Class: 12th

Subject: Chemistry

Chapter 7: Fundamental Principles of Organic Chemistry

🩸 Fundamental Principles of Organic Chemistry – Key Points MCQs

1. Source of Organic Compounds

Organic compounds are mainly obtained from:

(a) Mineral sources

(b) Living things ✅

(c) Metals

(d) Water

2. Early Belief about Organic Compounds

In early chemistry, it was believed that organic compounds:

(a) Could be synthesized from minerals

(b) Could not be synthesized from inorganic sources ✅

(c) Are always gases

(d) Do not contain carbon

3. **Modern Definition of Organic Chemistry**

Modern definition of organic chemistry is:

(a) Chemistry of metals

(b) Chemistry of carbon compounds ✅

(c) Chemistry of minerals

(d) Chemistry of acids only

4. Commercial Importance of Organic Compounds

Most commercially important compounds we use every day are:

(a) Inorganic

(b) Organic ✅

(c) Metallic

(d) Polyatomic ions

5. Major Sources of Organic Compounds

Major sources of organic compounds include:

(a) Coal, petroleum, and natural gas ✅

(b) Water and air

(c) Metals and alloys

(d) Rocks only

6. Cracking Process

The process developed to increase the yield of lower hydrocarbons is called:

(a) Fractional distillation

(b) Cracking ✅

(c) Refining

(d) Polymerization

7. Classification of Organic Compounds

Organic compounds are classified into:

(a) Acids and bases

(b) Metals and non-metals

(c) Acyclic and cyclic compounds ✅

(d) Solids and liquids

8. Organization of Organic Chemistry

The study of organic chemistry is organized around:

(a) Atomic number

(b) Functional groups ✅

(c) Molecular weight

(d) Bond angles

9. Hybridization and Shape of Carbon Compounds

The bonding and shapes of carbon compounds can be explained by:

(a) Ionic bonding

(b) sp^3, sp^2 and sp hybridization ✅

(c) Hydrogen bonding

(d) Metallic bonding

10. Isomerism

Compounds having the same molecular formula but different structural formulas are called:

(a) Polymers

(b) Isomers ✅

(c) Radicals

(d) Allotropes

🩸 Important MCQs:

1. Organic compounds were considered as those obtained from:

(a) Non-living things

(b) Minerals

(c) Living things ✅

(d) Metals

2. Inorganic compounds were obtained from:

(a) Plants and animals

(b) Non-living or mineral sources ✅

(c) Carbon-based sources

(d) Biological systems

3. The theory which stated that organic compounds could only be formed inside living organisms is called:

(a) Atomic theory

(b) Vital force theory ✅

(c) Molecular theory

(d) Cell theory

4. The vital force theory was rejected by:

(a) Dalton

(b) Lavoisier

(c) Friedrich Wohler ✅

(d) Rutherford

5. Friedrich Wohler synthesized urea from:

(a) Ammonium carbonate

(b) Ammonium cyanate ✅

(c) Ammonium hydroxide

(d) Ammonium chloride

6. The compound synthesized by Wohler in 1828 was:

(a) Methane

(b) Urea ✅

(c) Ethanol

(d) Glucose

7. According to the modern definition, organic chemistry is the study of:

(a) Compounds of carbon and oxygen

(b) Compounds of carbon and hydrogen and their derivatives ✅

(c) Compounds found only in living organisms

(d) Compounds of metals

8. Which of the following carbon compounds is studied as inorganic?

(a) Methane

(b) Carbon dioxide ✅

(c) Ethane

(d) Benzene

9. The self-linking property of carbon atoms to form long chains is called:

(a) Covalency

(b) Catenation ✅

(c) Coordination

(d) Catalysis

10. Organic compounds are generally:

(a) Ionic

(b) Covalent ✅

(c) Metallic

(d) Radioactive

11. The close relationship between different organic compounds is shown by:

(a) Homologous series ✅

(b) Catenation

(c) Hybridization

(d) Polymerization

12. Organic compounds usually have:

(a) Fast reactions

(b) Slow reactions and low yields ✅

(c) High solubility in water

(d) Ionic bonding

13. The complexity of organic compounds is due to:

(a) Their small molecular mass

(b) Large size and complex structure ✅

(c) Simple bonding

(d) High melting point

14. Compounds with the same molecular formula but different structural formulas show:

(a) Isomerism ✅

(b) Polymerization

(c) Ionization

(d) Catalysis

15. Most organic compounds are:

(a) Soluble in water

(b) Insoluble in water but soluble in organic solvents ✅

(c) Metallic in nature

(d) Crystalline solids

16. Most chemical reactions taking place in living systems are:

(a) Inorganic in nature

(b) Organic in nature ✅

(c) Metallic in nature

(d) Physical in nature

17. Proteins, enzymes, carbohydrates, lipids, vitamins, and nucleic acids are examples of:

(a) Inorganic molecules

(b) Organic molecules ✅

(c) Salts

(d) Minerals

18. Synthetic organic compounds like plastics, rubbers, and detergents are mainly produced to:

(a) Replace rare metals

(b) Prevent shortage of natural products ✅

(c) Increase pollution

(d) Reduce temperature

19. Petroleum, coal, and natural gas are known as:

(a) Metallic fuels

(b) Fossil fuels ✅

(c) Inorganic fuels

(d) Radioactive fuels

20. When coal is heated in the absence of air, it produces:

(a) Petroleum and water

(b) Coke, coal gas, and coal tar ✅

(c) Methane and oxygen

(d) Graphite and ash

21. The process of converting high-boiling hydrocarbons into low-boiling hydrocarbons is called:

(a) Polymerization

(b) Cracking ✅

(c) Refining

(d) Distillation

22. The main purpose of cracking is to:

(a) Produce kerosene oil

(b) Increase the yield of gasoline ✅

(c) Produce coal tar

(d) Decrease volatility

23. In cracking, large hydrocarbon molecules are broken into:

(a) Polymers

(b) Smaller hydrocarbons ✅

(c) Inorganic salts

(d) Metals

24. Cracking produces smaller molecules of:

(a) Alkanes and alkenes ✅

(b) Alcohols and acids

(c) Alkynes and ketones

(d) Salts and bases

25. In thermal cracking, large molecules are broken by:

(a) Electricity

(b) Heating at high temperature and pressure ✅

(c) Catalysts

(d) Cooling

26. Catalytic cracking takes place at lower temperature and pressure in the presence of:

(a) Silica and alumina ✅

(b) Copper and zinc

(c) Iron and nickel

(d) Sodium and potassium

27. The steam cracking process is suitable for obtaining:

(a) Alcohols

(b) Unsaturated hydrocarbons ✅

(c) Aromatic hydrocarbons

(d) Saturated hydrocarbons

28. Useful by-products of cracking such as ethene and propene are used to manufacture:

(a) Drugs, plastics, and detergents ✅

(b) Metals and alloys

(c) Rocks and minerals

(d) Salts and acids

29. The process used to improve the quality of gasoline is called:

(a) Distillation

(b) Reforming ✅

(c) Cracking

(d) Hydrogenation

30. The knocking sound in automobile engines is caused by:

(a) Rapid cooling of fuel

(b) Premature ignition of fuel ✅

(c) Slow burning of fuel

(d) Absence of air

31. The efficiency of a fuel is measured by its:

(a) Density

(b) Octane number ✅

(c) Boiling point

(d) Viscosity

32. The fuel component with an octane number of 100 is:

(a) Hexane

(b) Isooctane ✅

(c) Methane

(d) Propane

33. The additive used to increase the octane number of gasoline is:

(a) Ethanol

(b) Tetraethyl lead (TEL) ✅

(c) Acetone

(d) Benzene

34. Open-chain compounds are also known as:

(a) Aromatic compounds

(b) Aliphatic compounds ✅

(c) Heterocyclic compounds

(d) Carbocyclic compounds

35. Compounds containing a ring made up of atoms of more than one kind are called:

(a) Alicyclic compounds

(b) Aromatic compounds

(c) Heterocyclic compounds ✅

(d) Homocyclic compounds

36. Functional group imparts ______ properties to organic compounds.

(a) Physical

(b) Chemical ✅

(c) Magnetic

(d) Biological

37. The study of organic chemistry is mainly organized around ______.

(a) Atomic number

(b) Functional groups ✅

(c) Isotopes

(d) Molecular weight

38. The family of an organic compound is determined by its ______.

(a) Number of atoms

(b) Functional group ✅

(c) Molecular mass

(d) Shape

39. Carbon shows tetravalency because of ______.

(a) Promotion of an electron

(b) Hybridization of orbitals ✅

(c) Ionization

(d) Polarization

40. In methane molecule, carbon forms ______ bonds.

(a) Four π bonds

(b) Four σ bonds ✅

(c) Two π and two σ bonds

(d) Three σ and one π bond

41. The bond angle in a molecule with sp^3 hybridization is ______.

(a) 90°

(b) 109.5° ✅

(c) 120°

(d) 180°

42. In sp^3 hybridization, carbon atom forms a ______ geometry.

(a) Linear

(b) Tetrahedral ✅

(c) Trigonal planar

(d) Square planar

43. sp² hybridization occurs in which type of compounds?

