Carbon and its Compounds - Class 10 Science Notes

1. Introduction to Carbon

Unique Properties of Carbon

Carbon is a unique element that forms the basis of all living organisms and countless compounds. It has the atomic number 6 and electronic configuration 2,4.

Why Carbon is Special?

1. **Tetravalency:** Carbon has 4 electrons in outermost shell
2. **Catenation:** Ability to form chains with other carbon atoms
3. **Small size:** Allows strong bonding
4. **Forms multiple bonds:** Single, double, and triple bonds

Allotropes of Carbon

Crystalline Forms:

- **Diamond:** Each carbon bonded to 4 others in tetrahedral structure
- **Graphite:** Layered structure with each carbon bonded to 3 others
- **Fullerenes:** Spherical structures like C_{60} (Buckminsterfullerene)

Amorphous Forms:

- **Coal**
- **Charcoal**
- **Coke**
- **Carbon black**

2. Bonding in Carbon Compounds

Covalent Bonding

Carbon forms covalent bonds by sharing electrons since:

- Gaining 4 electrons (C^{4-}) would require enormous energy
- Losing 4 electrons (C^{4+}) would require enormous energy
- Sharing electrons is energetically favorable

Types of Covalent Bonds

1. **Single bond (C-C):** One pair of electrons shared

2. **Double bond (C=C):** Two pairs of electrons shared
3. **Triple bond (C≡C):** Three pairs of electrons shared

Versatile Nature of Carbon

- **Chain formation:** Long chains of carbon atoms
- **Branched chains:** Carbon chains with side branches
- **Ring formation:** Closed chains forming rings
- **Multiple bonding:** Double and triple bonds possible

3. Saturated and Unsaturated Carbon Compounds

Saturated Compounds (Alkanes)

- Contain only single bonds between carbon atoms
- General formula: C_nH_{2n+2}
- Also called paraffins
- Examples: Methane (CH_4), Ethane (C_2H_6), Propane (C_3H_8)

Unsaturated Compounds

Alkenes (One double bond)

- General formula: C_nH_{2n}
- Examples: Ethene (C_2H_4), Propene (C_3H_6)

Alkynes (One triple bond)

- General formula: C_nH_{2n-2}
- Examples: Ethyne (C_2H_2), Propyne (C_3H_4)

4. Homologous Series

Definition

A series of carbon compounds with the same functional group, similar chemical properties, and successive members differing by CH_2 unit.

Characteristics of Homologous Series

1. Same general formula
2. Same functional group
3. Similar chemical properties
4. Gradual change in physical properties

5. Successive members differ by CH_2 (14 amu)
6. Same method of preparation

Examples of Homologous Series

Alkanes (C_nH_{2n+2})

- Methane: CH_4
- Ethane: C_2H_6
- Propane: C_3H_8
- Butane: C_4H_{10}
- Pentane: C_5H_{12}

Alkenes (C_nH_{2n})

- Ethene: C_2H_4
- Propene: C_3H_6
- Butene: C_4H_8

Alcohols ($C_nH_{2n+1}OH$)

- Methanol: CH_3OH
- Ethanol: C_2H_5OH
- Propanol: C_3H_7OH

5. Nomenclature of Carbon Compounds

IUPAC Rules for Naming

1. **Identify longest carbon chain:** This gives the base name
2. **Number the carbon atoms:** Start from the end nearest to functional group
3. **Identify and name substituents:** Branches attached to main chain
4. **Name functional groups:** Use appropriate suffix or prefix

Word Roots for Carbon Chains

- 1 Carbon: Meth-
- 2 Carbons: Eth-
- 3 Carbons: Prop-
- 4 Carbons: But-
- 5 Carbons: Pent-
- 6 Carbons: Hex-

Suffixes for Different Compounds

- Alkanes: -ane
- Alkenes: -ene
- Alkynes: -yne
- Alcohols: -ol
- Aldehydes: -al
- Ketones: -one
- Carboxylic acids: -oic acid

6. Functional Groups

Definition

An atom or group of atoms that determines the chemical properties of a compound.

