CHEMISTRY

Unit 11

HYDROCARBONS

MCQs • Short Questions • Long Questions

Complete Study Booklet with Answer Keys

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Section 1 | Multiple Choice Questions

Tick the correct option. Correct answers are highlighted in green with a check mark.

1. An alkene undergoes ozonolysis followed by reduction with zinc dust and water to yield propanone and methanol. The alkene is:

(a) 1-Butene
(b) 2-Butene
✓ **(c) 2-Methylpropene**
(d) 2-Methyl-2-butene

2. Which of the following reagents is typically used for the acid-catalyzed hydration of alkenes to form alcohols?

(a) H2/Ni
(b) O3 followed by Zn/H2O
✓ **(c) Dilute H2SO4**
(d) Br2 in CCl4

3. Halogenation of alkanes is an example of:

(a) Electrophilic substitution
(b) Nucleophilic substitution
✓ **(c) Free-radical substitution**
(d) Oxidation

4. Which of the following reactions can an alkane undergo?

(a) Addition
✓ **(b) Substitution**
(c) Polymerization
(d) Nitration

5. What is the first step in the electrophilic addition reaction of alkenes?

(a) Formation of carbocation
(b) Attack by a nucleophile
✓ **(c) Attack by an electrophile on the double bond**
(d) Formation of a free radical

6. The addition of unsymmetrical reagent to an unsymmetrical alkene is in accordance with:

✓ **(a) Markovnikov's rule**
(b) Hund's rule
(c) Le Chatelier's principle
(d) Aufbau principle

7. The most stable carbonium ion among the following is:

(a) CH3+
(b) CH3CH2+
(c) (CH3)2CH+
✓ **(d) (CH3)3C+**

8. Markovnikov's rule is applicable to:

(a) CH2=CH2
(b) CH3-CH2-CH3
(c) CH3-CH=CH-CH3
✓ **(d) (CH3)2-C=CH2**

9. What intermediate is formed during the electrophilic addition of HBr to an alkene?

✓ **(a) Carbocation**

(b) Carbanion

(c) Radical

(d) Epoxide

10. The enhanced stability of conjugated dienes compared to isolated dienes is primarily attributed to:

(a) Inductive effects of the double bonds

(b) Increase s-character of the hybridized orbitals

✓ **(c) Delocalisation of pi electrons across the conjugated system**

(d) Steric hindrance between the double bonds

11. Which of the following carbocations would be the least stable?

(a) (CH3)2CH+

(b) CH3CH2+

✓ **(c) CH3+**

(d) (CH3)3C+

12. Which of the following is the repeating unit in the polymer poly(ethene) (polyethylene)?

(a) -CHCH3-

(b) -CH=CH-

✓ **(c) -CHCH2-**

(d) -CH(CH3)CH2-

13. Hydrocarbons are compounds made of:

(a) Hydrogen and oxygen

(b) Carbon and oxygen

✓ **(c) Carbon and hydrogen**

(d) Carbon, hydrogen, and oxygen

14. Alkanes are also called:

(a) Olefins

✓ **(b) Paraffins**

(c) Aromatics

(d) Alkynes

15. Which of the following is an aromatic hydrocarbon?

(a) Ethene

(b) Methane

✓ **(c) Benzene**

(d) Cyclohexane

16. Which hydrocarbon has only single bonds?

(a) Ethene

(b) Ethyne

✓ **(c) Propane**

(d) Benzene

17. Which of these hydrocarbons is saturated?

(a) Ethyne

(b) Butene

✓ **(c) Propane**

(d) Cyclopentene

18. Which class of hydrocarbons contains one or more double bonds?

(a) Alkanes
✓ **(b) Alkenes**
(c) Aromatics
(d) Cycloalkanes

19. Aromatic hydrocarbons must contain:

(a) Straight chains
(b) Double bonds only
✓ **(c) A benzene ring**
(d) A triple bond

20. Cycloalkanes differ from alkanes by:

(a) Having higher reactivity
✓ **(b) Being cyclic**
(c) Having pi -bonds
(d) Having delocalized electrons

21. The general formula for alkanes is:

(a) CnH2n
(b) CnH2n-2
✓ **(c) CnH2n+2**
(d) CnH2n+1

22. Ethene belongs to which class of hydrocarbons?

(a) Alkane
✓ **(b) Alkene**
(c) Alkyne
(d) Aromatic

23. What is the IUPAC name of CH3CH2CH3?

(a) Methane
(b) Butane
(c) Ethane
✓ **(d) Propane**

24. The shape of the ethane molecule is:

(a) Planar
✓ **(b) Tetrahedral**
(c) Linear
(d) Trigonal planar

25. What is the correct IUPAC name of CH3CH=CH2?

✓ **(a) Propene**
(b) Propane
(c) Ethene
(d) Butene

26. The shape of ethene molecule is due to:

(a) sp hybridization
✓ **(b) sp2 hybridization**
(c) sp3 hybridization
(d) d2sp3 hybridization

27. What is the prefix for a three-carbon chain in IUPAC nomenclature?

(a) Eth-
✓ **(b) Prop-**
(c) But-
(d) Pent-

28. The IUPAC name for CH#CH is:
(a) Ethene
✓ **(b) Ethyne**
(c) Propene
(d) Butyne

29. Which compound is a cycloalkane?
✓ **(a) Cyclopentane**
(b) Butene
(c) Ethane
(d) Benzene

30. The structure of methane contains how many sigma bonds?
(a) 3
✓ **(b) 4**
(c) 2
(d) 1

31. The bond angle in ethene is approximately:
(a) 109.5 deg
(b) 180 deg
✓ **(c) 120 deg**
(d) 90 deg

32. A molecule of ethyne contains how many pi -bonds?
(a) 1
✓ **(b) 2**
(c) 3
(d) 0

33. Alkanes react with halogens via:
(a) Electrophilic substitution
✓ **(b) Free radical substitution**
(c) Nucleophilic addition
(d) Electrophilic addition