(a) Saturated

(b) Unsaturated ✅

(c) Aromatic

(d) Cyclic

44. The bond angle between sp² hybrid orbitals is ______.

(a) 90°

(b) 109.5°

(c) 120° ✅

(d) 180°

45. The unhybridized p orbital in sp² hybridization forms a ______ bond.

(a) σ bond

(b) π bond ✅

(c) Hydrogen bond

(d) Ionic bond

46. The molecule of ethene (C_2H_4) contains ______.

(a) One π and five σ bonds ✅

(b) Two π and two σ bonds

(c) Four σ bonds only

(d) Three π bonds

47. sp hybridization leads to a ______ shape of molecule.

(a) Linear ✅

(b) Trigonal planar

(c) Tetrahedral

(d) Bent

48. The bond angle in sp hybridized carbon is ______.

(a) 90°

(b) 109.5°

(c) 120°

(d) 180° ✅

49. The molecule of ethyne (C_2H_2) contains ______.

(a) One σ and one π bond

(b) One σ and two π bonds ✅

(c) Two σ and one π bond

(d) Four σ bonds

50. The presence of one σ and two π bonds between carbon atoms causes the bond length to become ______.

(a) Longer

(b) Shorter ✅

(c) Equal

(d) Variable

51. Compounds having the same molecular formula but different structural formulas are called:

(a) Polymers

(b) Isomers ✅

(c) Radicals

(d) Homologues

52. The simplest hydrocarbon to show structural isomerism is:

(a) Methane

(b) Ethane

(c) Butane ✅

(d) Propane

53. Alkanes like methane, ethane, and propane do not show isomerism because:

(a) They are unsaturated

(b) They exist in one structural form only ✅

(c) They contain oxygen

(d) They are aromatic

54. As the number of carbon atoms in a hydrocarbon increases, the number of possible isomers:

(a) Decreases

(b) Remains same

(c) Increases rapidly ✅

(d) Becomes zero

55. Chain isomerism arises due to:

(a) Different functional groups

(b) Different carbon chain arrangements ✅

(c) Different positions of same functional group

(d) Cis-trans arrangement

56. Position isomerism arises due to:

(a) Different functional groups

(b) Different carbon chain lengths

(c) Different positions of same functional group ✅

(d) Different hybridization

57. Functional group isomerism arises due to:

(a) Difference in carbon chain

(b) Difference in position of atoms

(c) Difference in functional groups ✅

(d) Difference in cis-trans configuration

58. Metamerism is caused by:

(a) Unequal distribution of carbon atoms on either side of functional group ✅

(b) Different functional groups

(c) Different carbon chains

(d) Rotation around single bond

59. Cis-trans isomerism occurs due to:

(a) Free rotation around single bond

(b) Restricted rotation around double bond ✅

(c) Change in functional group

(d) Change in molecular formula

60. The necessary condition for geometric isomerism is:

(a) Carbon atoms must be single bonded

(b) Carbon atoms must have same substituents

(c) Carbon atoms must be joined by double bond with different groups attached ✅

(d) Molecule must be aromatic

🩸 Fundamental Principles of Organic Chemistry – Key Points Short Questions

1. Define organic compounds.

Answer:

👉 Organic compounds are chemical compounds mainly containing carbon and hydrogen, and sometimes oxygen, nitrogen, sulfur, etc.

2. Why were early chemists unable to synthesize organic compounds?

Answer:

👉 Early chemists believed organic compounds could only be made by living organisms, because they failed to synthesize them from inorganic substances.

3. What is the modern definition of organic chemistry?

Answer:

👉 Organic chemistry is the branch of chemistry which deals with compounds of carbon and hydrogen (hydrocarbons) and their derivatives.

4. Name three major natural sources of organic compounds.

Answer:

👉 The major sources are: coal, petroleum, and natural gas.

5. What is the purpose of the cracking process in petroleum refining?

Answer:

👉 Cracking is used to break larger hydrocarbons into smaller, more useful hydrocarbons, increasing the yield of gasoline and fuels.

6. Differentiate between acyclic and cyclic compounds.

Answer:

👉 **Acyclic compounds:** Carbon atoms form an open chain.

👉 **Cyclic compounds:** Carbon atoms form closed rings (homocyclic or heterocyclic).

7. What is a functional group? Give one example.

Answer:

👉 A functional group is an atom or group of atoms that gives a compound its chemical properties.

Example: −OH in alcohols.

8. Explain why carbon is tetravalent in most organic compounds.

Answer:

👉 Carbon becomes tetravalent by promotion of one 2s electron to 2p orbital and hybridization, allowing it to form four covalent bonds.

9. Define isomers with an example.

Answer:

👉 Isomers are compounds with the same molecular formula but different structural formulas.

Example: Butane (C_4H_{10}) ⟶ n-butane and isobutane

10. What is cis-trans (geometric) isomerism?

Answer:

👉 Cis-trans isomerism occurs when rotation around a carbon-carbon double bond is restricted, giving different spatial arrangements of groups.

Example: 2-butene ⟶ cis-2-butene and trans-2-butene

🩸 Important Short Questions:

1. What is the main difference between organic and inorganic compounds?

Answer:

👉 Organic compounds are obtained from living things (plants and animals), while inorganic compounds are obtained from non-living or mineral sources.

2. What did early chemists believe about the synthesis of organic compounds?

Answer:

👉 Early chemists believed organic compounds could only be manufactured by living organisms and could not be synthesized from inorganic materials.

3. Who disproved the "vital force theory" and how?

Answer:

👉 Friedrich Wöhler disproved it by synthesizing urea $(NH_2)_2CO$ from ammonium cyanate (NH_4CNO), an inorganic compound.

4. Write the reaction showing the synthesis of urea from ammonium cyanate.

Answer:

👉 $NH_4CNO \longrightarrow (NH_2)_2CO$

5. What is the modern definition of organic chemistry?

Answer:

👉 Organic chemistry is the branch of chemistry that deals with compounds of carbon and hydrogen (hydrocarbons) and their derivatives.

6. What elements are commonly present in organic compounds besides carbon?

Answer:

👉 Hydrogen, oxygen, nitrogen, sulfur, and sometimes halogens.

7. What is catenation? How does it contribute to the diversity of organic compounds?

Answer:

👉 Catenation is the ability of carbon atoms to link with each other to form long chains or rings, resulting in millions of different organic compounds.

8. Why are organic compounds generally non-ionic?

Answer:

👉 Organic compounds are mostly covalent, so they do not give ionic reactions.

9. What is the significance of homologous series in organic chemistry?

Answer:

👉 Homologous series show similar chemical behavior, reducing the study of millions of compounds to a few predictable series.

10. Name three characteristics of organic compounds that make them different from inorganic compounds.

Answer:

👉 1. Usually large and complex molecules

👉 2. Exhibit isomerism

👉 3. Slow reaction rates with low yields

11. Why is organic chemistry important in living systems?

Answer:

👉 Almost all chemical reactions in living systems are organic in nature, involving molecules like proteins, enzymes, carbohydrates, lipids, vitamins, and nucleic acids.

12. Name some life molecules that contain thousands of carbon atoms.

Answer:

👉 Proteins, carbohydrates, lipids, nucleic acids.

13. List some synthetic compounds prepared by chemists that are useful in daily life.

Answer:

👉 Plastics, synthetic rubber, medicines, preservatives, paints, varnishes, textile fibres, fertilizers, pesticides, detergents, cosmetics, dyes.

14. What are fossil fuels? Give three examples.

Answer:

👉 Fossil fuels are organic compounds formed over long periods from the decay of plants and animals.

Examples: Coal, petroleum, natural gas.

15. How is coal transformed into useful organic compounds? Name the products obtained by destructive distillation of coal.

Answer:

👉 Coal is heated in the absence of air (500–1000°C), a process called destructive distillation.

Products: Coke, coal gas, and coal tar.

16. What is cracking of petroleum?

Answer:

👉 Cracking is the process of breaking high-boiling, long-chain hydrocarbons into smaller, more volatile hydrocarbons such as gasoline.

17. Why is cracking of petroleum necessary?

Answer:

👉 Cracking increases the yield of valuable lower hydrocarbons (like gasoline) to meet high demand.

18. Name the three methods of cracking and briefly explain each.

Answer:

👉 **Thermal Cracking:** Breaking large molecules using high temperature and pressure to produce unsaturated hydrocarbons.

👉 **Catalytic Cracking:** Cracking at lower temperature and pressure in presence of a catalyst to produce high-octane gasoline.

👉 **Steam Cracking:** Heating hydrocarbons with steam at very high temperature to produce lower unsaturated hydrocarbons.

19. What are some useful by-products obtained from cracking of petroleum?

Answer:

👉 Ethene, propene, butene, benzene; used in manufacturing plastics, synthetic fibers, fertilizers, detergents, ethanol, phenol, acetone, and drugs.

20. What is reforming in the petroleum industry?

Answer:

👉 Reforming is the process of converting straight-chain hydrocarbons into branched-chain hydrocarbons to improve gasoline quality.

21. Define octane number and explain its importance.

Answer:

👉 Octane number measures the resistance of fuel to knocking in engines. Higher octane number = smoother combustion and less engine knocking.