Important Functional Groups

Functional Group	Formula	Suffix	Example
Alcohol	-OH	-ol	Ethanol
Aldehyde	-CHO	-al	Ethanal
Ketone	>C=O	-one	Propanone
Carboxylic acid	-COOH	-oic acid	Ethanoic acid
Ester	-COO-	-oate	Methyl ethanoate
Halogen	-X (F,Cl,Br,I)	halo-	Chloroethane

7. Important Carbon Compounds

1. Ethanol (C_2H_5OH)

Physical Properties

- Colorless liquid
- Pleasant smell
- Boiling point: 78°C
- Soluble in water
- Neutral to litmus

Chemical Properties

Combustion: $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O + Heat$

Oxidation: $C_2H_5OH + [O] \rightarrow CH_3COOH + H_2O$ (using oxidizing agents)

Reaction with sodium: $2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2$

Uses of Ethanol

- In alcoholic beverages
- As antiseptic in medicines
- As solvent for medicines, perfumes
- As fuel (gasohol)

Harmful Effects

- Addiction and health problems
- Affects nervous system
- Causes liver damage

2. Ethanoic Acid (CH_3COOH) - Acetic Acid

Physical Properties

- Colorless liquid
- Pungent smell
- Boiling point: 118°C
- Miscible with water
- Freezing point: 17°C (glacial acetic acid)

Chemical Properties

Reaction with metals: $2CH_3COOH + Mg \rightarrow (CH_3COO)_2Mg + H_2$

Reaction with bases: $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

Reaction with carbonates: $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$

Esterification: $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$

Uses of Ethanoic Acid

- In vinegar (5-8% solution)
- In manufacture of esters
- As food preservative
- In textile industry

3. Soaps and Detergents

Soaps

Preparation: Fat/Oil + NaOH → Soap + Glycerol (Saponification reaction)

Example: $C_{17}H_{35}COONa$ (Sodium stearate - a soap)

Structure of Soap

- **Hydrophilic head:** $-COONa^+$ (water-loving)
- **Hydrophobic tail:** Long carbon chain (water-hating)

Cleaning Action of Soap

1. Soap molecules form micelles in water
2. Hydrophobic tails trap dirt and oil
3. Hydrophilic heads remain in water
4. Dirt is washed away with water

Disadvantages of Soaps

- Don't work well in hard water
- Form insoluble precipitates with Ca^{2+} and Mg^{2+} ions
- Not effective in acidic conditions

Detergents

- Synthetic cleaning agents
- Work well in hard water
- More effective than soaps
- Examples: Sodium lauryl sulfate

Advantages of Detergents

- Effective in hard water
- Work in acidic conditions
- Better cleaning action
- Don't form precipitates

8. Chemical Reactions of Carbon Compounds

1. Combustion Reactions

Complete combustion: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + Heat$

Incomplete combustion: $2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O + Heat$

2. Oxidation Reactions

Oxidation of alcohols:

- Primary alcohol → Aldehyde → Carboxylic acid
- Secondary alcohol → Ketone

3. Addition Reactions

Hydrogenation: $C_2H_4 + H_2 \rightarrow C_2H_6$ (Ni catalyst)

Addition of water: $C_2H_4 + H_2O \rightarrow C_2H_5OH$ (in presence of acid)

4. Substitution Reactions

Halogenation of alkanes: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ (in presence of sunlight)

9. Life Processes and Carbon Compounds

Photosynthesis

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ (in presence of sunlight and chlorophyll)

Respiration

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP\ energy$

Importance of Carbon Compounds in Life

- **Carbohydrates:** Energy source (glucose, starch)
- **Proteins:** Body building (amino acids)
- **Fats:** Energy storage and insulation
- **Nucleic acids:** Genetic information (DNA, RNA)

10. Important Industrial Processes

1. Manufacture of Ethanol

From sugarcane (Fermentation)

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ (yeast enzyme)

From ethene (Industrial method)

$C_2H_4 + H_2O \rightarrow C_2H_5OH$ (300°C, 60-70 atm, phosphoric acid catalyst)