34. Which condition is essential for halogenation of methane?
✓ **(a) UV light**
(b) Acid catalyst
(c) Heat only
(d) Presence of water

35. What is the first step in the free radical mechanism?
(a) Termination
(b) Propagation
✓ **(c) Initiation**
(d) Elimination

36. Which is an example of propagation step?
(a) Cl2 -> 2Cl.

✓ (b) Cl. + CH4 -> HCl + CH3.
(c) CH3. + CH3. -> C2H6
(d) Cl. + Cl. -> Cl2

37. Free radical reactions typically occur in:
(a) Aromatic hydrocarbons
✓ (b) Saturated alkanes
(c) Unsaturated alkenes
(d) Alcohols

38. The termination step in a radical chain reaction involves:
(a) Light absorption
(b) Chain initiation
✓ (c) Chain breaking
(d) Hydrogen abstraction

39. Which of the following is not a free radical?
(a) CH3.
(b) Cl.
✓ (c) O2
(d) NO.

40. Chlorination of propane gives how many types of monochlorinated products?
(a) 1
✓ (b) 2
(c) 3
(d) 4

41. What type of bond cleavage occurs in the initiation step?
(a) Ionic
✓ (b) Homolytic
(c) Heterolytic
(d) Covalent

42. Which of the following is most stable?
(a) Primary radical
(b) Secondary radical
✓ (c) Tertiary radical
(d) Methyl radical

43. Alkenes react with bromine water to form:
(a) Alcohols
✓ (b) Dibromoalkanes
(c) Alkanes
(d) Haloarenes

44. The test for unsaturation in a hydrocarbon that disappears the colour is:
(a) Reaction with KMnO4
(b) Reaction with NaOH
✓ (c) Decolorization of Br2 water
(d) Precipitate with AgNO3

45. Alkenes undergo which type of reaction?
(a) Nucleophilic addition
(b) Free radical substitution

✓ (c) Electrophilic addition
(d) Nucleophilic substitution

46. In the electrophilic addition of HBr to propene, the major product is:
(a) 1-bromopropane
✓ (b) 2-bromopropane
(c) 3-bromopropane
(d) Isopropanol

47. The intermediate formed during electrophilic addition is:
(a) Free radical
✓ (b) Carbocation
(c) Carbene
(d) Carbanion

48. The product formed when ethene reacts with H2 in the presence of Ni is:
(a) Ethanol
✓ (b) Ethane
(c) Acetylene
(d) Butane

49. The addition of water to alkenes in presence of acid catalyst forms:
(a) Alkanes
✓ (b) Alcohols
(c) Ketones
(d) Ethers

50. Reaction of ethene with cold, dilute alkaline KMnO4 gives:
(a) CO2
(b) Ethanoic acid
✓ (c) Ethylene glycol
(d) Ethanol

51. Markovnikov's rule is used to predict:
(a) Stability of alkenes
(b) Products of free radical halogenation
✓ (c) Major product in addition of HX to alkenes
(d) Hydrolysis of esters

52. Anti-Markovnikov's addition occurs in the presence of:
(a) HBr only
✓ (b) Organic peroxide
(c) Water
(d) KMnO4

53. Isomers are compounds with:
(a) Same molecular formula, same structure
(b) Different molecular formula, same structure
✓ (c) Same molecular formula, different structure
(d) Same boiling points

54. Chain isomerism occurs due to differences in:
(a) Functional group
(b) Double bond position
✓ (c) Carbon chain branching

(d) Molecular formula

55. Which of the following shows position isomerism?

✓ **(a) But-1-ene and but-2-ene**

(b) Ethene and ethyne

(c) Cyclohexane and benzene

(d) Propane and propene

56. The number of possible isomers of C4H10 is:

(a) 1

✓ **(b) 2**

(c) 3

(d) 4

57. Which of the following has a branched chain structure?

(a) n-butane

✓ **(b) 2-methylpropane**

(c) Ethane

(d) Propene

58. Geometrical isomerism is possible in:

(a) Alkanes

(b) Cycloalkanes

(c) Alkenes

✓ **(d) Both b & c**

59. Which is a pair of geometrical isomers?

(a) Ethane and propane

(b) But-1-ene and but-2-ene

✓ **(c) cis-but-2-ene and trans-but-2-ene**

(d) Benzene and toluene

60. Geometrical isomerism is due to:

(a) Rotation around single bond

✓ **(b) Restricted rotation around double bond**

(c) Electronegativity difference

(d) Difference in functional groups

61. Structural isomers differ in:

(a) Only the boiling point

(b) Only the melting point

✓ **(c) Arrangement of atoms**

(d) Number of atoms

62. Which of the following represents a positional isomer of CH3CH2CH=CH2?

✓ **(a) CH3-CH=CH-CH3**

(b) CH4

(c) C2H2

(d) CH3C#CH

63. Polymerization of ethene gives:

(a) Polyvinyl chloride

(b) Polystyrene

✓ **(c) Polyethylene**

(d) Teflon

64. Which of the following is an addition polymer?

(a) Nylon
(b) Bakelite
✓ **(c) Polyethylene**
(d) Terylene

65. Monomer of polystyrene is:

(a) Ethene
✓ **(b) Styrene**
(c) Benzene
(d) Toluene

66. Teflon is a polymer of:

(a) C2H4
(b) C2H2F2
✓ **(c) C2F4**
(d) CH2=CHCN

67. Natural rubber is a polymer of:

(a) Styrene
✓ **(b) Isoprene**
(c) Vinyl chloride
(d) Butadiene

68. Which of the following is a copolymer?

(a) Polyethene
(b) PVC
✓ **(c) SBR rubber**
(d) Polypropylene

69. Vulcanization of rubber increases its:

(a) Conductivity
(b) Reactivity
✓ **(c) Hardness and elasticity**
(d) Transparency

