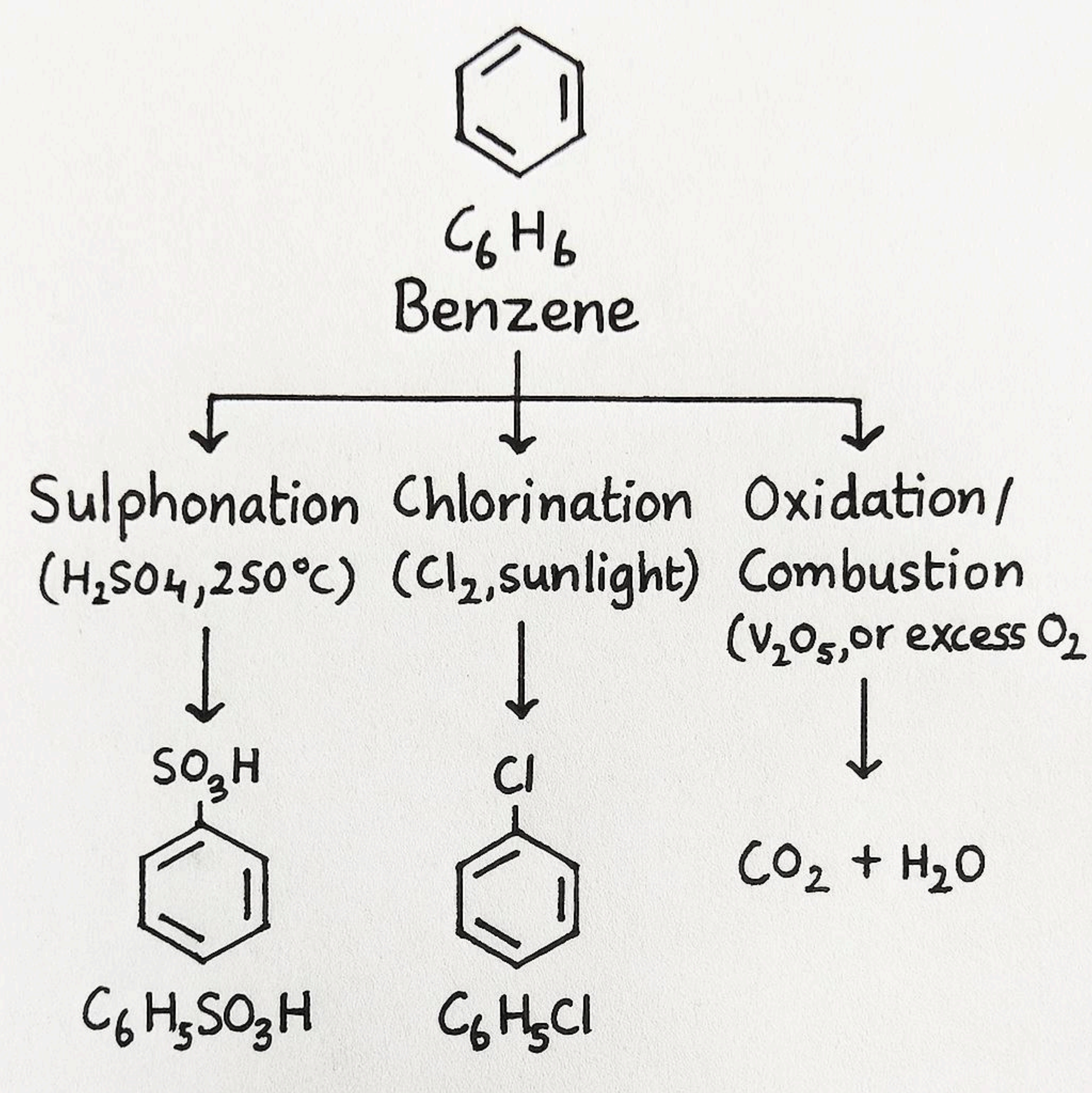
Aromatic hydrocarbons are highly stable organic compounds due to delocalized electrons. They are classified into monocyclic and polycyclic based on the number of benzene rings. Their chemical properties, like preference for substitution reactions and resistance to addition reactions, are explained by their resonance stability.

✦ **Summary**:

- **Aromatic hydrocarbons** = compounds containing benzene or benzene-like rings.
- **Monocyclic** = one benzene ring (e.g., benzene, toluene).
- **Polycyclic** = two or more fused benzene rings (e.g., naphthalene, anthracene).
- **Stability** arises from delocalized π-electrons.
- **Main reactions =** electrophilic substitution.

🌟 Q.5. What happens when benzene undergoes the following reactions?

✦ **Digram:**



❖ **Answer:**

(a) Benzene is heated with concentrated H_2SO_4 at 250°C

Reaction:

$C_6H_6 + H_2SO_4 \longrightarrow$ (250°C) $C_6H_5SO_3H$

Explanation:

- This reaction is called sulphonation of benzene.
- The sulfonic acid group (-SO_3H) is introduced into the benzene ring.
- It is an electrophilic substitution reaction: the benzene ring remains intact while a hydrogen atom is replaced.

Product: Benzene sulfonic acid ($C_6H_5SO_3H$)

(b) Chlorine is passed through benzene in sunlight

Reaction:

$C_6H_6 + Cl_2 \longrightarrow \text{(sunlight)}\ \ C_6H_5Cl + HCl$

Explanation:

- In the presence of UV light or sunlight, chlorine molecules split into free radicals.
- These radicals replace a hydrogen atom in benzene, forming chlorobenzene.
- This is a free radical substitution reaction.

Product: Chlorobenzene (C_6H_5Cl)

(c) A mixture of benzene vapours and air is passed over heated vanadium pentoxide (V_2O_5)

Reaction:

$C_6H_6 + 15/2\ O_2 \longrightarrow (V_2O_5)\ \ 6CO_2 + 3H_2O$

Explanation:

- **This** is catalytic oxidation of benzene.
- The **V_2O_5** catalyst accelerates the oxidation of benzene to carbon dioxide and water.
- The **benzene** ring is destroyed in this reaction.

Products: Carbon dioxide (CO_2) and water (H_2O)

(d) Benzene is burnt in free supply of air

Reaction:

$2C_6H_6 + 15O_2 \longrightarrow 12CO_2 + 6H_2O$

Explanation:

- This is complete combustion of benzene in excess oxygen.
- Benzene burns with a sooty flame because of its high carbon content.

Products: Carbon dioxide (CO_2) and water (H_2O)

🌟 Q.6. What is meant by the terms:

i) Aromatic

Definition: Aromatic compounds are a special class of organic compounds which contain benzene or benzene-like rings in their structure.

Key Features:

- Contain ring structures with conjugated π-electrons.
- Show extra stability due to delocalization of electrons (resonance).
- May or may not have a distinct smell.

Example: Benzene (C_6H_6), Toluene ($C_6H_5CH_3$)

Concept: Aromatic compounds are not just "fragrant"; they are chemically stable due to resonance.

ii) Oxidation

Definition: Oxidation is the process in which a compound loses hydrogen, gains oxygen, or gains electronegative atoms.

In Benzene:

- Benzene itself is resistant to mild oxidation.
- Alkylbenzenes (like toluene) can be oxidized to benzoic acid using $KMnO_4$.

Example Equation:

$C_6H_5CH_3 + [O] \longrightarrow C_6H_5COOH$

iii) Sulphonation

Definition: Sulphonation is the introduction of a sulfonic acid group ($-SO_3H$) into an aromatic ring.

