📘 Chapter 4: Carbon and Its Compounds

Carbon is a unique element. It forms millions of compounds due to its versatile bonding properties. In this chapter, we'll explore why carbon is special, what types of compounds it forms, and how these compounds behave.

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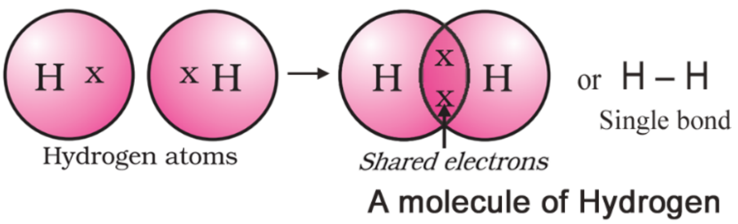
🔷 4.1 Bonding in Carbon – The Covalent Bond

📘 **Definition:**
A covalent bond is a bond formed when two atoms share electrons to complete their outer shells.

Carbon has four electrons in its outer shell (electronic configuration: 2,4).
It can neither gain nor lose four electrons easily, so it shares electrons with other atoms to form covalent bonds.

Types of covalent bonds:

- **Single bond:** One pair of electrons shared (e.g., H2, CH4)
- **Double bond:** Two pairs shared (e.g., O2, CO2)
- **Triple bond:** Three pairs shared (e.g., N2, C2H2)



📷 *Fig. 4.1 – Show electron dot structures of H2*

🧪 Properties of covalent compounds:

- Usually exist as gases, liquids or soft solids
- Have low melting and boiling points
- Do not conduct electricity (no ions present)

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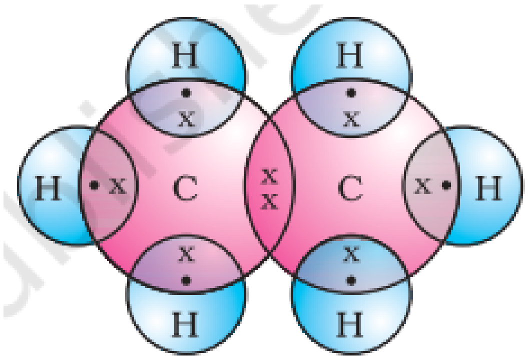
🔷 4.2 The Versatile Nature of Carbon

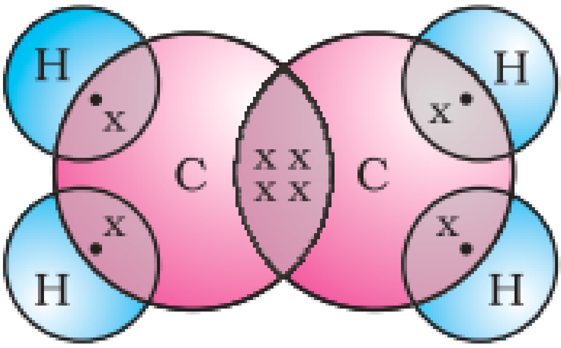
Carbon shows two key properties:

1. **Catenation** – Ability to form long chains, branched chains and rings with other carbon atoms.
2. **Tetravalency** – Carbon forms four covalent bonds with other atoms (e.g., H, O, N, Cl).

📘 Example:
Methane (CH_4), Ethane (C_2H_6), Ethene (C_2H_4), Ethyne (C_2H_2)



📷 *Fig. 4.6 – Open and closed carbon chains*



📷 *Fig. 4.7 – Structure of unsaturated hydrocarbons*

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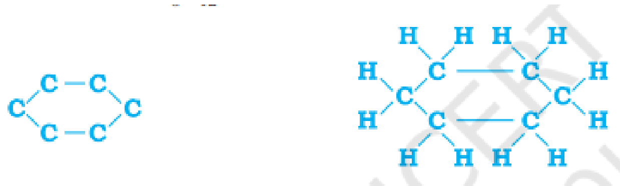
🔷 4.2.1 Chains, Branches and Rings

Carbon forms:

- Straight chains (e.g., Butane)
- Branched chains (e.g., Isobutane)
- Rings (e.g., Cyclohexane, Benzene)

Figure 4.8 *(a) Two possible carbon-skeletons*

Figure 4.8 *(b) Complete molecules for two structures with formula* C_4H_{10}



(a) (b)

Figure 4.9 Structure of cyclohexane (a) carbon skeleton (b) complete molecule

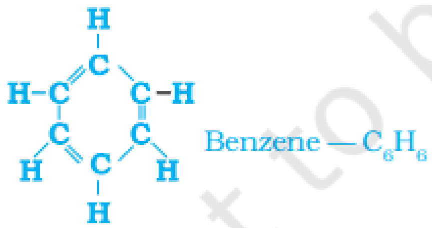


Figure 4.10 Structure of benzene

📘 Isomerism:

Compounds with the same molecular formula but different structural arrangement.
Example: Butane (C4H10) and Isobutane are isomers.

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🔷 4.2.2 Functional Groups

📘 Definition:

A functional group is an atom or group of atoms that determines the chemical properties of an organic compound.

Some common functional groups:

Functional Group	Symbol	Example
Alcohol	−OH	Ethanol
Aldehyde	−CHO	Ethanal
Ketone	−CO−	Propanone
Carboxylic Acid	−COOH	Ethanoic Acid
Halogen	−Cl, −Br	Chloroethane

📷 Table 4.3 – List of functional groups

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🔷 4.2.3 Homologous Series

📘 Definition:
A series of compounds with the same functional group, similar chemical properties, and each successive member differs by −CH2− unit.

Examples:

- Methane (CH4)
- Ethane (C2H6)
- Propane (C3H8)

Each member has a regular molecular formula and shows a gradual increase in physical properties like boiling point.

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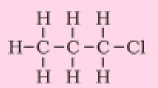
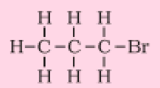
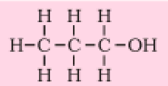
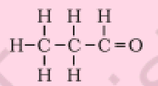
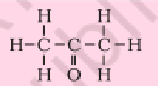
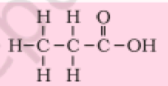
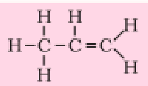
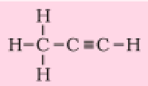
🔷 4.2.4 Nomenclature of Organic Compounds

Naming follows **IUPAC rules:**

- Identify the longest carbon chain.
- Number the chain from the end nearest to the functional group.
- Use appropriate prefix/suffix.

Class of compounds	Prefix/Suffix	Example	
1. Halo alkane	Prefix-chloro, bromo, etc.		Chloropropane
			Bromopropane
2. Alcohol	Suffix - ol		Propanol
3. Aldehyde	Suffix - al		Propanal
4. Ketone	Suffix - one		Propanone
5. Carboxylic acid	Suffix - oic acid		Propanoic acid
6. Alkenes	Suffix - ene		Propene
7. Alkynes	Suffix - yne		Propyne

📷 *Table 4.4 – Rules of IUPAC naming with examples*

Example: CH3CH2CH2OH → Propanol

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🔷 4.3 Chemical Properties of Carbon Compounds

🧪 **Activity 4.3** – Observing Flame of Carbon Compounds

Take samples of naphthalene, camphor, and alcohol.
Burn each and observe the color of the flame and smoke.
Hold a metal plate above the flame.

Observation:

- Yellow, sooty flame = incomplete combustion (presence of carbon)
- A clean blue flame = complete combustion (e.g., alcohol)
- Black mark on metal plate indicates unburnt carbon

Conclusion: Type of flame tells us about the carbon content and combustion.

🧪 **Activity 4.4** – Comparing Yellow and Blue Flame

Use a Bunsen burner:

- Close air hole → yellow sooty flame
- Open air hole → blue clean flame

Conclusion:
Incomplete combustion (less oxygen) gives yellow flame; complete combustion (more oxygen) gives blue flame.