70. Which of these monomers forms a condensation polymer?

(a) Ethene
(b) Styrene
✓ **(c) Adipic acid + hexamethylenediamine**
(d) Vinyl chloride

71. A polymer used for non-stick cookware is:

(a) Nylon
(b) Polyvinyl chloride
✓ **(c) Teflon**
(d) Polythene

72. Which of the following is not a property of polymers?

(a) High melting point
(b) Flexibility
(c) Insolubility in water
✓ **(d) Low molecular mass**

Section 2 | Short Questions

Q1. Define: (i) Cycloalkanes (ii) Isomerism (iii) Conjugated dienes (iv) Inductive effect

(i) Cycloalkanes: saturated hydrocarbons with carbon atoms arranged in a ring, general formula CnH2n.

(ii) Isomerism: the phenomenon where compounds have the same molecular formula but different structures or spatial arrangements.

(iii) Conjugated dienes: dienes in which two double bonds are separated by one single bond, allowing electron delocalization (e.g. 1,3-butadiene).

(iv) Inductive effect: the shifting of electrons in a sigma bond due to electronegativity differences, transmitted through the chain of atoms.

Q2. Differentiate between: (i) Aliphatic and Aromatic hydrocarbons, (ii) Homolytic and Heterolytic Fission, (iii) Electrophile and Nucleophile

(i) Aliphatic hydrocarbons are not aromatic (e.g. alkanes, alkenes); aromatic hydrocarbons are cyclic with a high C:H ratio, based on benzene and its derivatives.

(ii) Homolytic fission: bond breaks evenly, each atom gets one electron (forms free radicals). Heterolytic fission: bond breaks unevenly, one atom gets both electrons (forms ions).

(iii) Electrophile: electron-deficient species that accepts electrons (e.g. H+). Nucleophile: electron-rich species that donates electrons (e.g. OH-).

Q3. Explain why alkanes do not undergo addition reactions.

Alkanes are saturated hydrocarbons with strong C-C and C-H sigma bonds, which are relatively non-reactive, so they do not undergo addition reactions.

Q4. How is an elimination reaction considered the opposite of an addition reaction?

In an elimination reaction, atoms/groups are removed from a molecule, forming a double bond - the reverse of addition reactions, where atoms/groups are added to a molecule, breaking a double bond.

Q5. Compare the carbocation stability in propene and 2-butene.

2-butene forms a more stable secondary carbocation, while propene forms a less stable primary carbocation - the carbocation from 2-butene is more stable due to greater alkyl group stabilization.

Q6. Given C5H10, list all possible structural isomers that are alkenes.

Pent-1-ene; Pent-2-ene; 2-Methylbut-1-ene; 2-Methylbut-2-ene; 3-Methylbut-1-ene.

Q7. Why is 2-bromopropane favored over 1-bromopropane when propene reacts with HBr?

This follows Markovnikov's rule - the more stable secondary carbocation intermediate forms at C-2 during HBr addition, leading preferentially to 2-bromopropane.

Q8. Explain why conjugated alkenes may show different reactivity compared to isolated alkenes.

Conjugated alkenes show electron delocalization over alternating double bonds, making them more stable and giving different reactivity in specific conditions, such as Diels-Alder reactions.

Q9. Explain how inductive effects from alkyl groups stabilize carbocations in alkenes.

The inductive effect of alkyl groups stabilizes carbocations by pushing electron density toward the positively charged carbon, reducing the intensity of its positive charge.

Q10. Write reaction equations: (i) CH3CH2CH=CH2 with H2 (Ni), (ii) CH3CH=CH2 with Cl2, (iii) CH3CH2CH=CHCH2CH3 with H2O (H2SO4)

(i) CH3CH2CH=CH2 + H2 -(Ni, 250 deg C)-> CH3CH2CH2CH3

(ii) CH3CH=CH2 + Cl2 -(CCl4)-> CH3CH(Cl)CH2Cl

(iii) CH3CH2CH=CHCH2CH3 + H2O -(H2SO4)-> CH3CH2CH(OH)CH2CH2CH3

Q13. What are hydrocarbons? Name their main classes.

Hydrocarbons are organic compounds composed only of carbon and hydrogen atoms. Main classes: alkanes (saturated), alkenes (unsaturated, C=C), alkynes (unsaturated, triple bond), and aromatic hydrocarbons (contain benzene rings).

Examples: Methane (alkane), Ethene (alkene), Ethyne (alkyne), Benzene (aromatic).

Q14. What are alkanes and how are they named?

Alkanes are saturated hydrocarbons with single covalent bonds between carbon atoms. They are named using Greek/Latin prefixes for carbon count, ending in '-ane'.

Examples: CH4-Methane, C2H6-Ethane, C3H8-Propane.