Reagents & Conditions: Concentrated H_2SO_4 or fuming H_2SO_4, heating at 250°C.

Example Equation:

$C_6H_6 + H_2SO_4 \longrightarrow (250°C)\ C_6H_5SO_3H + H_2O$

iv) Nitration

Definition: Nitration is the introduction of a nitro group ($-NO_2$) into an aromatic ring.

Reagents & Conditions: Conc. HNO_3 and Conc. H_2SO_4 (50–55°C).

Mechanism: H_2SO_4 generates NO_2^+ (nitronium ion) which acts as the electrophile.

Example Equation:

$C_6H_6 + HNO_3 \longrightarrow (H_2SO_4)\ C_6H_5NO_2 + H_2O$

v) Halogenation

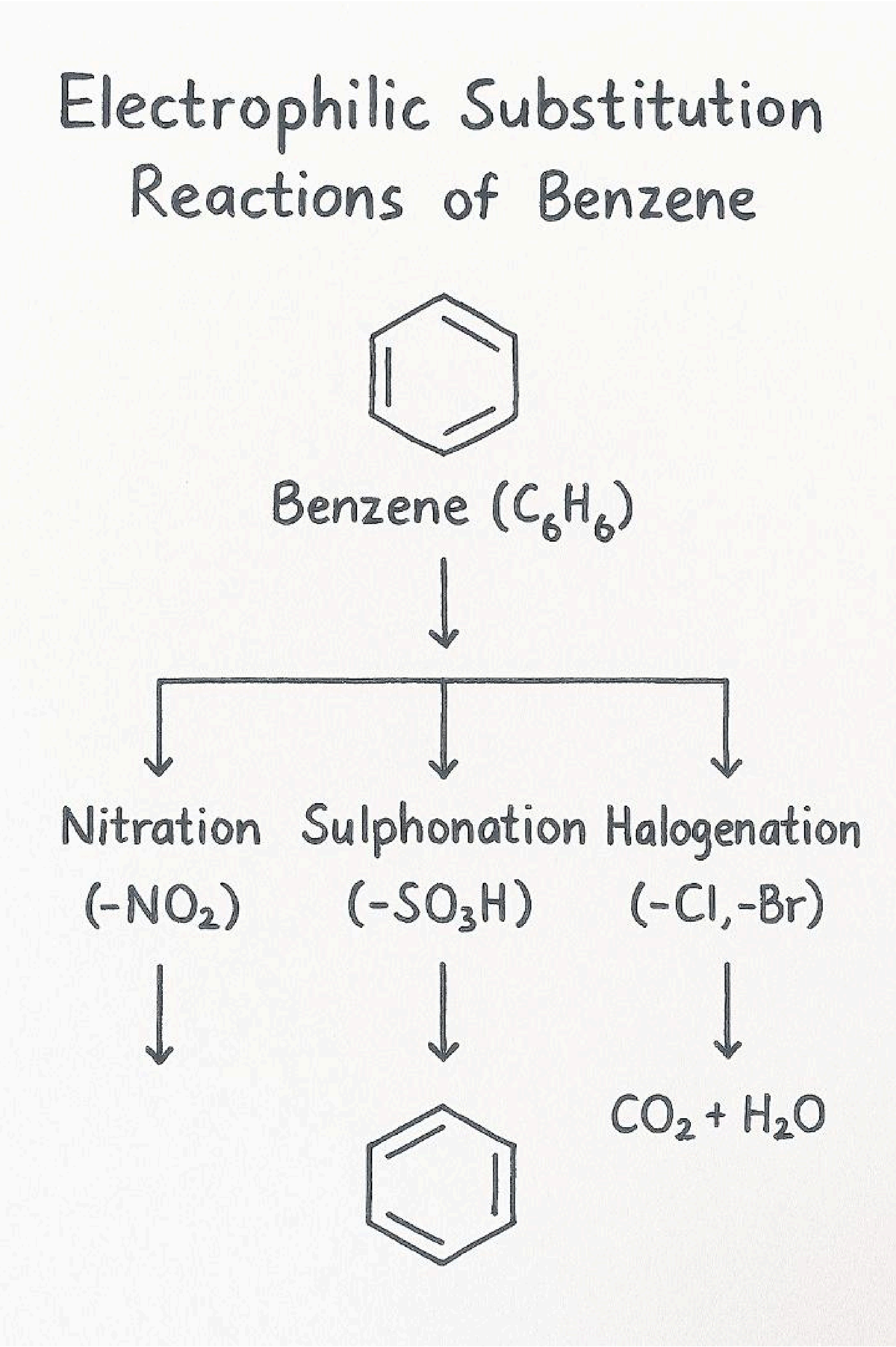
Definition: Halogenation is the introduction of a halogen (Cl, Br, I) into an aromatic ring.

Reagents & Conditions: Cl_2 or Br_2 with $FeCl_3$ or $FeBr_3$ as catalyst.

Example Equation:

$C_6H_6 + Cl_2 \longrightarrow (FeCl_3)\ C_6H_5Cl + HCl$

✦ **Digram:**


Electrophilic Substitution Reactions of Benzene
Benzene (C_6H_6)
Nitration
($-NO_2$)
Sulphonation
($-SO_3H$)
Halogenation
($-Cl$, $-Br$)
$CO_2 + H_2O$

✦ Summary:

Aromatic compounds = benzene-like rings, chemically stable.

Major reactions: Nitration, Sulphonation, Halogenation, Oxidation.

All are electrophilic substitution reactions keeping the benzene ring intact.

Conceptual understanding: Electrons in benzene are delocalized ⟶ stable ⟶ react selectively with strong electrophiles.

🌟 Q.7 (a) Structural Formulas of Aromatic Compounds

i) m-Chlorobenzoic acid

Chlorine at meta (1,3) position relative to COOH.

COOH

|

C6H4

|

Cl (meta)

ii) p-Hydroxybenzoic acid

Hydroxyl (-OH) at para (1,4) position relative to COOH.

COOH

|

C_6H_4

|

OH (para)

iii) o-Bromonitrobenzene

Bromine (-Br) at ortho (1,2) position relative to Nitro ($-NO_2$).

NO_2

|

C_6H_4

|

Br (ortho)

iv) o-Ethyltoluene acid

Ethyl ($-C_2H_5$) and carboxyl (-COOH) at ortho (1,2) positions.

COOH

|

C_6H_4

|

C2H5 (ortho)

v) p-Nitroaniline

Nitro (-NO2) at para (1,4) position relative to amino (-NH2).

NH2

|

C6H4

|

NO2 (para)

vi) 2,4,6-Trinitrotoluene (TNT)

Methyl (-CH3) at position 1, Nitro groups (-NO2) at positions 2,4,6.

CH3

|

C6H3

| | |

NO2 NO2 NO2 (2,4,6)

vii) m-Nitrophenol

Nitro (-NO2) at meta (1,3) position relative to hydroxyl (-OH).

OH

|

C6H4

|

NO2 (meta)

viii) p-Dibenzylbenzene

Two benzyl (-CH2C6H5) groups at para (1,4) positions.

CH2C6H5

|

C6H4

|

CH2C6H5 (para)

ix) 2-Amino-5-bromo-3-nitrobenzenesulphonic acid

Amino (-NH2) at position 2, Bromine (-Br) at 5, Nitro (-NO2) at 3, Sulfonic acid (-SO3H) at 1.

SO3H

|

C6H2

/ | \

NH2 NO2 Br

(2,3,5)

✅ **Notes for Students:**

Always number the ring starting from the highest priority group (COOH > NO2 > NH2 > Br > CH3 > OH).