22. What is tetraethyl lead (TEL) and why is it added to gasoline?

Answer:

👉 TEL $(C_2H_5)_4Pb$ is an antiknock additive added to gasoline to improve octane number. Its disadvantage is air pollution due to lead.

23. How are organic compounds broadly classified?

Answer:

👉 **Organic compounds are broadly classified into:**

- **Acyclic** (open-chain) compounds
- **Cyclic** (closed-chain) compounds

24. Differentiate between straight-chain and branched-chain compounds.

Answer:

👉 **Straight-chain:** Carbon atoms connected in a continuous series.

👉 **Branched-chain:** Carbon atoms attached to the side of the main chain.

25. What are acyclic compounds?

Answer:

👉 Compounds containing open chains of carbon atoms; also called aliphatic compounds.

26. What are cyclic compounds?

Answer:

👉 Compounds containing closed carbon chains (rings); also called ring compounds.

27. Define homocyclic (carbocyclic) compounds.

Answer:

👉 Compounds in which the ring consists entirely of carbon atoms.

28. What are alicyclic compounds? Give their general formula.

Answer:

👉 Saturated homocyclic compounds with ring structures resembling aliphatic compounds.

General formula: C_nH_{2n}

29. Define aromatic compounds and mention one characteristic feature.

Answer:

👉 Compounds containing at least one benzene ring with alternating single and double bonds.

Feature: Resonance-stabilized ring (circle often shown in structure).

30. What are heterocyclic compounds and what is a hetero atom?

Answer:

👉 Compounds in which the ring contains atoms other than carbon, e.g., nitrogen, oxygen, or sulfur.

👉 The **non-carbon** atom in the ring is called a hetero atom.

31. What is a functional group?

Answer:

👉 A functional group is an atom, group of atoms, double bond, or triple bond that imparts specific chemical properties to an organic compound.

32. Why is the study of organic chemistry organized around functional groups?

Answer:

👉 Because each functional group defines a family of organic compounds and helps classify millions of compounds into manageable categories.

33. How many main types of hybridization are there for carbon atoms?

Answer:

👉 Three main types: sp^3, sp^2, and sp hybridization.

34. Explain sp^3 hybridization.

Answer:

👉 In sp^3 hybridization, one 2s and three 2p orbitals mix to form four equivalent tetrahedral orbitals with bond angles of 109.5°, forming sigma bonds in saturated compounds like methane.

35. What is the shape of molecules with sp^3 hybridized carbon?

Answer:

👉 Tetrahedral shape with bond angles of 109.5°.

36. Explain sp^2 hybridization.

Answer:

👉 In sp^2 hybridization, one 2s and two 2p orbitals mix to form three equivalent coplanar orbitals with bond angles of 120°, used in alkenes like ethene. The unhybridized 2p orbital forms a π bond.

37. What is the bond angle in sp^2 hybridized carbon?

Answer:

👉 120°

38. Explain sp hybridization.

Answer:

👉 In sp hybridization, one 2s and one 2p orbital mix to form two degenerate linear orbitals with bond angle 180°, used in alkynes like ethyne. Two unhybridized p orbitals form two π bonds.

39. What is the shape of molecules with sp hybridized carbon?

Answer:

👉 Linear shape with bond angle 180°.

40. How do sp, sp^2, and sp^3 hybridizations explain the tetravalency of carbon?

Answer:

👉 They show how carbon forms equivalent covalent bonds in different molecules: sp^3 in saturated compounds, sp^2 in alkenes, and sp in alkynes, making carbon tetravalent in all these compounds.

41. What is isomerism?

Answer:

👉 Isomerism is the phenomenon in which two or more compounds have the same molecular formula but different structural formulas and properties.

42. Which is the simplest hydrocarbon to show structural isomerism?

Answer:

👉 Butane (C_4H_{10}) is the simplest hydrocarbon to show structural isomerism.

43. Name the five types of structural isomerism.

Answer:

👉 (i) Chain isomerism

👉 (ii) Position isomerism

👉 (iii) Functional group isomerism

👉 (iv) Metamerism

👉 (v) Tautomerism

44. What is cis-trans (geometric) isomerism?

Answer:

👉 Cis-trans isomerism occurs when two carbon atoms joined by a double bond cannot rotate freely, causing identical groups to occupy different positions in space (same side = cis, opposite side = trans).

45. What is the necessary condition for a compound to show cis-trans isomerism?

Answer:

👉 The two groups attached to each carbon of the double bond must be different.

🩸 EXERCISE

Q1. Fill in the blanks:

(i) Alkali metals are ______ reactive than alkaline-earth metals.

Answer: more ✅

(ii) Organic compounds having same molecular formula but different ______ are called isomers.

Answer: structural formulas ✅

(iii) The state of hybridization of carbon atom in ______ is sp^2.

Answer: ethene ✅

(iv) Alkenes show ______ due to restricted rotation around a carbon-carbon double bond.

Answer: cis-trans isomerism ✅

(v) Heating an organic compound in the absence of oxygen and in the presence of ______ as a catalyst is called cracking.

Answer: catalyst ✅

(vi) A group of atoms which confers characteristic properties to an organic compound is called ______.

Answer: functional group ✅

(vii) 2-Butene is ______ of 1-butene.

Answer: positional isomer ✅

(viii) Carbonyl functional group is present in both ______ and ketones.

Answer: aldehydes ✅

(ix) A heterocyclic compound contains an atom other than ______ in its ring.

Answer: carbon ✅

(x) The quality of gasoline can be checked by finding out its ______.

Answer: octane number ✅

(xi) A carboxylic acid contains ______ as a functional group.

Answer: −COOH ✅

Q2. Indicate True or False:

(i) There are three possible isomers for pentane.

Answer: True ✅

(ii) Alkynes do not show the phenomenon of cis-trans isomerism.

Answer: True ✅

(iii) Organic compounds can not be synthesized from inorganic compounds.

Answer: False ❌

(iv) All close chain compounds are aromatic in nature.

Answer: False ❌

(v) The functional group present in amides is called an amino group.

Answer: False ❌ (Correct: Carbonyl + $-NH_2$)

(vi) Government of Pakistan is trying to use coal for power generation.

Answer: True ✅

(vii) Crude petroleum is subjected to fractional sublimation in order to separate it into different fractions.

Answer: False ❌ (Correct: fractional distillation)

(viii) A bond between carbon and hydrogen serves as a functional group for alkanes.

Answer: False ❌ (Correct: $-CH$ or $-CH_3$ is part of the structure, but not considered a functional group)

(ix) o-Nitrotoluene and p-nitrotoluene are the examples of functional group isomerism.

Answer: False ❌ (Correct: these are position isomers)

(x) Almost all the chemical reactions taking place in our body are inorganic in nature.

Answer: False ❌ (Correct: organic in nature)

🩸 Q 3. Multiple choice questions. Encircle the correct answer.