Q15. How do alkanes show isomerism?

Alkanes show chain isomerism, where compounds have the same molecular formula but different carbon-chain arrangements.

Example: C4H10 gives n-butane and isobutane (2-methylpropane).

Q16. Why are alkanes called paraffins?

From Latin 'parum affinis' meaning 'little affinity' - they are less reactive due to strong C-C and C-H bonds and the absence of functional groups.

Q17. Describe the halogenation of alkanes with an example.

Halogenation is a substitution reaction where hydrogen atoms are replaced by halogens in the presence of heat or UV light.

Example: CH4 + Cl2 -> CH3Cl + HCl (in UV light).

Q18. What are alkenes? Give their general formula.

Alkenes are unsaturated hydrocarbons with at least one double bond between carbon atoms. General formula: CnH2n.

Examples: Ethene (C2H4), Propene (C3H6).

Q19. How do alkenes show isomerism?

Alkenes show chain isomerism, position isomerism (location of double bond), and geometrical (cis-trans) isomerism due to restricted rotation of the double bond.

Example: But-2-ene exists as cis-but-2-ene and trans-but-2-ene.

Q20. What is electrophilic addition? Give an example.

The reaction where an electrophile adds to the double bond of alkenes.

Example: CH2=CH2 + HBr -> CH3-CH2Br

Q21. Explain Markovnikov's Rule with an example.

In the addition of HX to an alkene, hydrogen attaches to the carbon with more hydrogens, and the halogen attaches to the carbon with fewer hydrogens.

Example: CH3-CH=CH2 + HBr -> CH3-CHBr-CH3 (2-bromopropane).

Q22. What is ozonolysis of alkenes?

Ozonolysis breaks the double bond of an alkene using ozone (O3) to form aldehydes or ketones.

Example: CH2=CH2 + O3 -> 2HCHO (formaldehyde).

Q23. What are alkynes and their general formula?

Alkynes are unsaturated hydrocarbons with one or more triple bonds between carbon atoms. General formula: CnH2n-2.

Examples: Ethyne (C2H2), Propyne (C3H4).

Q24. How are alkynes more reactive than alkanes?

Due to the triple bond's high electron density, alkynes are more reactive in addition reactions than alkanes.

Q25. Give an example of hydrogenation of alkynes.

Ethyne + H2 -> Ethene -> Ethane, in the presence of a Ni or Pd catalyst.

Q26. Write the reaction of an alkyne with halogens.

C2H2 + Br2 -> CHBr=CHBr (1,2-dibromoethene)

Q27. What are terminal and non-terminal alkynes?

Terminal alkyne: triple bond at the end (e.g. ethyne) - acidic alkynes.

Non-terminal alkyne: triple bond in the middle (e.g. but-2-yne) - non-acidic alkynes.

Q28. What are aromatic hydrocarbons?

Compounds that contain benzene ring(s) with delocalized pi electrons, following Huckel's rule (4n+2 pi electrons).

Q29. Describe the structure of benzene.

Benzene (C6H6) has a hexagonal ring with alternating double bonds, showing resonance where electrons are delocalized over the ring.

Q30. Why does benzene show substitution reactions instead of addition?

Benzene avoids addition to preserve its aromatic stability - substitution maintains the delocalized pi system.

Q31. What is electrophilic aromatic substitution? Give one reaction.

An electrophile replaces a hydrogen atom in benzene.

Example: C6H6 + Br2 -> C6H5Br + HBr (with FeBr3 catalyst).

Q32. Give examples of aromatic hydrocarbons.

Benzene (C6H6), Toluene (C6H5CH3), Naphthalene (C10H8).

Q33. What is the trend of boiling point in alkanes?

Boiling point increases with molecular size due to greater van der Waals forces; branching lowers boiling point.

Example: n-butane > isobutane.

Q34. How does the solubility of hydrocarbons vary?

Hydrocarbons are non-polar, so they are insoluble in water but soluble in organic solvents like ether and benzene.

Q35. Are hydrocarbons denser than water?

No, most hydrocarbons are less dense than water and float on it, having more empty space than water.

Q36. What is combustion of hydrocarbons?

Combustion is the oxidation of hydrocarbons, producing CO2 and H2O with energy release.

Example: CH4 + 2O2 -> CO2 + 2H2O + heat.

Q37. What are substitution reactions? Give an example.

A reaction where an atom/group is replaced by another - common in alkanes.

Example: CH4 + Cl2 -> CH3Cl + HCl (UV light).

Q38. How is methane prepared in the lab?

By heating sodium acetate with soda lime (NaOH+CaO): CH3COONa + NaOH -(CaO)-> CH4 + Na2CO3

Q39. How is ethene prepared in the lab?

By dehydration of ethanol with concentrated H2SO4: C2H5OH -(H2SO4, heat)-> C2H4 + H2O

Q40. What is the test for unsaturation in hydrocarbons?

Unsaturated compounds decolorize bromine water (reddish-brown to colorless) or alkaline KMnO4 (purple to brown).

Q41. What are the uses of methane?

Fuel (natural gas); production of hydrogen and methanol; a source of energy in homes.

Q42. Give the environmental impact of hydrocarbons.

Incomplete combustion produces carbon monoxide (CO) and soot, contributing to air pollution, the greenhouse effect, and acid rain (from sulfur/nitrogen compounds).

Q43. Write uses of isomers of butane.

Butane is a fuel used in lighters; isobutane is used as a propellant in products such as shaving gel.