Ortho = 1,2, Meta = 1,3, Para = 1,4.

🌟 Q.7 (b) Names and Possible Isomeric Structures

i) Xylenes ($C_6H_4(CH_3)_2$)

Definition: Xylenes are dimethylbenzene compounds with two methyl ($-CH_3$) groups attached to the benzene ring.

- Number of possible isomers: 3

Isomers & Positions:

1. Ortho-xylene (o-xylene): Methyl groups at 1,2-positions

2. Meta-xylene (m-xylene): Methyl groups at 1,3-positions

3. Para-xylene (p-xylene): Methyl groups at 1,4-positions

Structures:

Ortho: CH3

|

C6H4

|

CH3

Meta: CH3

|

C6H4

\

CH3

Para: CH3

|

C6H4

|

CH3 (opposite side)

ii) Trimethylbenzene ($C_6H_3(CH_3)_3$)

- **Definition:** Benzene ring with three methyl groups.
- Number of possible isomers: 3

Isomers & Positions:

1. 1,2,3-Trimethylbenzene

2. 1,2,4-Trimethylbenzene

3. 1,3,5-Trimethylbenzene

Structures:

1,2,3: CH3

|

C6H3

|

CH3

|

CH3

1,2,4: CH3

|

C6H3

CH3

|

CH3

1,3,5: CH3

|

C6H3

|

CH3

|

CH3 (alternate positions)

iii) Bromonitrotoluene ($C_6H_4BrNO_2CH_3$)

- **Definition:** Toluene (CH_3-benzene) derivative with one bromine (-Br) and one nitro (-NO_2) group.
- Number of possible isomers: 6 (depends on positions of Br and NO_2 relative to CH_3)

Isomers & Positions:

1. 2-Bromo-3-nitrotoluene (Br ortho, NO_2 meta to CH_3)

2. 2-Bromo-4-nitrotoluene (Br ortho, NO_2 para to CH_3)

3. 2-Bromo-5-nitrotoluene (Br ortho, NO_2 meta to CH_3)

4. 3-Bromo-2-nitrotoluene (Br meta, NO_2 ortho to CH_3)

5. 3-Bromo-4-nitrotoluene (Br meta, NO_2 para to CH_3)

6. 4-Bromo-2-nitrotoluene (Br para, NO_2 ortho to CH_3)

Structure concept:

- **Start numbering** from CH_3 as position 1

- **Place Br and NO_2** in all possible non-redundant positions

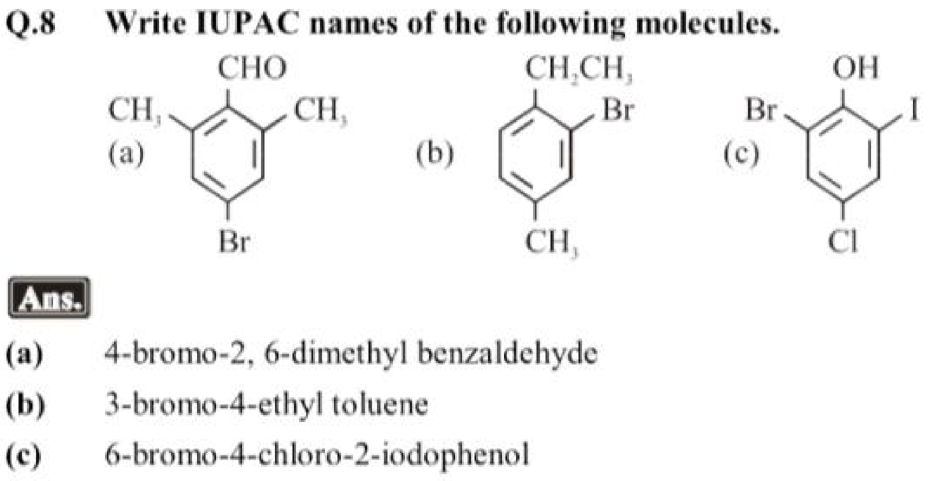
✅ Tips for Students:

1. Always number from the highest priority group (COOH > NO_2 > NH_2 > Br > CH_3).

2. Draw all possible positions carefully to avoid missing isomers.

3. Visualizing positions on benzene rings helps in exams for isomer problems.

🌟 Q.8. Write IUPAC Names of the Following Molecules



Q.8 **Write IUPAC names of the following molecules.**

Ans.

(a) 4-bromo-2, 6-dimethyl benzaldehyde

(b) 3-bromo-4-ethyl toluene

(c) 6-bromo-4-chloro-2-iodophenol

🌟 Q.9. General Mechanism of Electrophilic Aromatic Substitution (EAS)

❖ **Answer:**

👉 **Electrophilic Aromatic** Substitution is a reaction in which an electrophile (E^+) replaces a hydrogen atom of an aromatic ring (benzene) while maintaining the aromaticity of the ring.

👉 **Benzene** does not allow easy addition because it wants to preserve its aromatic stability.

Therefore, it reacts by substitution, not addition.

General Mechanism of EAS

Electrophilic Aromatic Substitution takes place in three major steps:

Step 1: Generation of Electrophile (E^+)

- This is the most important step.
- Electrophile is produced by reaction between a reagent and a catalyst.

Examples:

Nitration: $HNO_3 + H_2SO_4 \longrightarrow NO_2^+$ (electrophile)

Halogenation: $Br_2 + FeBr_3 \longrightarrow Br^+$

Sulphonation: $SO_3 + H_2SO_4 \longrightarrow SO_3H^+$

Friedel–Crafts: $R{-}Cl + AlCl_3 \longrightarrow R^+$ (carbocation)

Purpose:

To create a strong electrophile that can attack benzene.

Step 2: Formation of Carbocation Intermediate (Arenium or Sigma Complex)

Benzene donates π-electrons to electrophile:

Benzene + E^+ ⟶ Sigma Complex (Arenium Ion)

During this step:

- One carbon of benzene forms a bond with E^+
- Aromaticity is temporarily lost
- A resonance-stabilized carbocation is formed

Text Diagram (Copyable):

E^+ attacks benzene:

$C6H6 + E^+ \rightarrow [C6H6{-}E]^+$

(Resonance-stabilized arenium ion)

This intermediate is highly unstable but resonance-stabilized, which helps the reaction continue.

Step 3: Deprotonation and Restoration of Aromaticity

A base (often the catalyst complex) removes a proton (H^+) from the sigma complex:

$[C6H6{-}E]^+ \longrightarrow C6H5{-}E + H^+$

Aromaticity is fully restored, and substituted product forms.