1. The state of hybridization of carbon atom in methane is:

(a) sp^3 ✅

(b) sp^2

(c) sp

(d) dsp^2

2. In t-butyl alcohol, the tertiary carbon is bonded to:

(a) two hydrogen atoms

(b) three hydrogen atoms

(c) one hydrogen atom ✅

(d) no hydrogen atom

3. Which set of hybrid orbitals has planar triangular shape?

(a) sp^3

(b) sp

(c) sp^2 ✅

(d) dsp^2

4. The chemist who synthesized urea from ammonium cyanate was:

(a) Berzelius

(b) Kolbe

(c) Wohler ✅

(d) Lavoisier

5. Linear shape is associated with which set of hybrid orbitals?

(a) sp ✅

(b) sp^2

(c) sp^3

(d) dsp^2

6. A double bond consists of:

(a) two sigma bonds

(b) one sigma and one pi bond ✅

(c) one sigma and two pi bonds

(d) two pi bonds

7. Ethers show the phenomenon of:

(a) position isomerism

(b) functional group isomerism

(c) metamerism ✅

(d) cis-trans isomerism

8. Select from the following the one which is alcohol:

(a) CH3-CH2-OH ✅

(b) CH3-O-CH3

(c) CH3COOH

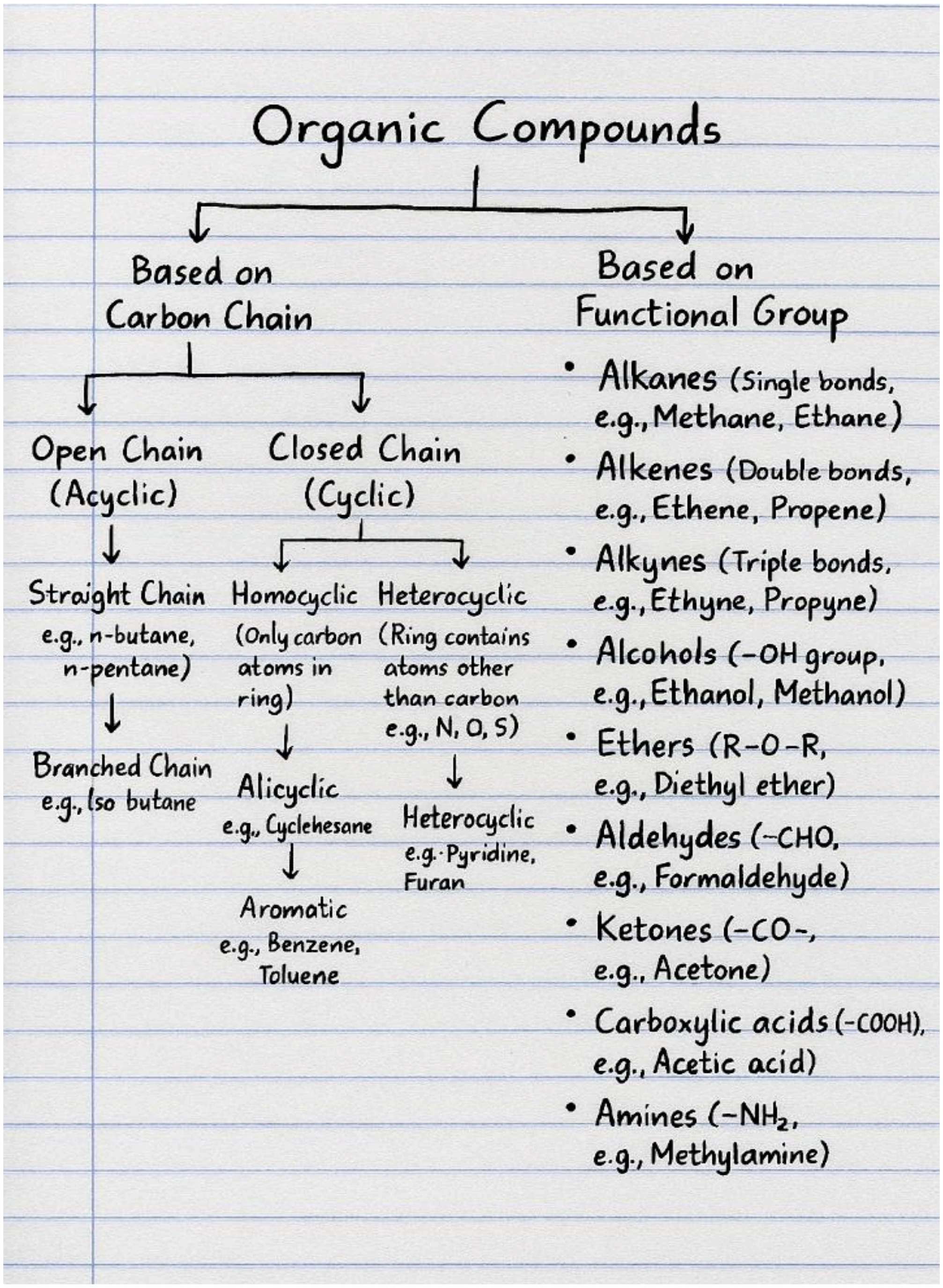
(d) CH3-CH2-Br

🌟 Q4. How Organic Compounds are Classified? Give Suitable Example of Each Type.

❖ **Answer:**

Organic compounds are chemical compounds that contain carbon atoms. They form the basis of all living organisms and are widely used in everyday life. Due to the large number of organic compounds, it is essential to classify them to study their properties systematically. Organic compounds are mainly classified in two ways:

✦ **Digram:**



1. Classification Based on Carbon Chain Structure

This classification depends on how the carbon atoms are arranged in the compound.

(a) Open Chain or Acyclic Compounds

- In these compounds, carbon atoms form a straight or branched chain, without any rings.
- **Straight Chain** (Unbranched): Carbon atoms connected in series.

Example: n-Butane (CH3-CH2-CH2-CH3), 1-Butene (CH2=CH-CH2-CH3)

- **Branched Chain:** Carbon atoms attached to the main chain forming branches.

Example: Isobutane ((CH3)2CH-CH3), t-Butyl alcohol ((CH3)3COH)

(b) Closed Chain or Cyclic Compounds

- Carbon atoms form rings in these compounds.
- **Homocyclic** (Carbocyclic) **Compounds**: Rings containing only carbon atoms
- **Alicyclic compounds:** Rings resembling aliphatic compounds.

Example: Cyclohexane (C6H12)

- **Aromatic compounds:** Rings containing benzene or fused benzene rings.

Example: Benzene (C_6H_6), Naphthalene ($C_{10}H_8$)

- **Heterocyclic Compounds:** Rings contain atoms other than carbon (like N, O, S).

Example: Pyridine (contains N), Furan (contains O)

2. Classification Based on Functional Groups

A functional group is an atom or group of atoms that imparts specific chemical properties to a molecule. Organic compounds are also classified according to their functional groups:

- **Alkanes**: Only single bonds (C−C and C−H).

Example: CH_4, C_2H_6

- **Alkenes**: Contain carbon-carbon double bond.

Example: C_2H_4, C_3H_6

- **Alkynes**: Contain carbon-carbon triple bond.

Example: C_2H_2, C_3H_4

- **Alcohols**: Contain −OH group.

Example: CH_3CH_2OH

- **Ethers**: Contain C−O−C group.

Example: $CH_3{-}O{-}CH_3$

- **Aldehydes**: Contain −CHO group.

Example: HCHO

- **Ketones**: Contain C=O group inside the chain.

Example: CH_3COCH_3

- **Carboxylic Acids:** Contain −COOH group.

Example: CH_3COOH

- **Amines**: Contain $-NH_2$ group.

Example: CH_3NH_2

> **Note**: Each functional group defines a family of compounds, and the chemical reactions of compounds within a family are often similar.

✦ **Summary**

Organic compounds are classified in two major ways:

1. Based on Carbon Chain:

- **Open chain** (straight/branched) ⟶ e.g., n-Butane, Isobutane
- **Closed chain** (cyclic) ⟶ Homocyclic (Cyclohexane, Benzene), Heterocyclic (Pyridine)

2. Based on Functional Groups:

- 👉 **Alkanes** (CH_4), Alkenes (C_2H_4), Alkynes (C_2H_2)
- 👉 **Alcohols** (CH_3CH_2OH), Ethers ($CH_3{-}O{-}CH_3$)
- 👉 **Aldehydes** (HCHO), Ketones (CH_3COCH_3)
- 👉 **Carboxylic** acids (CH_3COOH), Amines (CH_3NH_2)

This classification helps organize millions of compounds for easier study and understanding of their chemical behavior and reactions.

🌟 **Q5. What are homocyclic and heterocyclic compounds? Give one example of each.**

❖ **Answer:**

1. Homocyclic Compounds:

Definition: Homocyclic compounds are organic compounds in which the ring is made up entirely of carbon atoms.

Key Points:

- Only carbon atoms in the ring.
- Can be alicyclic (non-aromatic) or aromatic.

Examples:

- **Alicyclic:** Cyclohexane (C_6H_{12}) – saturated ring.
- **Aromatic:** Benzene (C_6H_6) – contains a delocalized π electron system.

2. Heterocyclic Compounds:

Definition: Heterocyclic compounds are organic compounds in which the ring contains at least one atom other than carbon (e.g., nitrogen, oxygen, sulfur).

Key Points:

- Atoms other than carbon are called a heteroatom.
- Can be aromatic or non-aromatic.

Examples:

- **Aromatic:** Pyridine (C_5H_5N), Furan (C_4H_4O)
- **Non-aromatic:** Piperidine ($C_5H_{11}N$)

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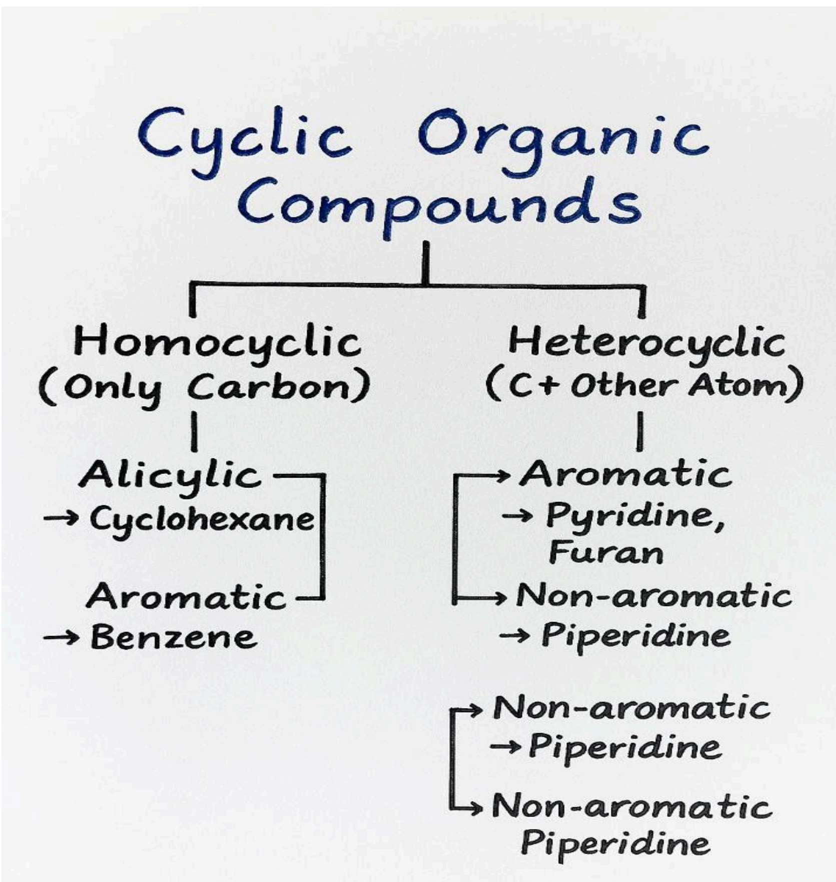

✦ Summary:

- **Homocyclic:** Rings made of only carbon. **Example**: Benzene.
- **Heterocyclic**: Rings contain carbon + heteroatom. **Example**: Pyridine.
- Homocyclic can be alicyclic or aromatic, heterocyclic can be aromatic or non-aromatic.
- **Easy way to remember:** “Homo = all C, Hetero = C + others.”