🧪 **Activity 4.5** – Oxidation of Ethanol

Add ethanol to a test tube, heat in a water bath, and add potassium permanganate dropwise.

Observation:

- Pink color of KMnO4 disappears → ethanol is oxidized to ethanoic acid

Conclusion: KMnO4 acts as an oxidising agent.

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🔷 4.3.1 Addition and Substitution Reactions

Addition Reaction:

- Hydrogen is added to an unsaturated compound (alkene or alkyne) in the presence of a catalyst (Ni/Pd).
- Example: Ethene + H2 → Ethane

📘 Used in hydrogenation of vegetable oils (to make margarine)

Substitution Reaction:

- One atom replaces another in a compound.
- Example: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ (in sunlight)

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🔷 4.4 Some Important Carbon Compounds

🔹 Ethanol (C_2H_5OH)

Properties:

- Liquid, soluble in water, used in medicines and perfumes
- Good solvent and volatile

🧪 **Activity 4.6** – Reaction of Ethanol with Sodium

Add a small piece of sodium to ethanol in a test tube.

Observation:

- Bubbles of hydrogen gas form.
- A ‘pop’ sound occurs when gas is tested with a burning splint.

Equation:
$2Na + 2C_2H_5OH \rightarrow 2C_2H_5ONa + H_2$

📘 Ethanol is a weak acid – reacts slowly with sodium.

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🧪 **Activity 4.7** – Comparing Strength of Acids

Test pH of HCl and acetic acid using universal indicator.

Observation:

- HCl has lower pH → stronger acid
- Acetic acid has pH closer to 5 → weaker acid

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🔹 Ethanoic Acid (CH_3COOH)

Properties:

- Sour-smelling liquid
- Commonly called acetic acid
- 5–8% solution in water = vinegar
- Melting point = 290 K → becomes solid in winter (called glacial acetic acid)

🧪 **Activity 4.8 – Esterification**

Mix ethanol and ethanoic acid with a few drops of concentrated H_2SO_4. Warm in water bath.

Observation:

- Fruity smell appears → formation of ester

Equation:
$CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_5 + H_2O$

🧪 **Activity 4.9** – Reaction with Sodium Bicarbonate

Add sodium bicarbonate to ethanoic acid in a test tube and pass gas through lime water.

Observation:

- CO_2 is released → turns lime water milky

Equation:
$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$

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🔷 4.5 Soaps and Detergents

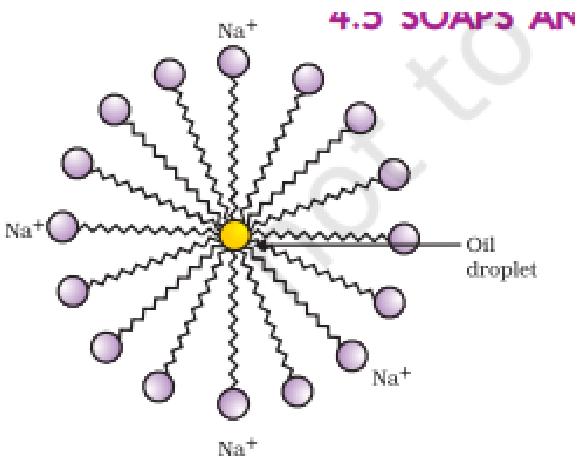
📘 Soaps are sodium/potassium salts of long-chain carboxylic acids.

🧪 **Activity 4.10** – Soap Action on Oil

Add soap to a mixture of oil and water, then shake.

Observation:

- Oil is emulsified → forms micelles (soap molecules trap oil particles)



📷 *Fig. 4.12 – Micelle structure*

🧪 **Activity 4.11** – Soap with Hard Water

Shake soap solution in hard water.

Observation:

- Less foam, white scum forms (due to calcium/magnesium ions)

🧪 **Activity 4.12** – Comparing Soap and Detergent

Repeat same with detergent in hard water.

Observation:

- Detergent forms foam easily → works better in hard water

📘 **Detergents:** Synthetic substances that clean even in hard water