Example:

Sigma complex → Aromatic substituted product

✦ **Digram:**

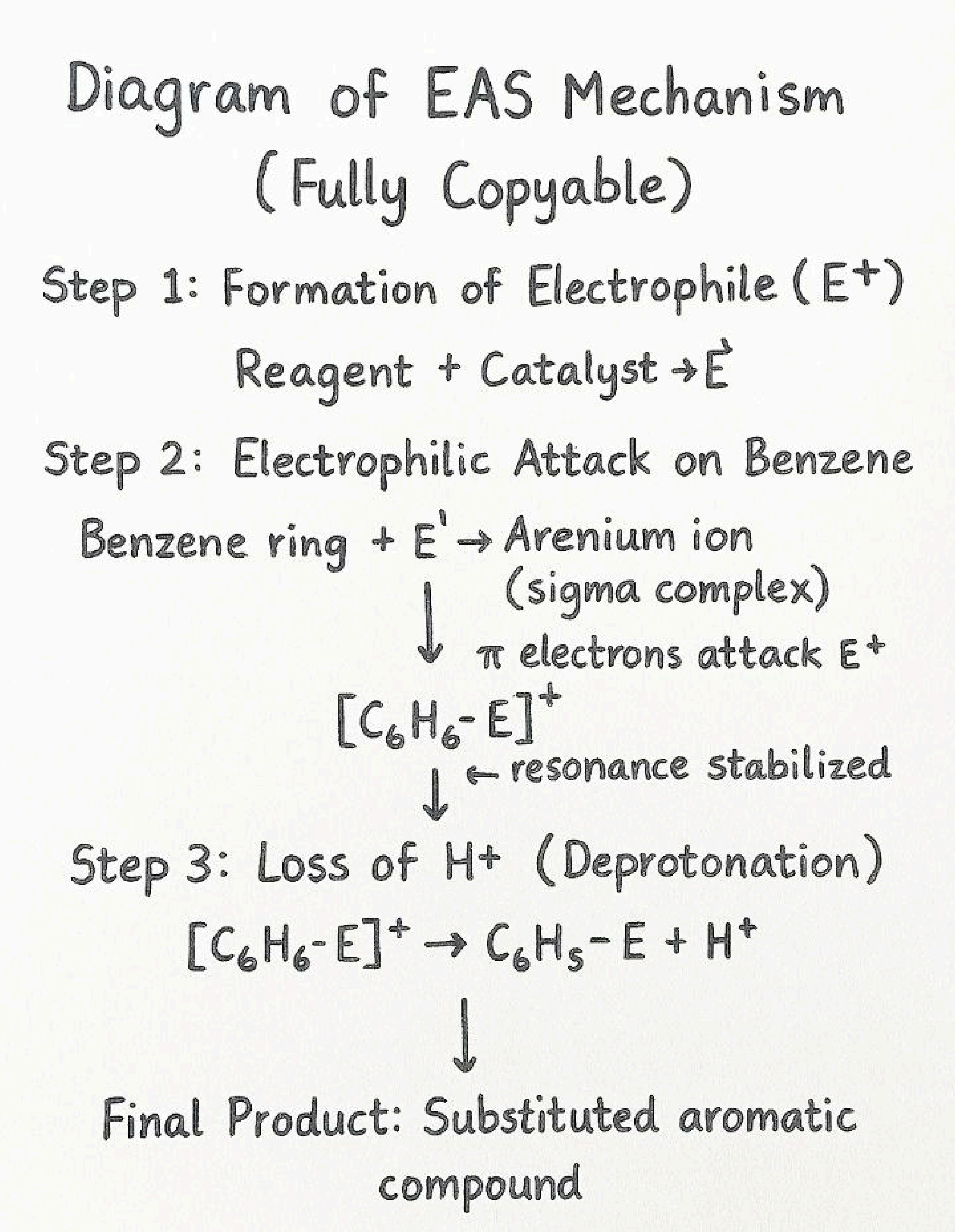


Diagram of EAS Mechanism
(Fully Copyable)

Step 1: Formation of Electrophile (E^+)

Reagent + Catalyst → E'

Step 2: Electrophilic Attack on Benzene

Benzene ring + E' → Arenium ion
(sigma complex)

π electrons attack E^+

$[C_6H_6-E]^+$

← resonance stabilized

Step 3: Loss of H+ (Deprotonation)

$[C_6H_6-E]^+ \rightarrow C_6H_5-E + H^+$

Final Product: Substituted aromatic compound

Why Benzene Undergoes Substitution (Not Addition)?

- Benzene is highly stable due to resonance & delocalized π electrons
- Addition reactions would destroy aromaticity ⟶ high energy, unfavorable
- Substitution preserves aromatic stability

Therefore, benzene chooses substitution.

✦ Summary:

EAS reactions proceed through three steps:

- **(1) formation of** electrophile, **(2) electrophilic** attack forming sigma complex, (3) deprotonation and restoration of aromaticity.
- **Benzene remains** aromatic throughout the reaction.

Examples include nitration, sulphonation, halogenation, Friedel–Crafts alkylation & acylation.

🌟 Q. 10. (a) Describe the structure of benzene on the basis of following.

- i) Atomic orbital treatment
- ii) Resonance method

🌟 (b) Prove that benzene has a cyclic structure.

(a) Describe the structure of benzene

i) Atomic Orbital Treatment of Benzene

- Each carbon atom in benzene is sp^2 hybridized.

Each carbon forms three sigma bonds:

  - Two with adjacent carbon atoms
  - One with a hydrogen atom

The unhybridized 2pz orbitals on each carbon remain perpendicular to the plane of the ring.

- These 2pz orbitals overlap sideways to form a delocalized π-electron cloud above and below the plane of the ring.

Key Points:

- **All C-H and** C-C bonds lie in the same plane ⟶ planar structure
- **Bond angles** = 120° ⟶ regular hexagon
- **Delocalized** electrons give extra stability to benzene

ii) Resonance Method

- Benzene cannot be represented by a single structure; it is a resonance hybrid.
- **Kekulé Structures**: Two alternating single and double bond forms
- **Dewar Structures:** Three less contributing structures

Concept:

- True structure = hybrid of all five structures

Delocalization explains:

- Equal C-C bond lengths (1.397 Å)
- Stability of benzene (resonance energy = 150.5 kJ/mol)

🌟 (b) Prove that benzene has a cyclic structure

1. Molecular Formula Evidence

- **Molecular** formula = C6H6 ⟶ highly unsaturated
- **Open chain** structures do not match molecular formula