🌟 **Q6. Write the structural formulas of the two possible isomers of C_4H_{10}**

❖ **Answer:**

1. Understanding the question:

Molecular formula: C_4H_{10}

- It is an alkane (saturated hydrocarbon).
- Alkanes with 4 carbon atoms can exist in more than one arrangement of carbon atoms.
- This phenomenon is called structural isomerism.

2. Structural Isomers of C_4H_{10}

(i) n-Butane (Normal Butane)

- Straight chain arrangement of carbon atoms.

Structural formula:

CH3 - CH2 - CH2 - CH3

Explanation: Four carbon atoms are connected in a continuous chain.

(ii) Isobutane (or Methylpropane)

- Branched chain arrangement of carbon atoms.

Structural formula:

```
   CH3
      |
CH3 - CH - CH3
```

Explanation: Three carbon atoms form the main chain and one carbon is attached as a branch.

✦ **Summary:**

C_4H_{10} has two structural isomers:

1. n-Butane: straight chain.

2. Isobutane (Methylpropane): branched chain.

Both have the same molecular formula, but different structural formulas and physical properties.

🌟 Q7. Why is ethene an important industrial chemical?

❖ Answer:

1. Introduction

Ethene (C_2H_4), also called ethylene, is the simplest alkene containing a carbon-carbon double bond (C=C). This double bond makes ethene highly reactive, allowing it to undergo a variety of chemical reactions. Because of this reactivity, ethene is one of the most important raw materials in the chemical industry.

👉 **Ethene** is obtained mainly from petroleum and natural gas through processes such as cracking.

2. Industrial Uses of Ethene

(i) Production of Polymers

- Ethene is the starting material for polyethylene (PE), the most common plastic in the world.

Polyethylene is used in:

- Plastic bags and films
- Bottles and containers
- Pipes and insulation materials

(ii) Production of Alcohols

- Ethene reacts with steam in the presence of a catalyst (phosphoric acid) to produce ethanol (C_2H_5OH):

$C_2H_4 + H_2O \longrightarrow [H_3PO_4, 300°C]\ C_2H_5OH$

Ethanol is used as a solvent, fuel, and raw material for other chemicals.

(iii) Production of Chemicals for Industry

Ethene is used to make ethylene oxide, which is further converted into:

- Ethylene glycol (used in antifreeze and polyester fibers)
- Detergents and surfactants
- Vinyl chloride (used to make PVC plastics)

(iv) Agricultural Uses

Ethene acts as a plant hormone and is responsible for:

- Fruit ripening (e.g., bananas, tomatoes)
- Leaf shedding (abscission)
- Flower opening

(v) Fuel and Energy Source

- Ethene can also be combusted to provide energy in some industrial chemical processes.

3. Reasons for Industrial Importance

1. Versatility: Its double bond allows it to react with many chemicals.

2. Availability: Produced easily from petroleum and natural gas.

3. Wide Applications: Used in plastics, solvents, alcohols, fertilizers, synthetic fibers, detergents, and agriculture.

4. Economic Value: Ethene-based products support multiple industries worldwide.

✦ **Summary:**

Ethene (C_2H_4) is an essential industrial chemical because it is:

- A key raw material for polymers like polyethylene.
- **Used in ethanol** production and other chemical industries.
- **Important** in agriculture as a plant hormone.
- **Highly reactive,** allowing numerous chemical transformations.

🌟 **Q8. What is meant by a functional group? Name typical functional groups containing oxygen.**

❖ **Answer:**

1. Introduction

A **functional group is a** specific atom or group of atoms in an organic molecule that determines its chemical properties and reactions.

👉 It is **called** "**functional**" because it is the chemically reactive part of a molecule.

👉 **The presence** of a functional group classifies a compound into a family of organic compounds (e.g., alcohols, ketones, carboxylic acids).

2. Definition

Functional Group:

> An atom or group of atoms whose presence in a molecule imparts characteristic chemical properties to the compound.

Example:

- In ethanol (CH_3CH_2OH), the –OH group is the functional group that makes it an alcohol.

3. Typical Oxygen-Containing Functional Groups

1. Hydroxyl Group (–OH)

- **Found in alcohols** (e.g., ethanol, CH_3CH_2OH) and phenols.
- **Responsible** for properties like solubility in water and ability to form hydrogen bonds.

2. Carbonyl Group (C=O)

Found in:

- **Aldehydes** (e.g., ethanal, CH_3CHO)
- **Ketones** (e.g., propanone, CH_3COCH_3)

Gives reactivity like oxidation and nucleophilic addition.

3. Carboxyl Group (–COOH)

- Found in **carboxylic** acids (e.g., acetic acid, CH_3COOH)
- **Makes compounds** acidic and reactive with alcohols to form esters.

4. Ester Group (–COO–)

- **Found in esters** (e.g., ethyl acetate, $CH_3COOCH_2CH_3$)
- **Responsible** for fruity odors and esterification reactions.

5. Ether Group (–O–)

- **Found** in ethers (e.g., dimethyl ether, $CH_3–O–CH_3$)
- **Makes** compounds relatively inert but good solvents.

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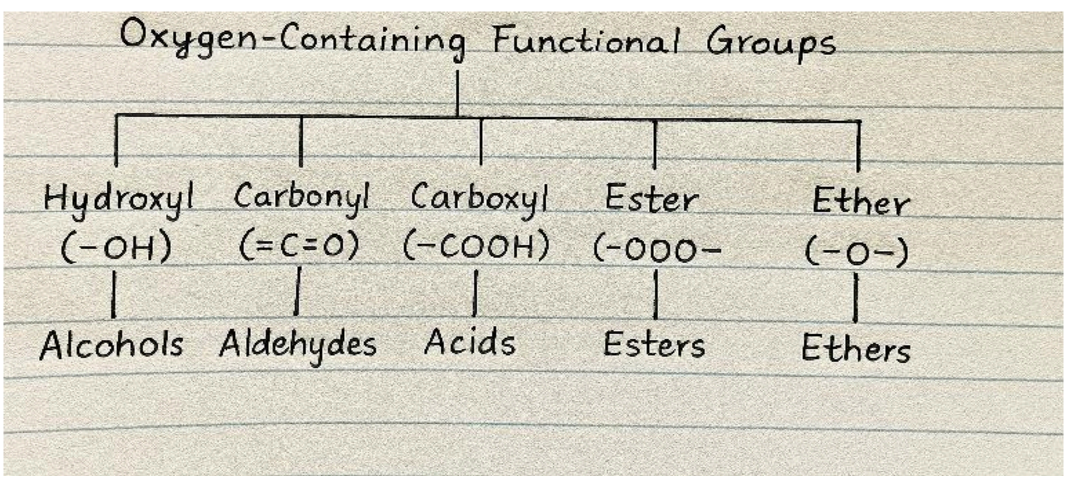

✦ **Summary:**

A **functional group** is the reactive part of an organic molecule that defines its chemical behavior.

Oxygen-containing functional groups include:

- **Hydroxyl** (–OH) ⟶ alcohols, phenols
- **Carbonyl** (C=O) ⟶ aldehydes, ketones
- **Carboxyl** (–COOH) ⟶ carboxylic acids
- **Ester** (–COO–) ⟶ esters
- **Ether** (–O–) ⟶ ethers

🌟 **Q9. What is an organic compound? Explain the importance of Wohler's work in the development of organic chemistry.**

❖ **Answer:**

1. Definition of Organic Compounds

👉 **Organic compounds** are chemical compounds that contain carbon as the essential element, usually bonded with hydrogen, oxygen, nitrogen, and sometimes other elements like sulfur or halogens.

👉 **Traditionally**, organic compounds were considered as compounds obtained from living organisms (plants and animals).

Examples: Methane (CH_4), Ethanol (CH_3CH_2OH), Glucose ($C_6H_{12}O_6$)

Modern Definition:

- Organic chemistry is the study of carbon compounds (except a few like CO, CO_2, carbonates) and their derivatives.

2. Importance of Wohler's Work

Before the 19th century:

- **Chemists believed** in the vital force theory, which stated that organic compounds could only be produced by living organisms.
- **No one thought** that organic compounds could be synthesized artificially from inorganic substances.

Friedrich Wohler's Experiment (1828):

- Wohler synthesized urea (NH_2CONH_2), an organic compound, from ammonium cyanate (NH_4CNO), an inorganic compound.