Section 3 | Descriptive Questions

Q5 (Descriptive). Describe the mechanism of electrophilic addition of hydrogen halides to alkenes. Discuss Markovnikov's rule in this context.

Hydrogen halides (HX) are polar molecules; the H atom is electrophilic (delta+) and X- is nucleophilic. Step 1: the alkene's pi bond attacks H+, forming the more stable carbocation (secondary preferred over primary). Step 2: X- attacks the carbocation to give the final product.

Markovnikov's Rule: when a polar reagent adds to an unsymmetrical alkene, the negative part (X-) attaches to the carbon bearing fewer hydrogen atoms. Example: HBr + propene gives mainly 2-bromopropane (80%) over 1-bromopropane (20%), since the secondary carbocation intermediate is more stable.

Q6 (Descriptive). Explain the following reactions of alkenes with examples: (a) Halogenation (b) Ozonolysis (c) Epoxidation (d) Polymerization

(a) Halogenation: addition of Cl2/Br2 across the double bond forms vicinal dihalides, e.g. CH2=CH2+Br2 -> BrCH2CH2Br (tested using bromine water, which decolorizes).

(b) Ozonolysis: oxidative cleavage of C=C using ozone (O3), forming ozonides that break down into carbonyl compounds; e.g. CH2=CH2+O3 -> 2HCHO (with Zn/H2O).

(c) Epoxidation: forms a three-membered cyclic ether (epoxide), e.g. an alkene with a peroxide/silver catalyst; used to make glycols, plastics, and detergents.

(d) Polymerization: many alkene monomers join through their C=C bonds (which become C-C single bonds) to form long-chain polymers, e.g. n CH2=CH2 -> [-CH2-CH2-]n (polyethene).

Section 4 | Long Questions

Q1. What are hydrocarbons? Briefly discuss aliphatic and aromatic hydrocarbons.

Hydrocarbons

Definition: organic compounds made up of only carbon (C) and hydrogen (H) atoms, found abundantly in petroleum and natural gas.

Uses: domestic and industrial fuels; raw materials for medicines, plastics, perfumes, and polymers; unsaturated hydrocarbons (especially alkenes) are starting materials in industrial synthesis.

Classification of Hydrocarbons

(i) Aliphatic Hydrocarbons: organic compounds that do not contain aromatic rings - open-chain (acyclic) or closed-chain (cyclic); saturated (alkanes) or unsaturated (alkenes and alkynes). Cyclic aliphatic examples: cyclopropane, cyclobutane, cyclopentane, cyclohexane.

(ii) Aromatic Hydrocarbons: a special class of cyclic compounds with a high carbon-to-hydrogen ratio and delocalized electrons (resonance), based on benzene (C6H6) and its derivatives. Examples: benzene, toluene, ethylbenzene, phenol, naphthalene.

'Aromatic' derives from the Greek word for 'fragrance', reflecting the characteristic odour of many early-studied aromatic compounds.

Q2. What are alkanes? Give their physical properties. Also discuss alkyl radical.

Alkanes (Paraffins)

Definition: saturated hydrocarbons containing only single bonds between carbon and hydrogen atoms. General formula: CnH2n+2. Simplest alkane: methane (CH4).

Examples: Methane CH4, Ethane C2H6, Propane C3H8, Butane C4H10, Pentane C5H12.

Alkyl Groups

Definition: when one hydrogen atom is removed from an alkane, the remaining part is called an alkyl group, named by replacing the '-ane' suffix with '-yl'.

Examples: Methyl (CH3-), Ethyl (CH3CH2-). For alkanes with more than two carbons, multiple alkyl groups can be derived - e.g. propane gives n-propyl (CH3CH2CH2-) and iso-propyl (CH3CH(CH3)-); butane gives n-butyl, sec-butyl, iso-butyl, and tert-butyl groups.

Q3. Explain the IUPAC rules for naming alkanes.

IUPAC Naming Rules

Rule 1 - Longest chain: identify the longest continuous chain of carbon atoms, which determines the parent name.

Rule 2 - Numbering: number the chain from the end nearest a substituent.

Rule 3 - Position of substituents: use the numbers from Rule 2 to designate substituent locations; the parent name is placed last (e.g. 3-Methylheptane).

Rule 4 - Alphabetical order: when multiple substituents are present, list them alphabetically, ignoring multiplying prefixes like 'di' and 'tri' (e.g. 4-Ethyl-2-methylhexane).

Rule 5 - Same carbon substituents: use the locant number twice if two substituents are on the same carbon (e.g. 3-Ethyl-3-methylhexane).

Rule 6 - Identical substituents: use prefixes di-, tri-, tetra- etc.

Rule 7 & 8 - Complex substituents: named using the same rules, with alphabetical order based on the first letter of the complete substituent name.

Structure of Alkanes

Each carbon is sp3 hybridized, forming four sigma bonds arranged tetrahedrally; bond angle = 109.5 degrees; C-C bond length = 1.54 Angstrom.

Structure of Cycloalkanes

Cycloalkanes are saturated cyclic hydrocarbons - all C-C bonds are single bonds forming a closed ring; each carbon is sp3 hybridized with 4 sigma bonds.

Physical Properties of Alkanes

(i) Physical state: C1-C4 are colourless, odourless gases; C5-C17 are colourless, odourless liquids; C18 and beyond are waxy solids.

(ii) Solubility: non-polar or very weakly polar - insoluble in water, soluble in non-polar solvents like hexane, benzene, and diethyl ether.

(iii) Physical constants: boiling point, melting point, and density increase with carbon number; solubility decreases as molecular size increases.