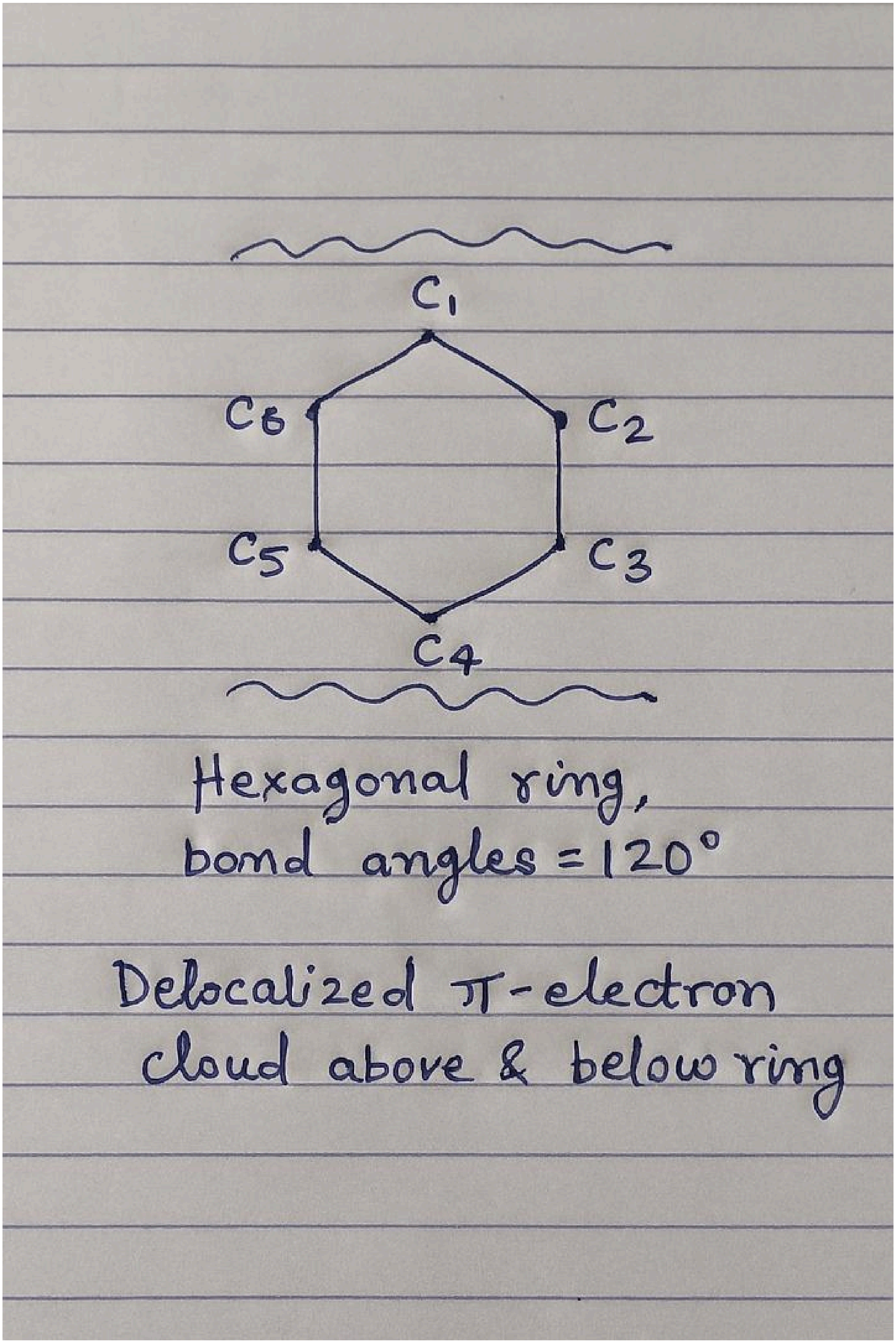
2. Chemical Reactions Evidence

- **Benzene undergoes** substitution reactions (not addition like alkenes)
- **Gives only one** monosubstituted product ⟶ all C atoms equivalent

3. X-ray and Bond Length Evidence

- All C-C bond lengths equal ⟶ hexagonal cyclic structure
- Planar structure confirmed by X-ray studies

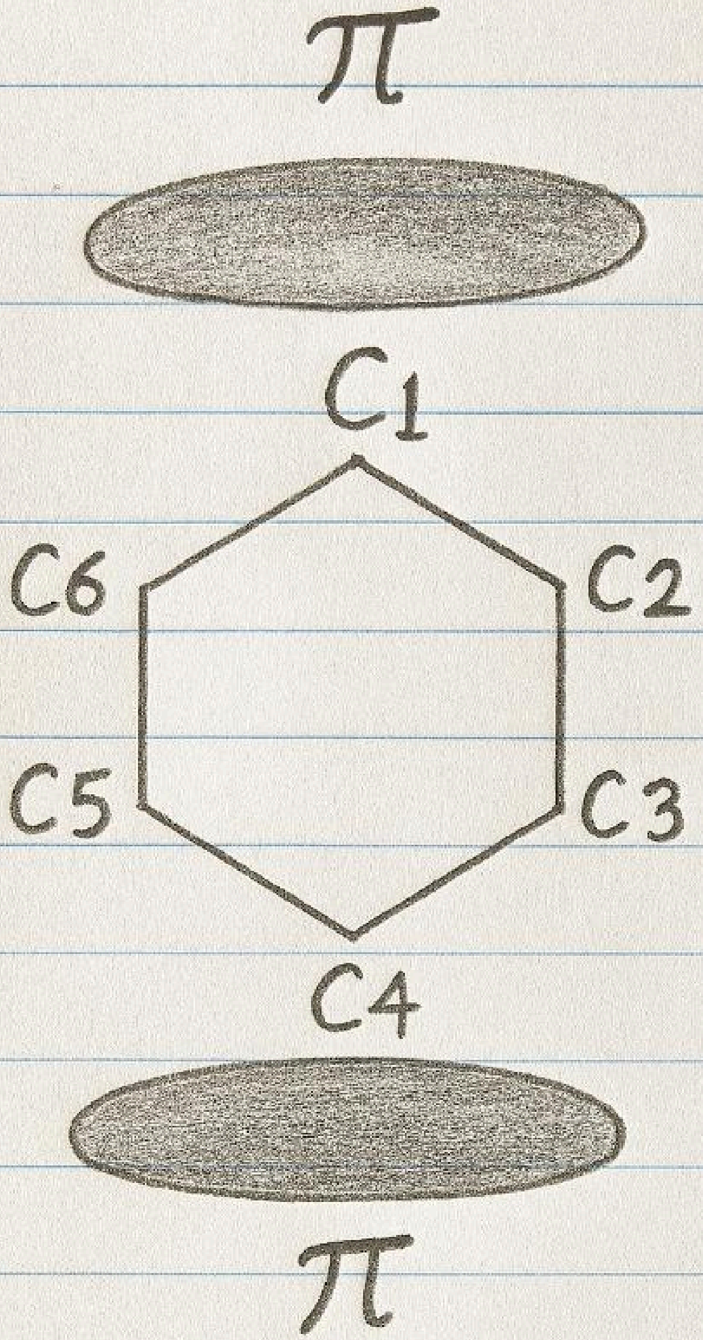
✦ Diagram:



Hexagonal ring,
bond angles = 120°

Delocalized π-electron
cloud above & below ring

✦ Electron cloud diagram:



Hexagonal ring,
bond angles = 120°

✦ Summary Points:

- **Benzene** = planar hexagonal ring
- **sp^2 hybridized** carbons
- **Delocalized** π-electrons → resonance hybrid
- **Extra stability** due to delocalization → resonance energy
- **Undergoes** substitution rather than addition → confirms cyclic structure

🌟 Q.11 Predict the major products of bromination of the following compounds

(a) Toluene ($C_6H_5CH_3$)

Explanation:

- **$-CH_3$ is an** electron-donating group → activates ortho and para positions.
- **Major product** → para-bromotoluene (sterically favored). Minor products → ortho.

Structure:

CH3

|

Br - C   C

| |

C   C

\ /

C

(b) Nitrobenzene ($C_6H_5NO_2$)

Explanation:

$-NO_2$ is an electron-withdrawing group → deactivates the ring, directs electrophiles to meta position.