Reaction:

$NH_4CNO \longrightarrow (NH_2)_2CO$ (urea)

Significance:

1. Disproved the vital force theory: Organic compounds can be made in the lab.

2. Laid the foundation of modern organic chemistry.

3. Encouraged chemists to synthesize millions of organic compounds in laboratories.

4. Showed that chemical laws are the same for both organic and inorganic compounds.

✦ Summary:

Organic compounds: Carbon-containing compounds, usually with hydrogen, and sometimes with oxygen, nitrogen, sulfur, etc.

Wohler's work: Synthesized urea from ammonium cyanate, disproving the vital force theory and marking the beginning of modern organic chemistry.

🌟 Q10. Write a short note on cracking of hydrocarbons

❖ Definition:

👉 **Cracking** is the process in which **long-chain**, high-boiling hydrocarbons are broken into smaller, more useful lower hydrocarbons.

👉 The **resulting** products are usually alkanes and alkenes.

Purpose: To increase the yield of gasoline and produce valuable industrial chemicals.

✦ Importance of Cracking

1. Supplies more gasoline from less desirable petroleum fractions like kerosene and gas oil.

2. Produces unsaturated hydrocarbons such as ethene, propene, and butene, which are raw materials for:

- Plastics
- Synthetic fibers
- Detergents
- Fertilizers
- Pharmaceuticals

✦ Types of Cracking:

(i) Thermal Cracking:

- **Uses high temperature** (≈700°C) and high pressure.
- **Produces** unsaturated hydrocarbons (alkenes) like ethene and propene.

(ii) Catalytic Cracking:

- Uses a catalyst (silica + alumina) at lower temperature (~500°C) and lower pressure.
- **Produces** high-octane gasoline for engines.

(iii) Steam Cracking:

- **Hydrocarbons** in the vapor phase are mixed with steam and heated to ≈900°C.
- **Produces** lower alkenes efficiently.

➢ Example of Cracking Reaction

$C_{16}H_{34} \longrightarrow C_7H_{16} + C_5H_{10} + C_4H_8$

(Long-chain alkane) ⟶ (Shorter alkanes and alkenes)

✦ **Summary:**

- **Cracking** breaks large hydrocarbons into smaller ones.
- **Helps produce** more gasoline and valuable alkenes for industrial use.

Types: Thermal, Catalytic, and Steam cracking.

🌟 **Q11. Explain reforming of petroleum with the help of suitable example**

❖ **Definition:**

👉 Reforming is the process of improving the quality of petroleum (gasoline) by converting straight-chain hydrocarbons into branched-chain or cyclic hydrocarbons.

👉 **Purpose**: To increase the octane number of gasoline, which prevents engine knocking.

👉 **Engine knocking** occurs when fuel ignites prematurely, reducing engine efficiency.

✦ **Importance of Reforming:**

1. Converts poor-quality, straight-chain hydrocarbons into high-octane branched-chain hydrocarbons.

2. Produces better fuel for automobiles.

3. Can be combined with additives like tetraethyl lead (TEL) to further improve fuel performance.

🔹 Process of Reforming

Catalytic Reforming:

- **Hydrocarbons** are heated in the absence of oxygen.
- A **catalyst** is used (commonly platinum or a mixture of platinum and alumina).
- **Straight-chain** alkanes are converted into branched alkanes, cycloalkanes, or aromatic hydrocarbons.

Example:

n-Heptane (C7H16) ⟶ Isoheptane (branched C7H16)

Effect:

- Octane number increases from low (≈20–30) to high (≈90–100).

🔸 Use of Additives

- Tetraethyl lead (TEL, C2H5)4Pb can be added to gasoline to further prevent knocking.

Disadvantage: Produces lead oxide, which causes air pollution.

✦ **Summary:**

- **Reforming** improves the octane number of gasoline.
- **Converts straight-chain** hydrocarbons into branched or cyclic hydrocarbons.
- **Helps in producing high-quality** fuel suitable for modern engines.

🌟 Q12. Describe important sources of organic compounds

❖ **Introduction:**

👉 Organic compounds are carbon-based compounds widely used in daily life, industry, and biological systems.

👉 Their main sources include fossil fuels and natural resources.

✦ Major Sources of Organic Compounds

(a) Coal

Formation: Formed from decayed plant remains buried over millions of years.

Uses:

- **Solid** fuel for heating and industrial purposes.

Carbonization (heating in absence of air) produces:

- **Coke** – used in metallurgy
- **Coal** gas – used as fuel
- **Coal tar** – contains many organic compounds for dyes, chemicals, and medicines.

Example: Fractional distillation of coal tar yields benzene, toluene, and naphthalene.

(b) Petroleum (Crude Oil)

👉 **Formation:** Result of slow decomposition of marine plants and animals over millions of years.

Refinement: Fractional distillation separates crude oil into different fractions:

- **Gasoline** – fuel for cars
- **Kerosene** – fuel for lamps and jet engines

- **Diesel oil** – fuel for vehicles and machines
- **Lubricating oil** – reduces friction in engines

Other uses: Manufacturing of plastics, synthetic rubber, detergents, fertilizers, and chemicals.

(c) Natural Gas

👉 **Composition:** Mainly methane (CH4) with small amounts of other hydrocarbons.

👉 **Formation:** From decomposition of organic matter under high pressure and temperature.

Uses:

- **Fuel for heating,** electricity, and cooking.
- **Raw material** in fertilizer production (ammonia synthesis).
- **Used** in the chemical industry for making methanol and other chemicals.

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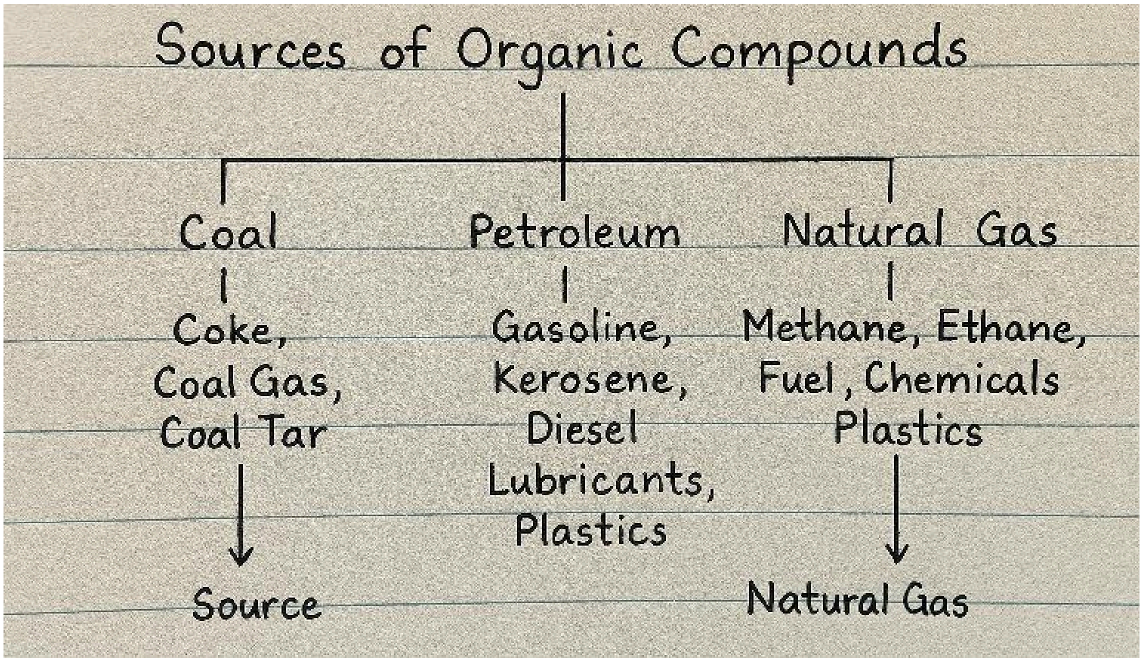

✦ **Summary:**

👉 **Coal**, petroleum, and natural gas are the main natural sources of organic compounds.

👉 **Organic compounds** from these sources are essential for fuel, industry, medicines, and everyday products.

👉 **Coal tar**, petroleum fractions, and natural gas derivatives provide a wide range of chemicals and fuels.

🌟 **Q13. What is orbital hybridization? Explain sp^3, sp^2, and sp modes of hybridization of carbon**

❖ **Definition of Orbital Hybridization**

👉 **Orbital hybridization** is a concept in chemistry where atomic orbitals of the same atom mix together to form new equivalent orbitals.

👉 These **hybrid orbitals** have equal energy and specific orientation in space, which explains the geometry and bonding of molecules.

👉 **Hybridization** is particularly important in carbon compounds, because carbon forms four covalent bonds even though in its ground state it appears divalent.

Ground state electronic configuration of carbon:

$1s^2\ 2s^2\ 2p_x^1\ 2p_y^1\ 2p_z^0$

- Carbon is apparently divalent (only 2 unpaired electrons in 2p).

Excited state of carbon:

$1s^2\ 2s^1\ 2p_x^1\ 2p_y^1\ 2p_z^1$

- **Now** it has four unpaired electrons, which can form four covalent bonds.
- **Hybridization** explains how these orbitals mix to form equivalent bonding orbitals.

✦ sp^3 Hybridization (Tetrahedral Geometry)

Definition: Mixing of one 2s orbital and three 2p orbitals ⟶ four equivalent sp^3 hybrid orbitals.