2. Manufacture of Ethanoic Acid

From methanol

$CH_3OH + CO \rightarrow CH_3COOH$ (catalyst, high pressure)

Oxidation of ethanol

$C_2H_5OH + [O] \rightarrow CH_3COOH + H_2O$

3. Cracking of Hydrocarbons

Long chain hydrocarbons → Short chain hydrocarbons
(High temperature and pressure)

11. Environmental Impact

Greenhouse Effect

- CO_2 from combustion of fossil fuels
- Traps heat in atmosphere
- Causes global warming

Air Pollution

- Incomplete combustion produces CO (toxic)
- Burning of fossil fuels releases pollutants
- Formation of smog in cities

Solutions

- Use of renewable energy
- Efficient combustion
- Catalytic converters in vehicles
- Alternative fuels (ethanol, biodiesel)

12. Key Chemical Equations

Combustion Reactions

- $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

- $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$

Oxidation Reactions

- $C_2H_5OH + [O] \rightarrow CH_3COOH + H_2O$
- $C_2H_5OH + [O] \rightarrow CH_3CHO + H_2O$

Addition Reactions

- $C_2H_4 + H_2 \rightarrow C_2H_6$ (Ni catalyst)
- $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$
- $C_2H_4 + HCl \rightarrow C_2H_5Cl$

Substitution Reactions

- $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$
- $C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$

Esterification

- $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$

Saponification

- Fat + 3NaOH → 3Soap + Glycerol

13. Structural Formulas

Alkanes

- **Methane:** H-C-H (with H above and below C)
- **Ethane:** $H_3C\text{-}CH_3$
- **Propane:** $H_3C\text{-}CH_2\text{-}CH_3$

Alkenes

- **Ethene:** $H_2C{=}CH_2$
- **Propene:** $H_3C\text{-}CH{=}CH_2$

Functional Groups

- **Alcohol:** R-OH
- **Aldehyde:** R-CHO
- **Ketone:** R-CO-R'
- **Carboxylic acid:** R-COOH

14. Tests for Carbon Compounds

Test for Unsaturation

- **Bromine water test:** Unsaturated compounds decolorize orange bromine water
- **Potassium permanganate test:** Decolorizes purple $KMnO_4$ solution

Test for Alcohols

- **Sodium test:** Alcohols liberate hydrogen gas with sodium metal
- $2ROH + 2Na \rightarrow 2RONa + H_2$

Test for Carboxylic Acids

- **Litmus test:** Turn blue litmus red
- **Sodium carbonate test:** Liberate CO_2 gas
- $2RCOOH + Na_2CO_3 \rightarrow 2RCOONa + H_2O + CO_2$

15. Important Points to Remember

1. **Carbon** shows tetravalency and catenation
2. **Homologous series** members have similar properties
3. **Functional groups** determine chemical behavior
4. **Saturated compounds** have only single bonds
5. **Unsaturated compounds** have double or triple bonds
6. **IUPAC naming** follows systematic rules
7. **Ethanol** is neutral but ethanoic acid is acidic
8. **Soaps** don't work in hard water, detergents do
9. **Addition reactions** occur with unsaturated compounds
10. **Substitution reactions** occur with saturated compounds

16. Real-life Applications

Fuels

- **Natural gas:** Mainly methane
- **LPG:** Butane and propane
- **Petrol:** Mixture of hydrocarbons
- **Ethanol:** Biofuel additive

Plastics

- **Polyethene:** From ethene
- **PVC:** From chloroethene
- **Polystyrene:** From styrene

Medicines

- **Ethanol:** Antiseptic
- **Ethanoic acid:** In aspirin synthesis
- **Various organic compounds:** Drug molecules

Food Industry

- **Ethanoic acid:** Vinegar
- **Ethanol:** In food flavoring
- **Esters:** Artificial flavors and fragrances

These comprehensive notes cover all essential topics in Carbon and its Compounds for Class 10 Science. Focus on understanding functional groups, chemical reactions, and nomenclature for better exam preparation.