Major product → meta-bromonitrobenzene

Structure:

NO2

|

C

Br - C   C

| |

C   C

\ /

C

(c) Bromobenzene (C_6H_5Br)

Explanation:

- **–Br is slightly** deactivating, but ortho-para directing.
- **Bromination** occurs at ortho and para, major product → para-bromobromobenzene

Structure:

Br

|

Br - C   C

| |

C   C

\ /

C

(d) Benzoic acid (C_6H_5COOH)

Explanation:

- **–COOH is** electron-withdrawing, directs incoming electrophiles to meta position.
- **Major product** → meta-bromobenzoic acid

Structure:

COOH

|

C

Br - C   C

| |

C   C

\ /

C

(e) Benzaldehyde (C_6H_5CHO)

Explanation:

- **−CHO is** electron-withdrawing, meta-directing.
- **Major product** ⟶ meta-bromobenzaldehyde

Structure:

CHO

|

C

Br - C   C

| |

C   C

\ /

C

(f) Phenol (C_6H_5OH)

Explanation:

- **−OH is** electron-donating, strongly activates ortho and para positions.
- **Major product** ⟶ para-bromophenol, minor ⟶ ortho

Structure:

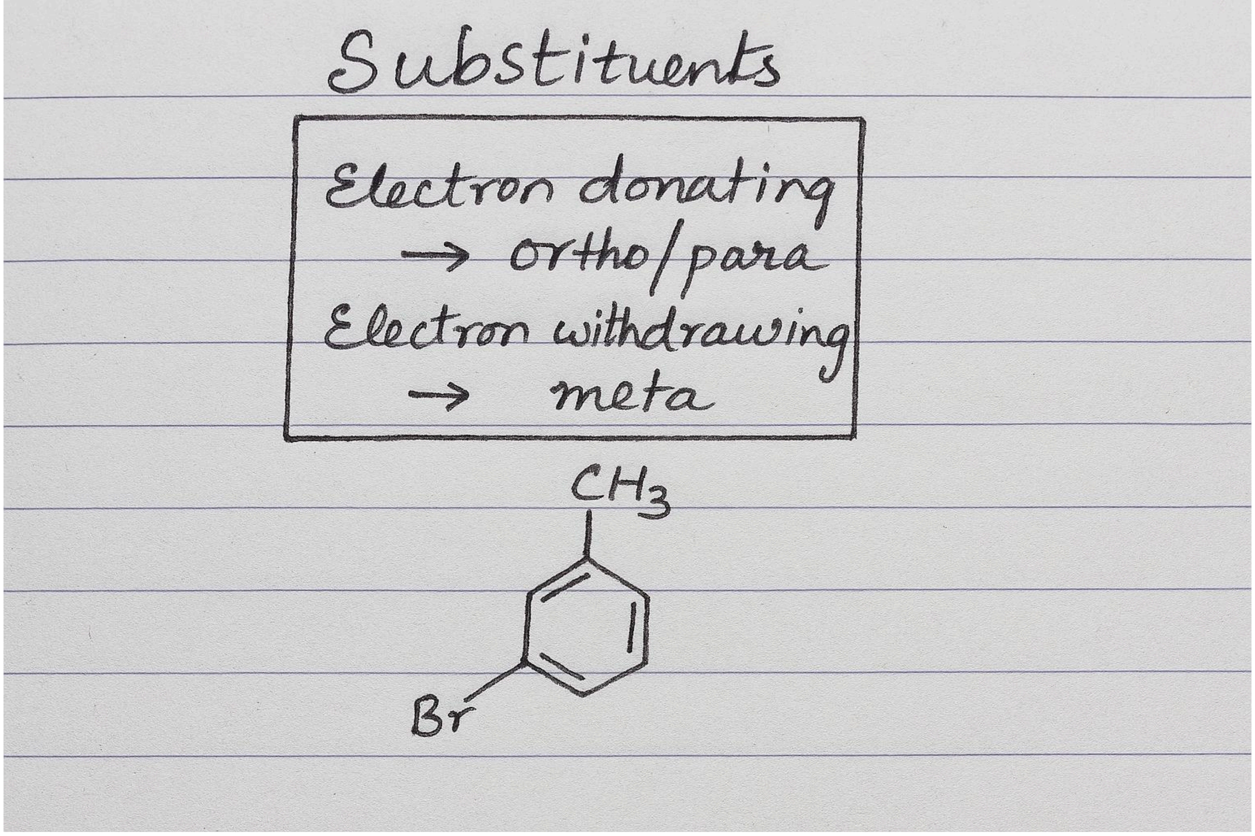
```
 OH

   |

Br - C    C

   |    |

   C    C

    \  /

     C
```

✅ Summary of Directing Effects:

Substituent	Directing Effect	Major Product
CH_3	Ortho/Para	para
NO_2	Meta	meta
Br	Ortho/Para	para
COOH	Meta	meta
CHO	Meta	meta

OH	Ortho/Para	para

💡 Digram:



Substituents

Electron donating → ortho/para

Electron withdrawing → meta

🌟 Q.12 How will you prepare the following compounds from benzene in two steps?

(a) m-Chloronitrobenzene

Objective: Introduce $-Cl$ and $-NO_2$ on benzene in meta position.

Step 1: Nitration

- **Reagents:** $HNO_3 + H_2SO_4$ (conc.)
- **Condition:** 50–55°C

- **Product**: Nitrobenzene ($C_6H_5NO_2$)

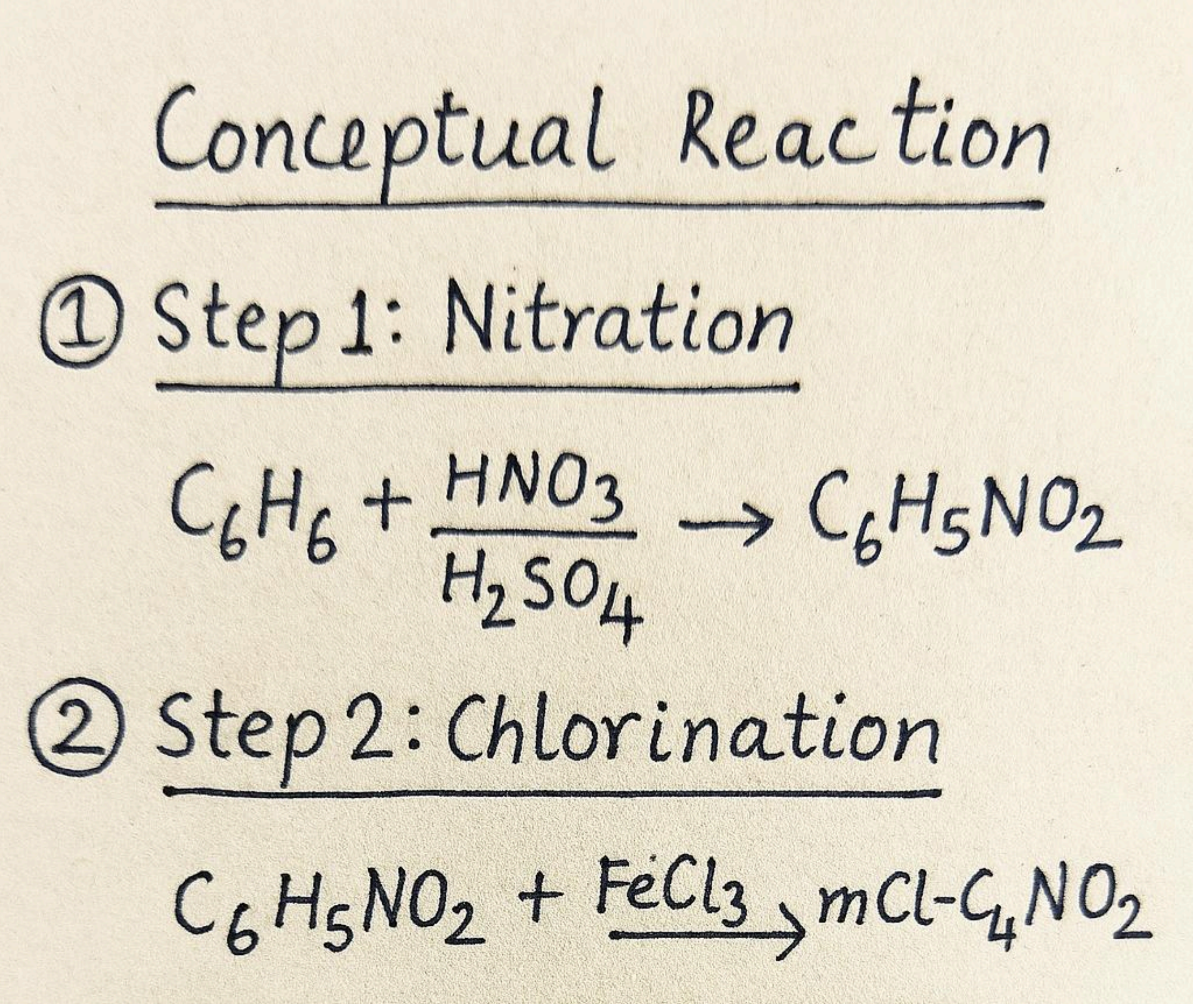
Reason:

- $-NO_2$ is electron-withdrawing ⟶ meta-directing.