- **Geometry:** Tetrahedral
- **Bond angle**: 109.5°
- **Example**: Methane (CH_4)

Explanation:

- **Each** of the **four sp^3** orbitals overlaps with the 1s orbital of a hydrogen atom to form four σ bonds.
- **All bonds** are equivalent in length and energy.

structure:

```
  H
   |
H - C - H
   |
   H
```

Other examples: Ethane (C_2H_6), n-butane

✦ sp² Hybridization (Trigonal Planar Geometry)

Definition: Mixing of one 2s orbital and two 2p orbitals → three equivalent sp² hybrid orbitals.

- **Geometry**: Trigonal planar
- **Bond angle**: 120°

Example: Ethene (C_2H_4)

Explanation:

- The three sp² orbitals form σ bonds with other atoms.
- The remaining unhybridized 2p orbital forms a π bond, resulting in a double bond.

structure:

```
H     H
  \   /
   C = C
```

/ \

H H

Other examples: Propene (C_3H_6), Butene (C_4H_8)

✦ sp Hybridization (Linear Geometry)

Definition: Mixing of one 2s orbital and one 2p orbital → two equivalent sp hybrid orbitals.

- **Geometry**: Linear
- **Bond angle**: 180°

Example: Ethyne (C_2H_2)

Explanation:

- **The two** sp orbitals form σ bonds with hydrogen and carbon.
- The **two unhybridized 2p** orbitals on each carbon overlap sideways to form two π bonds, resulting in a triple bond.

structure:

H - C ≡ C - H

Other examples: Acetylene derivatives

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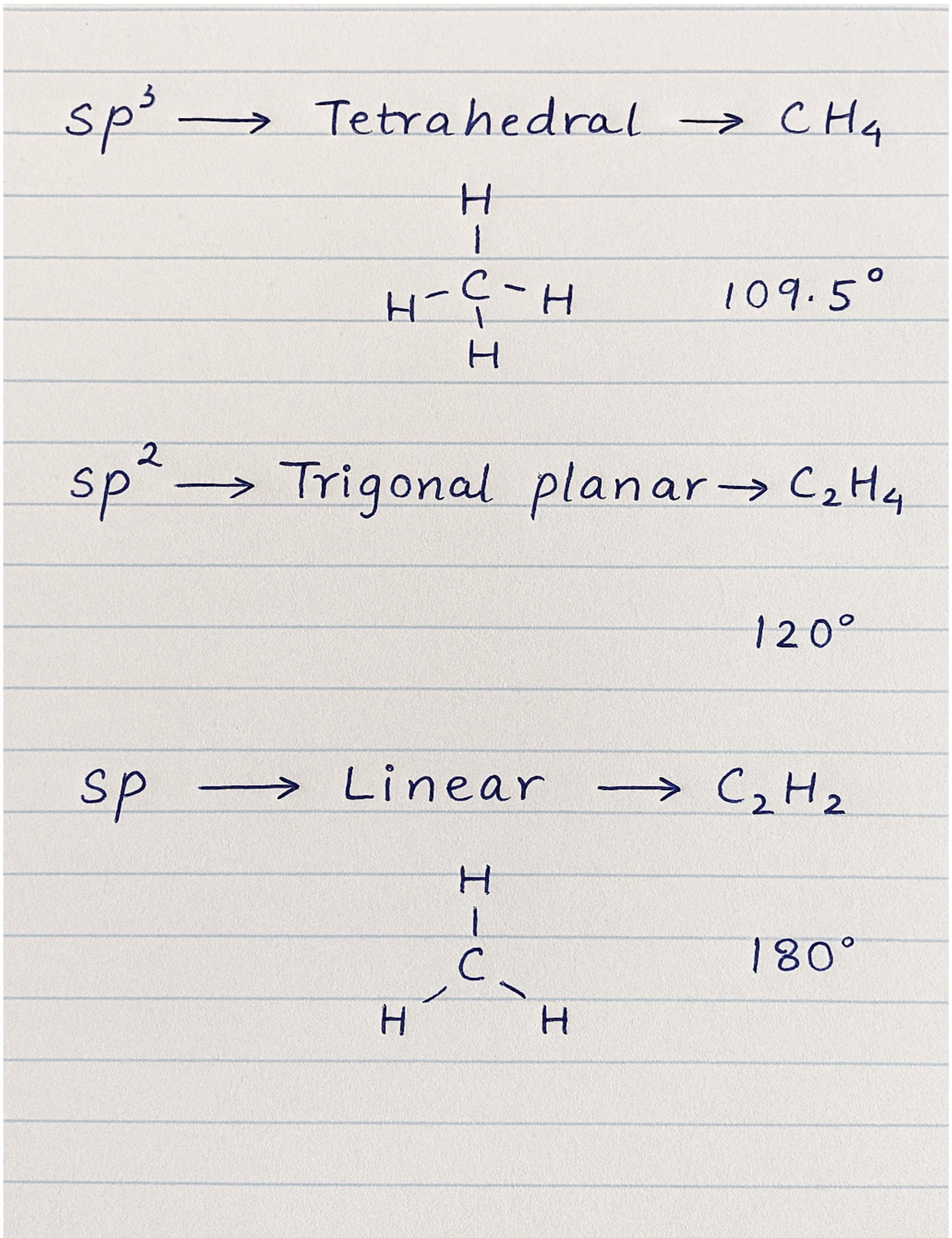


⭐ Key Points

- Hybridization explains carbon's tetravalency and the shapes of organic molecules.

sp³: Tetrahedral, 4 σ bonds, 109.5° (CH_4, C_2H_6)

sp²: Trigonal planar, 3 σ + 1 π bond, 120° (C_2H_4, C_3H_6)

sp: Linear, 2 σ + 2 π bonds, 180° (C_2H_2)

🌟 **Q14. Explain the type of bonds and shapes of the following molecules using hybridization approach**

❖ **Answer:**

👉 Hybridization helps us predict the type of bonds, molecular geometry, and bond angles in organic compounds. The type of hybridization of the central atom (usually carbon) determines whether the molecule is linear, planar, or tetrahedral, and whether it has single, double, or triple bonds.

1. Ethane (CH_3-CH_3)

- **Central atoms:** Both carbons
- **Hybridization**: sp³ for each carbon
- **Bond type:** 1 C-C σ bond, 6 C-H σ bonds
- **Geometry/Shape:** Tetrahedral around each carbon
- **Bond angle**: 109.5°

Explanation:

- **Each carbon** mixes 2s and three 2p orbitals → four sp^3 hybrid orbitals.
- **Each sp^3 orbital** overlaps with a hydrogen 1s orbital or the other carbon's sp^3 orbital to form σ bonds.

Structure:

```
 H   H
  |  |
H - C - C - H
  |  |
  H   H
```

2. Ethene (CH_2=CH_2)

- **Central atoms:** Two carbons
- **Hybridization**: sp^2 for each carbon
- **Bond type**: 1 C=C (1 σ + 1 π), 4 C-H σ bonds
- **Geometry/Shape**: Trigonal planar around each carbon
- **Bond angle**: 120°

Explanation:

- Each carbon mixes 2s and two 2p orbitals ⟶ three sp^2 hybrid orbitals.
- One unhybridized p orbital overlaps to form a π bond.

Structure:

```
H     H
  \   /
   C = C
  /   \
 H     H
```

3. Ethyne (CH≡CH)

- **Central atoms**: Two carbons
- **Hybridization**: sp for each carbon
- **Bond type**: 1 σ + 2 π bonds between carbons, 2 C-H σ bonds
- **Geometry/Shape**: Linear
- **Bond angle**: 180°

Explanation:

👉 Each carbon mixes 2s and 1 2p orbital ⟶ 2 sp hybrid orbitals.

👉 The remaining two unhybridized p orbitals on each carbon form two perpendicular π bonds.

Structure:

H - C ≡ C - H

4. Formaldehyde (HCHO)

- **Central atom:** Carbon
- **Hybridization**: sp^2
- **Bond type**: 2 σ bonds with H and O, 1 σ + 1 π bond with O
- **Geometry/Shape**: Trigonal planar
- **Bond angle:** 120°

Explanation:

- **Carbon forms** two single bonds with H and one double bond with O.
- **sp^2 hybridization** explains planar structure, while π bond is from unhybridized p orbital on carbon overlapping with oxygen's p orbital.

Structure:

H

|

C = O

5. Chloromethane (CH_3Cl)

- **Central atom:** Carbon
- **Hybridization**: sp^3
- **Bond type:** 3 C-H σ bonds, 1 C-Cl σ bond
- **Geometry/Shape:** Tetrahedral
- **Bond angle:** 109.5°

Explanation:

- **Carbon mixes** 2s and 3 2p orbitals → 4 sp^3 hybrid orbitals.
- **These orbitals** form σ bonds with three H atoms and one Cl atom.