(iv) Effect of branching: branched alkanes have lower boiling points than straight-chain isomers (e.g. n-butane -0.5 deg C vs isobutane -11.7 deg C) because branching reduces surface area and weakens van der Waals forces.

Q5. What is a reaction mechanism? Why are alkanes unreactive towards polar reagents?

Reaction Mechanism

Definition: the step-by-step sequence of elementary steps by which an overall chemical change occurs. Covalent bonds break in two main ways:

(i) Homolytic Fission: the bond breaks evenly, each atom retaining one electron, producing free radicals (species with an unpaired electron, highly reactive).

(ii) Heterolytic Fission: the bond breaks unevenly, one atom taking both electrons, producing a cation and an anion; shown using curly arrows to indicate electron-pair movement.

Reactive Nature of Alkanes Towards Polar Reagents

'Paraffin' comes from Latin (parum = little, affinis = affinity), reflecting their low reactivity, especially towards polar reagents. Alkanes are inert towards acids, alkalis, oxidizing and reducing agents under ordinary conditions.

(i) Non-polarity of bonds: C-C and C-H bonds have only a small electronegativity difference (C=2.5, H=2.1), making them non-polar, so polar reagents cannot interact easily.

(ii) Stability of sigma bonds: alkane bonds are strong sigma bonds with electrons tightly held between nuclei, requiring large amounts of energy to break.

Q6. What are the two main types of reactions that alkanes undergo? Explain free radical substitution.

Reactions of Alkanes

(i) Thermal and catalytic reactions: occur at high temperature or with catalysts, e.g. combustion and cracking.

(ii) Free radical substitution reactions: replace one atom/group with another via a free-radical mechanism, e.g. halogenation.

Free Radical Halogenation

Halogenation is the substitution of a hydrogen atom of an alkane with a halogen atom, occurring in the presence of UV light. Reactivity order: F2 > Cl2 > Br2 > I2. Fluorine reacts violently; chlorine and bromine substitute under UV light; iodine's reaction is too slow and reversible.

Mechanism of Halogenation (Three Steps)

(i) Initiation: the halogen molecule splits into radicals under UV light, e.g. Cl2 -> 2Cl. (dot for radical).

(ii) Propagation: radicals attack alkanes, generating more radicals and continuing the chain, e.g. Cl.+CH4 -> CH3.+HCl, then CH3.+Cl2 -> CH3Cl+Cl. - this repeats to give various chloroalkanes.

(iii) Termination: two free radicals combine to form a product - e.g. a chloride and alkyl radical combine to form a chloroalkane, or two chlorine radicals combine to reform Cl2.

Q7. Discuss the nomenclature of alkenes with examples.

Alkenes

Definition: unsaturated hydrocarbons containing at least one carbon-carbon double bond (C=C). General formula: CnH2n - two fewer hydrogens than the corresponding alkane.

IUPAC Rules for Naming Alkenes

(i) Select the longest chain containing the double bond, changing the ending from '-ane' to '-ene'.

(ii) Number the chain to include both carbons of the double bond, starting from the end nearer the double bond.

(iii) Indicate the double bond position using the number of its first carbon as a prefix (e.g. 2-Butene, 1-Pentene).

(iv) Identify and number substituent groups by the carbon atoms to which they are attached.

Preparation of Alkenes

Dehydration of Alcohols: removal of H2O from an alcohol using concentrated H2SO4. Example: CH3CH2OH -> CH2=CH2+H2O (conc. H2SO4, heat).

Dehydrohalogenation of Alkyl Halides: removal of HX using alcoholic KOH. Example: CH3CH2Br+KOH(alc) -> CH2=CH2+KBr+H2O

Physical Properties of Alkenes

(i) Physical state: the first three alkenes are gases; C5-C15 are liquids; C16 and above are solids.

(ii) Solubility: insoluble in water, soluble in organic solvents like alcohol, ether, and benzene.

(iii) They have a characteristic smell and burn with a luminous (smoky) flame due to their higher carbon content.

(iv) Polarity: alkenes are weakly polar due to sp2 hybridization at the double bond.

Q9. Discuss the structure and reactivity of alkenes.

Structure of Ethene (C2H4)

Each carbon in ethene is sp2 hybridized - three equivalent sp2 orbitals form from one 2s and two 2p orbitals, all in the same plane; one unhybridized p-orbital remains perpendicular (90 degrees) to this plane on each carbon.

Geometry and Bonding

Each carbon uses sp2 orbitals to form two C-H bonds and one C-C sigma bond (from sp2-sp2 overlap); the unhybridized parallel p-orbitals overlap sideways to form a pi bond. A double bond = one sigma bond + one pi bond, with all six atoms lying in the same plane.

Molecular shape: trigonal planar geometry, bond angles approximately 120 degrees.

Reactivity of the Pi Bond

(i) Nature: pi electrons lie above and below the bonding plane (not directly between nuclei), making the pi bond weaker and more easily broken than a sigma bond, so alkenes are more reactive than alkanes.

(ii) Electrophilic attack: the exposed pi electrons are readily attacked by electrophiles, giving characteristic electrophilic addition reactions. Alkenes act as nucleophiles because of their pi electrons.

Q10. Explain the stability of carbocations and the inductive effect.

Stability of Carbocation

A carbocation is an alkyl group where a carbon atom carries a single positive charge - highly unstable and reactive, typically formed during electrophilic addition. More alkyl groups attached means greater stability.