Step 2: Chlorination

- **Reagents**: Cl_2 + $FeCl_3$ (catalyst)
- **Product**: m-Chloronitrobenzene

Diagram (Conceptual Reaction):



Conceptual Reaction

① Step 1: Nitration

$$C_6H_6 + \frac{HNO_3}{H_2SO_4} \longrightarrow C_6H_5NO_2$$

② Step 2: Chlorination

$$C_6H_5NO_2 + \xrightarrow{FeCl_3} mCl\text{-}C_4NO_2$$

(b) p-Chloronitrobenzene

Objective: Introduce –Cl and –NO_2 on benzene in para position.

Step 1: Chlorination

- **Reagents:** Cl_2 + $FeCl_3$ (catalyst)
- **Product:** Chlorobenzene (C_6H_5Cl)

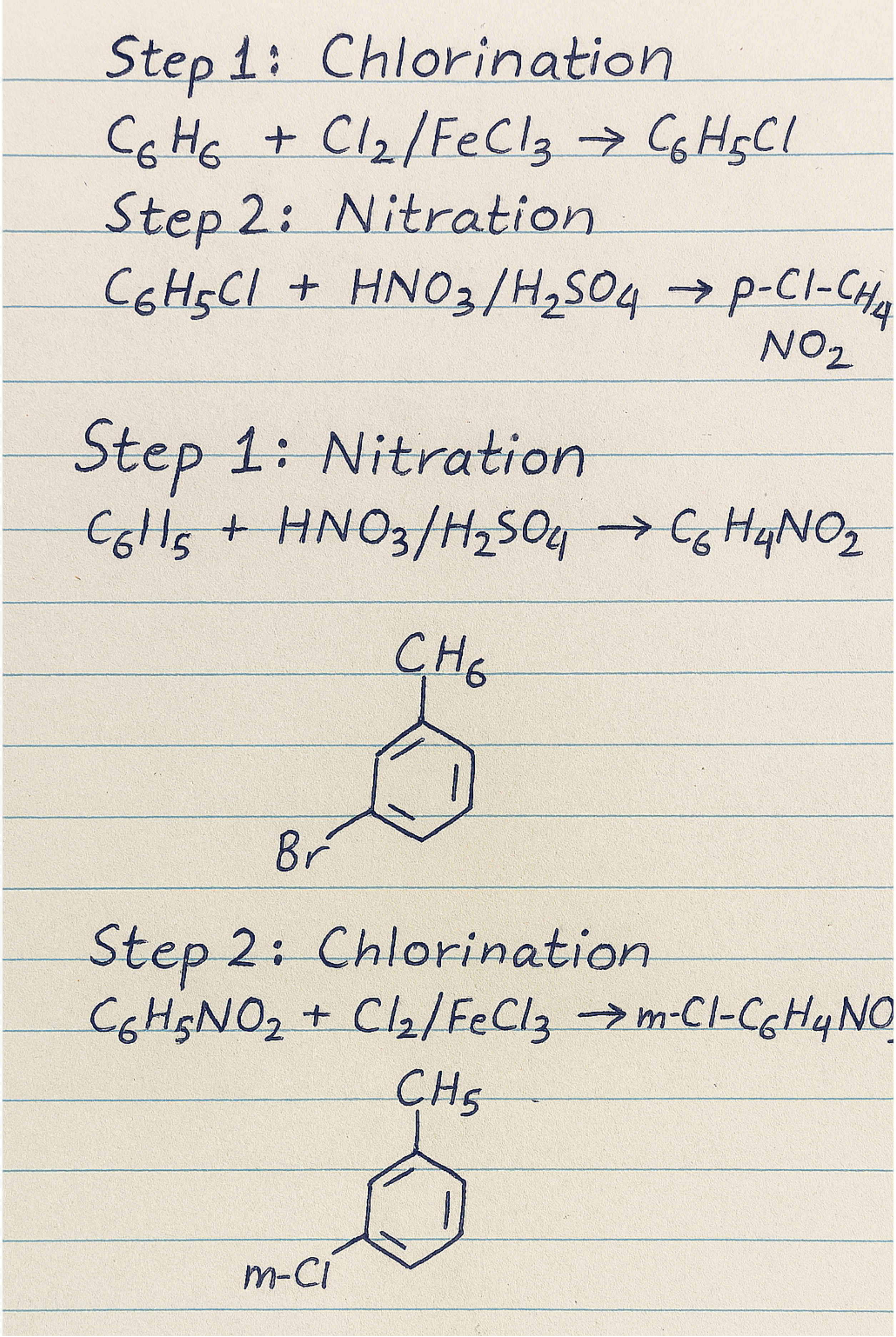
Reason:

–Cl is ortho/para directing, so nitration will occur at para position.

Step 2: Nitration

- **Reagents:** HNO_3 + H_2SO_4
- **Condition:** 50–55°C
- **Product:** p-Chloronitrobenzene

Diagram (Conceptual Reaction):