Structure:

H

|

H - C - Cl

|

H

✦ **Summary:**

👉 **sp^3 hybridization**: Single bonds ⟶ tetrahedral geometry ⟶ CH_3-CH_3, CH_3Cl

👉 **sp^2 hybridization:** Double bonds ⟶ trigonal planar geometry ⟶ CH_2=CH_2, HCHO

👉 **sp hybridization:** Triple bonds ⟶ linear geometry ⟶ CH≡CH

Bond types:

- **σ bonds**: single bond overlaps
- **π bonds:** formed from unhybridized p orbitals in double/triple bonds

Shapes are determined by hybridization + lone pair repulsion (if any)

🌟 Q15. Why there is no free rotation around a double bond and a free rotation around a single bond? Discuss cis-trans isomerism.

❖ **Answer:**

1. Free rotation around a single bond

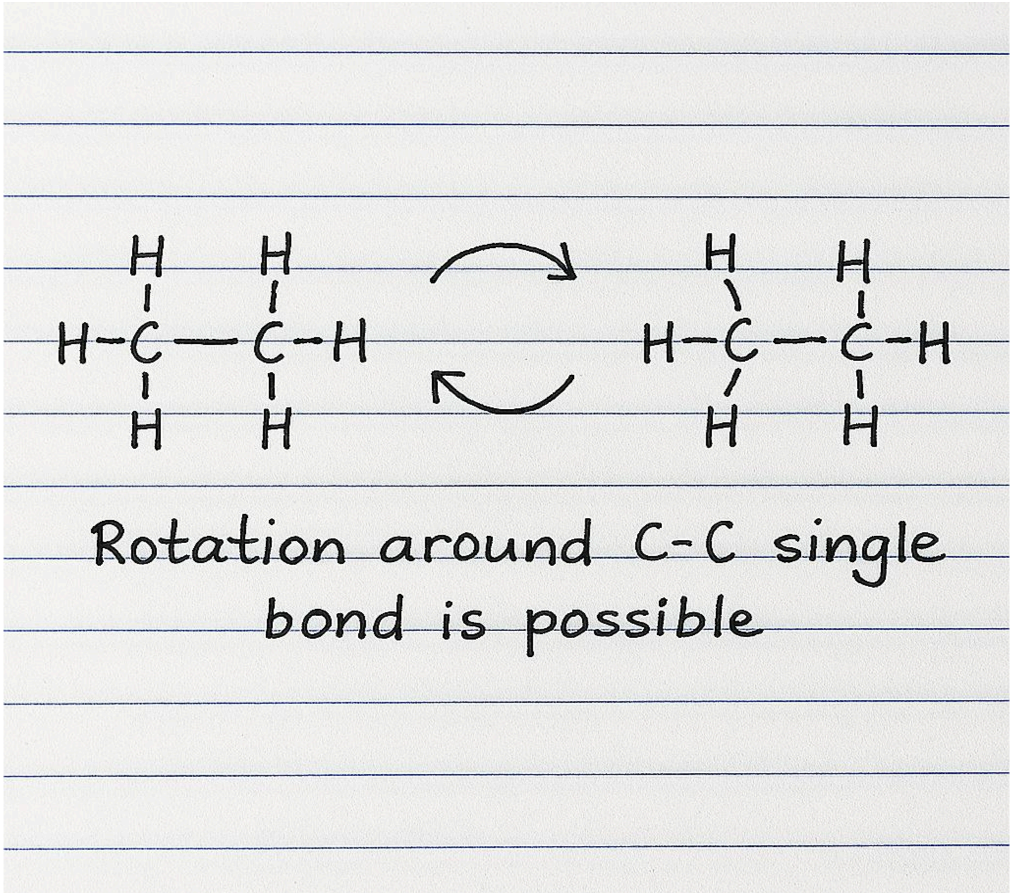
👉 **In single bonds** (σ bonds), the bond is formed by the head-on overlap of orbitals (usually sp^3 or sp^2 hybrid orbitals).

👉 **The cylindrical** symmetry of a σ bond allows free rotation of atoms around the bond without breaking the bond.

Example:

In ethane (CH_3-CH_3), the two carbon atoms are connected by a single σ bond, so the CH_3 groups can rotate freely around the C−C bond.

Structure:



2. No free rotation around a double bond

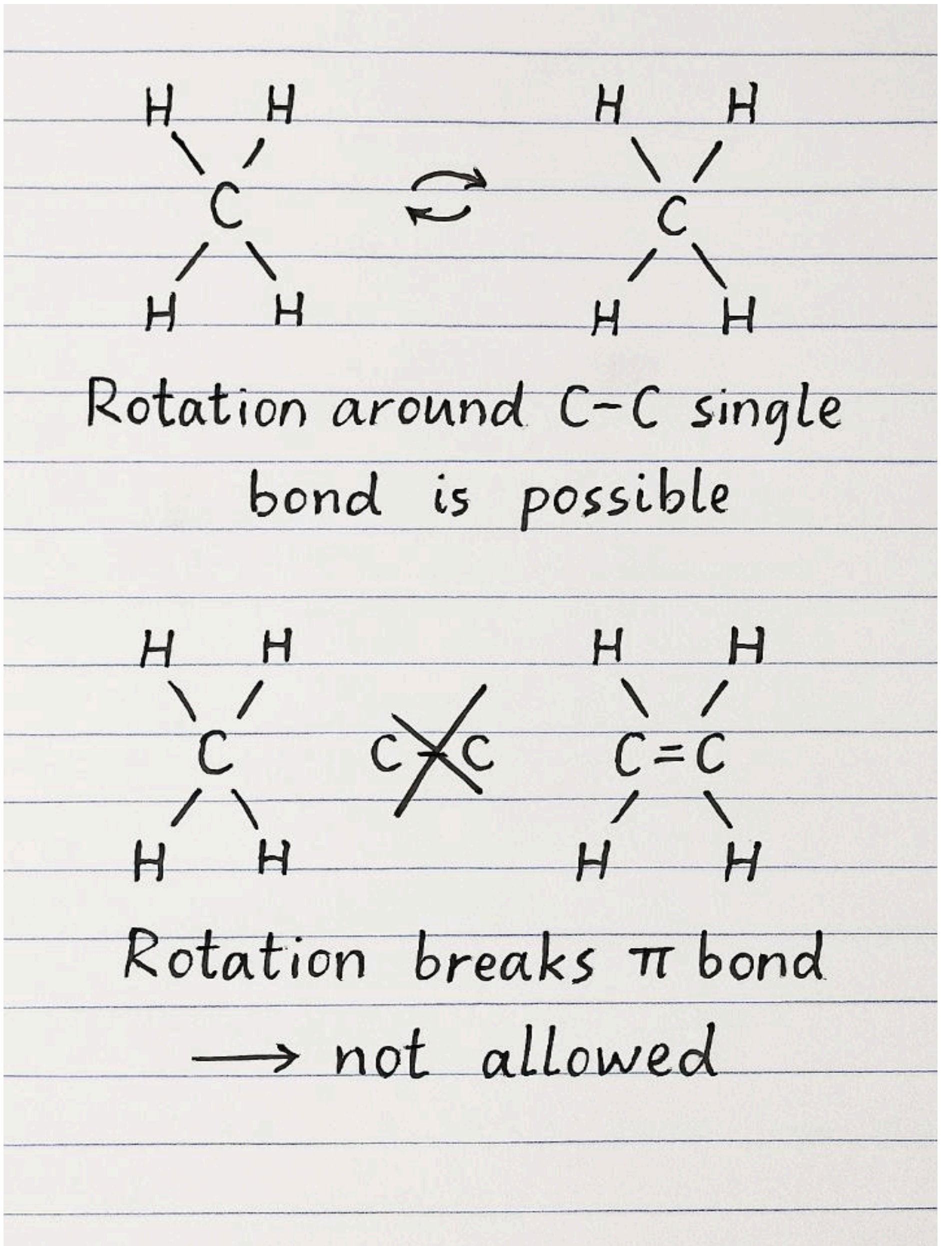
👉 A **double bond** (C=C) consists of one σ bond and one π bond.

👉 The π **bond** is formed by the side-by-side overlap of unhybridized p orbitals above and below the plane of the molecule.

👉 **Rotating** the atoms around the double bond would break the π bond, which requires a large amount of energy.

Hence, double bonds are rigid and do not allow free rotation.

Structure:



3. Cis-Trans (Geometric) Isomerism

👉 **Cis-trans** isomerism occurs due to the rigidity of the C=C double bond, which locks the relative positions of substituents.

- **Cis isomer**: Similar groups are on the same side of the double bond.
- **Trans isomer:** Similar groups are on opposite sides of the double bond.

Example: 2-butene (C_4H_8)

Cis-2-butene:

```
H     CH3

   \   /

   C = C

   /   \

 CH3     H
```

Trans-2-butene:

```
CH3     H
```

```
 \   /

C = C

 /   \

H    CH3
```

Key Points:

- **Cis-trans** isomers have different physical and chemical properties.
- **Only compounds** with two different groups on each carbon of the double bond can show cis-trans isomerism.

✦ Summary:

1. Single bonds (σ bonds): Free rotation ⟶ molecules can rotate around the bond easily.

2. Double bonds (σ + π): No free rotation ⟶ π bond prevents rotation.

3. Cis-trans isomerism:

Arises due to restricted rotation around a double bond.

- **Cis** → similar groups on the same side.
- **Trans** → similar groups on opposite sides.

4. Importance: Explains different properties of molecules with the same molecular formula.

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.

Author: Muhammad Asghar

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