Inductive Effect

Definition: the polarization of a sigma bond due to electron-donating or withdrawing effects of adjacent groups/atoms.

Electron Donating (+I) Effect

Alkyl groups exhibit a positive inductive effect (+I) - they push electron density toward the positively charged carbon, reducing the intensity of the positive charge and stabilizing the carbocation. More alkyl groups means greater stability.

Electron Withdrawing (-I) Effect

Halogens (Cl, Br, F) are highly electronegative and pull electron density through sigma bonds, creating a permanent dipole - the halogen becomes partially negative and the attached carbon becomes electron-deficient (partially positive). The inductive effect weakens with distance from the halogen along the chain.

Q11. What are electrophilic addition reactions of alkenes? Explain the halogenation of alkenes.

Electrophilic Addition Reactions

Definition: reactions in which an electrophile (X+) is added across the C=C double bond. The pi electrons are electron-rich, attracting electrophiles and initiating the reaction.

General Mechanism

Step 1: the electrophile (X+) is attracted to the pi electrons; the pi bond breaks and X+ adds to one carbon, forming a carbocation intermediate.

Step 2: the nucleophile (Y-) quickly attacks the carbocation, completing the addition.

Halogenation

Definition: addition of halogen molecules (Cl2 or Br2) across the double bond, forming vicinal dihalides.

Test for unsaturation: bromine water (reddish-brown) decolorizes when bubbled through an alkene solution (e.g. in CCl4), indicating a C=C double bond.

Reaction: CH2=CH2+Br2 -> Br-CH2-CH2-Br (in CCl4).

Mechanism of Halogenation

Step 1 - Induced dipole: as non-polar Br2 approaches the electron-rich C=C, the Br-Br electrons are repelled, creating a temporary dipole with one Br atom partially positive (electrophilic).

Step 2 - Electrophilic attack: pi electrons attack the electrophilic Br+, forming a cyclic bromonium ion or carbocation intermediate.

Step 3 - Nucleophilic attack: Br- attacks the intermediate to give the final vicinal dibromide product (e.g. 1,2-dibromoethane).

Q12. Explain the hydrohalogenation and hydrogenation of alkenes.

Hydrohalogenation

Definition: addition of a dry gaseous hydrogen halide (HX) at room temperature to an alkene, forming a haloalkane. Example: CH2=CH2+HBr -> CH3-CH2-Br (bromoethane).

HX molecules are polar - the H atom is electrophilic (delta+), X- is nucleophilic. Reaction rate increases from HF to HI as bond strength decreases, so addition becomes easier.

Markovnikov's Rule

'When a polar reagent adds to an unsymmetrical alkene, the negative part of the reagent (X-) attaches to the double-bonded carbon bearing fewer hydrogen atoms.'

Example: HBr addition to propene gives 2-bromopropane (80%, major) and 1-bromopropane (20%, minor).

Mechanism for Propene + HBr

Step 1: the pi bond attacks H+, forming the more stable secondary carbocation (HBr breaks heterolytically to give Br-).

Step 2: Br- attacks the carbocation to give 2-bromopropane as the major product; the minor, less stable primary carbocation pathway gives 1-bromopropane.

Hydrogenation

Definition: addition of H2 across the double bond in the presence of a metal catalyst (Ni, Pt, Pd) at 250-300 deg C, forming a saturated alkane. Example: CH2=CH2+H2 -> CH3-CH3 (Ni, 250-300 deg C).

Industrial use: converts vegetable oil into margarine (banaspati ghee) by turning unsaturated fats into saturated fats.

Q13. Explain the following reactions of alkenes: hydration, halohydration, epoxidation, ozonolysis.

(i) Hydration

Addition of steam (H2O) to alkenes to form alcohols, using concentrated H2SO4 as catalyst; forms a carbocation intermediate, then OH- attacks. Example: CH2=CH2+H2O -> C2H5OH (ethanol, with H2SO4).

(ii) Halohydration

Addition of a halogen (Cl2 or Br2) and water to an alkene, forming a halohydrin (-OH and -X on adjacent carbons). Example: CH2=CH2+Br2+H2O -> CH2OH-CH2Br (bromohydrin).

(iii) Epoxidation

Forms an oxygen-containing three-membered cyclic ether (epoxide) using various oxidizing agents; ethene can form ethylene oxide using molecular oxygen and a metal catalyst. Used as an intermediate for glycols, plastics, and detergents.

(iv) Ozonolysis

Oxidative cleavage of the C=C bond using ozone (O3), forming ozonides that break down into carbonyl compounds (aldehydes/ketones); useful for identifying the position of a double bond in an alkene. Example (ethene): CH2=CH2+O3 -> 2HCHO (formaldehyde, with Zn/H2O).

Q14. Write a note on polymerization of alkenes and conjugated dienes.

Polymerization

Definition: the formation of very long molecules (polymers) from small reactive molecules (monomers) joining together.

Addition polymerization: many monomers, each with a C=C double bond, join to form a polymer without by-products - the pi bond breaks and monomers link via new C-C single bonds.

Examples

(i) Ethene to Polyethene: n CH2=CH2 -> [-CH2-CH2-]n, used in plastic bags, containers, packaging.

(ii) Chloroethene to PVC: n CH2=CHCl -> [-CH2-CHCl-]n, used in pipes, electrical insulation, pens.

Repeating unit: the smallest repeated group in the polymer chain - for simple polyalkenes, it is the same as the monomer with the C=C changed to C-C.