Step 1: Chlorination

$C_6H_6 + Cl_2/FeCl_3 \rightarrow C_6H_5Cl$

Step 2: Nitration

$C_6H_5Cl + HNO_3/H_2SO_4 \rightarrow p\text{-}Cl\text{-}CH_4$

NO_2

Step 1: Nitration

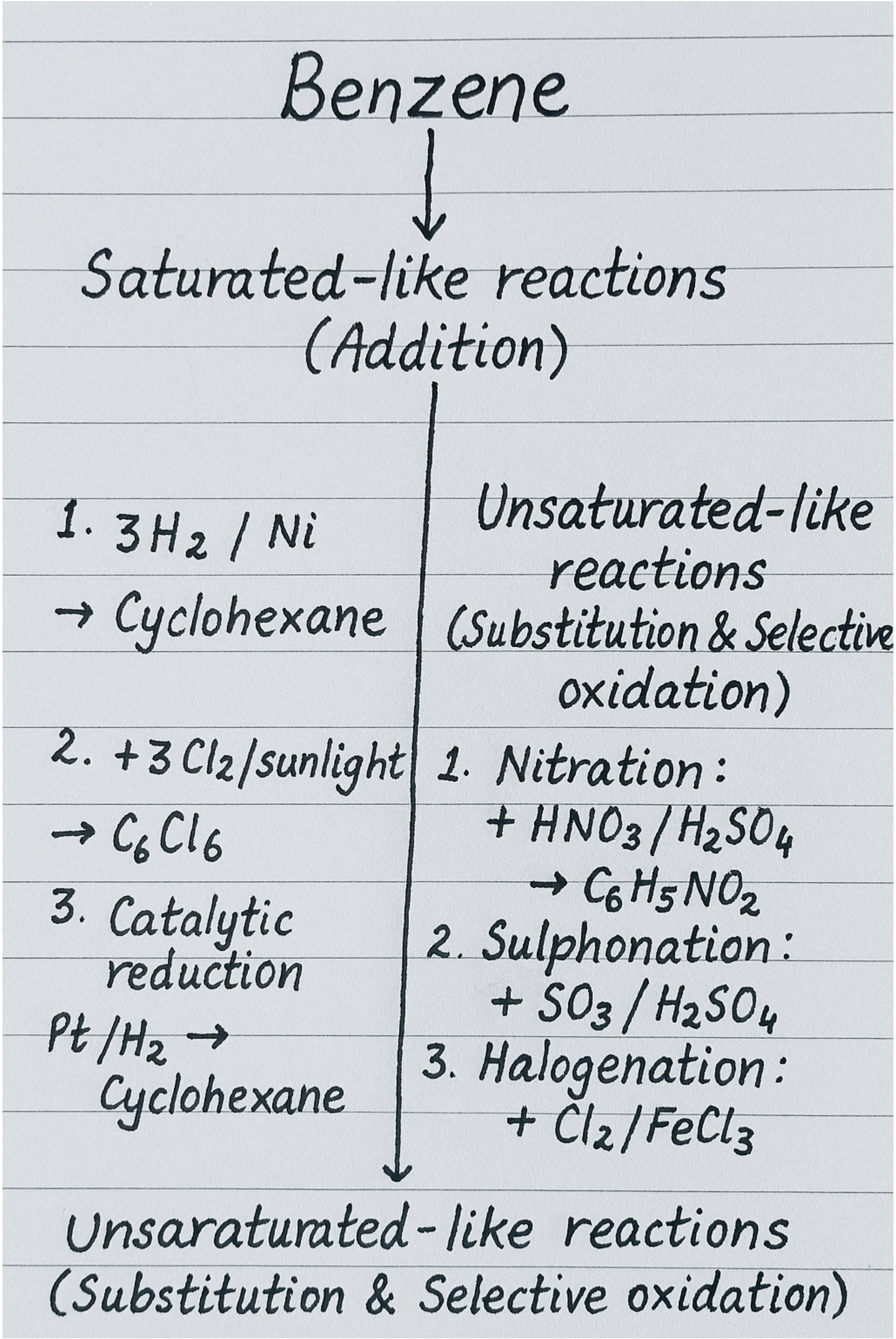
$C_6H_5 + HNO_3/H_2SO_4 \longrightarrow C_6H_4NO_2$

Step 2: Chlorination

$C_6H_5NO_2 + Cl_2/FeCl_3 \rightarrow m\text{-}Cl\text{-}C_6H_4NO$

🌟 Q.14. Reactions of Benzene Showing Saturated and Unsaturated Behavior

✦ Digram:



Benzene

↓

Saturated-like reactions

(Addition)

1. $3H_2$ / Ni

→ Cyclohexane

2. $+3Cl_2$/sunlight

→ C_6Cl_6

3. Catalytic reduction

Pt/H_2 → Cyclohexane

Unsaturated-like reactions

(Substitution & Selective oxidation)

1. Nitration:

$+ HNO_3/H_2SO_4$

→ $C_6H_5NO_2$

2. Sulphonation:

$+ SO_3/H_2SO_4$

3. Halogenation:

$+ Cl_2/FeCl_3$

↓

Unsaraturated-like reactions

(Substitution & Selective oxidation)

👉 **Benzene** is a unique compound because it shows both saturated and unsaturated behavior depending on the reaction conditions.

A) Benzene behaves like a saturated hydrocarbon

1. Hydrogenation (Addition of H_2)

$C_6H_6 + 3H_2 \longrightarrow C_6H_{12}$ (Ni catalyst, 200°C)

- **All three double bonds** are saturated to give cyclohexane.
- **Shows addition reaction,** characteristic of unsaturated alkenes.

2. Halogenation in sunlight (Addition of Cl_2 or Br_2)

C6H6 + 3Cl2 ⟶ C6Cl6 + 3HCl (sunlight)

- **The reaction** is similar to addition in alkenes, temporarily behaving as if it were unsaturated.

3. Catalytic Reduction to Cyclohexane

C6H6 ⟶ C6H12 (Pt, H2, acidic solvent)

- **Again**, behaves like an alkene under drastic conditions.

B) Benzene behaves like an unsaturated hydrocarbon

1. Electrophilic Substitution Reactions

Nitration:

C6H6 + HNO3 ⟶ (H2SO4, 50°C) C6H5NO2 + H2O

C6H6 + SO3 →(H2SO4) C6H5SO3H

C6H6 + Cl2 →(FeCl3) C6H5Cl + HCl

- **Benzene** does not add these reagents but undergoes substitution, keeping the ring intact.
- **This shows** stability and saturated character, unlike alkenes that undergo addition.

2. Oxidation of alkyl side chain

C6H5CH3 + [O] →(KMnO4) C6H5COOH

- Shows selective reactivity, a property of aromatic compounds.

3. Resistance to $KMnO_4$

- **Unlike alkenes,** benzene does not decolorize alkaline $KMnO_4$ solution at room temperature.
- **Shows stability** of delocalized electrons, behaving like a saturated compound.

🌟 Q.15. Friedel-Crafts Reactions

👉 Friedel-Crafts reactions are electrophilic substitution reactions in which an alkyl or acyl group is introduced into a benzene ring using a catalyst like $AlCl_3$.

✦ There are two types:

i) Friedel-Crafts Alkylation

Definition:

- Introduction of an alkyl group (R) into benzene using an alkyl halide (R−Cl) and $AlCl_3$ catalyst.

General Reaction:

$C_6H_6 + R-Cl \xrightarrow{AlCl_3} C_6H_5-R + HCl$

Mechanism:

1. Formation of carbocation:

$R-Cl + AlCl3 \longrightarrow R^+ + AlCl_4^-$

2. Attack on benzene:

- The benzene π-electrons attack the carbocation to form a sigma complex (arenium ion).

3. Restoration of aromaticity:

- Loss of a proton (H^+) from the sigma complex regenerates the benzene ring, giving the alkylated benzene.

Example:

C6H6 + CH3Cl ⟶(AlCl3) C6H5CH3 (Toluene)

ii) Friedel-Crafts Acylation

Definition:

- Introduction of an acyl group (R−CO) into benzene using an acyl halide (R−COCl) and $AlCl_3$ catalyst.

General Reaction:

$C_6H_6 + R{-}COCl \xrightarrow{AlCl_3} C_6H_5{-}CO{-}R + HCl$

Mechanism:

1. Formation of acylium ion:

$R{-}COCl + AlCl_3 \rightarrow R{-}C^+{=}O + AlCl_4^-$

2. Electrophilic attack:

- Benzene attacks the acylium ion forming a sigma complex.

3. Restoration of aromaticity:

- Loss of H^+ restores the aromaticity and gives the acylated benzene.

Example:

$C_6H_6 + CH_3COCl \xrightarrow{AlCl_3} C_6H_5COCH_3$ (Acetophenone)

Key Points to Remember

- **Alkylation** may lead to carbocation rearrangement, but acylation does not.
- **$AlCl_3$** is regenerated at the end of the reaction.

Both reactions are electrophilic substitutions, preserving the aromaticity of benzene.

Note:

This chapter is designed to provide a solid foundation of knowledge, with the goal of deepening understanding and encouraging further exploration of the subject. The content has been carefully selected to support effective learning and inspire students to engage with the topic more deeply.

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Purpose: To contribute to education by offering insightful, valuable content that enhances learning and understanding.

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