Conjugated Dienes

Definition: a hydrocarbon with two C=C double bonds separated by a single bond, allowing overlap of p-orbitals on three or more adjacent atoms and electron delocalization, which stabilizes the molecule and affects its reactivity.

Example: 1,3-Butadiene (CH2=CH-CH=CH2) - a key raw material for synthetic rubber; polymerization gives long, elastic chains used in tyres, elastic materials, and latex products.

Q15. Define isomerism and discuss types of isomerism with examples.

Isomerism

Definition: two or more compounds with the same molecular formula but different structural formulas and properties are isomers.

Example: butane (C4H10) has n-butane and isobutane (2-methylpropane) as isomers; 1-chlorobutane and 2-chlorobutane are isomers of C4H9Cl. The number of possible isomers rises rapidly with carbon number - e.g. pentane has three isomers.

A. Structural Isomerism

(i) Chain Isomerism: differs in carbon-chain arrangement, e.g. pentane's n-pentane, isopentane, and neopentane.

(ii) Position Isomerism: same functional group, different position on the chain, e.g. positional isomers of chloropropane or butene.

(iii) Functional Group Isomerism: same molecular formula, different functional groups, e.g. C2H6O gives ethanol (alcohol) and methoxymethane (ether).

(iv) Metamerism: unequal distribution of carbon atoms on either side of the functional group, e.g. diethyl ether vs methoxypropane.

(v) Tautomerism: shifting of a proton within the same molecule, commonly seen in amino acids forming zwitterions (internal salts).

B. Stereoisomerism

Definition: same structural formula but different spatial arrangement of identical groups. Types: geometrical (cis-trans) isomerism and optical isomerism.

Q16. Explain organic redox reactions in detail.

Organic Redox Reactions

Definition: oxidation-reduction reactions involving organic compounds, involving the transfer of electrons through addition or removal of oxygen and hydrogen atoms.

Organic oxidation: oxygen is added or hydrogen is removed. Organic reduction: hydrogen is added or oxygen is removed.

1. Oxidation

(i) Combustion: reaction with excess oxygen/air. Example: 2C2H6+7O2 -> 4CO2+6H2O (complete oxidation of ethane).

(ii) Ozonolysis: oxidative cleavage of C=C using ozone, forming carbonyl compounds.

(iii) Catalytic Oxidation: using catalysts like Ag or V2O5, e.g. ethene -> ethylene oxide (Ag catalyst), or ethene -> acetaldehyde (Wacker process).

2. Reduction

(i) Hydrogenation: alkenes + H2 -> alkanes (Ni catalyst). Example: CH2=CH2+H2 -> CH3-CH3 (Ni, 250-300 deg C).

(ii) Reducing agents: lithium aluminum hydride (LiAlH4), sodium borohydride (NaBH4), tin and hydrochloric acid (Sn+HCl). Common reductions: nitriles to amines, amides to amines, carboxylic acids to primary alcohols, nitrobenzene to phenylamine (aniline).

Section 5 | Answer Key & Formula Summary

MCQ Answer Key (Q1-Q72)

Q.No	Ans	Q.No	Ans	Q.No	Ans	Q.No	Ans
1	C	19	C	37	B	55	A
2	C	20	B	38	C	56	B
3	C	21	C	39	C	57	B
4	B	22	B	40	B	58	D
5	C	23	D	41	B	59	C
6	A	24	B	42	C	60	B
7	D	25	A	43	B	61	C
8	D	26	B	44	C	62	A
9	A	27	B	45	C	63	C
10	C	28	B	46	B	64	C
11	C	29	A	47	B	65	B
12	C	30	B	48	B	66	C
13	C	31	C	49	B	67	B
14	B	32	B	50	C	68	C
15	C	33	B	51	C	69	C
16	C	34	A	52	B	70	C
17	C	35	C	53	C	71	C
18	B	36	B	54	C	72	D

Important Formulas

Formula	Description
Alkanes: CnH2n+2	General formula of saturated hydrocarbons
Alkenes: CnH2n	General formula of hydrocarbons with one double bond
Alkynes: CnH2n-2	General formula of hydrocarbons with one triple bond
Cycloalkanes: CnH2n	General formula of saturated cyclic hydrocarbons
Cl2 -> 2Cl. (UV light)	Initiation step of free-radical halogenation
X(+) adds first, then Y(-) attacks	General mechanism of electrophilic addition

Key Constants & Notes

Constant/Note	Value
C-C bond angle in alkanes (sp3)	109.5 degrees
C-C bond angle in alkenes (sp2)	120 degrees

C-C single bond length	1.54 Angstrom
Electronegativity of Carbon	2.5
Electronegativity of Hydrogen	2.1
Reactivity order of halogens with alkanes	F2 > Cl2 > Br2 > I2
Rate of HX addition to alkenes	HI > HBr > HCl
Order of carbocation stability	3 degree > 2 degree > 1 degree > methyl

Alkanes vs Alkenes - Quick Comparison

Property	Alkanes	Alkenes
Bond type	Single bonds (sigma only)	Double bond (sigma + pi)
Hybridization	sp3	sp2
Bond angle	109.5 deg	120 deg
General formula	CnH2n+2	CnH2n
Reactivity	Less reactive (inert)	More reactive (pi bond)

Carbocation Stability Order

Type	Stability	Reason
Tertiary (3 deg)	Most stable	3 alkyl groups donate electrons (+I effect)
Secondary (2 deg)	Medium stable	2 alkyl groups donate electrons
Primary (1 deg)	Low stable	1 alkyl group donates electrons
Methyl	Least stable	No alkyl groups

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