9. Carbon Compounds

- The bonds that are formed by sharing electrons are known as **covalent bonds**. Covalently bonded molecules have strong intermolecular forces, but intramolecular forces are weak.
- Carbon has four valence electrons and requires four more electrons to complete its octet. Therefore, it is capable of bonding with four other atoms of carbon or atoms of other elements having a valency of 1.
- Some properties of covalent compounds are:
    - Covalent compounds are non- conductors of electricity.
    - They also have low melting and boiling points.
    - These compounds mostly exist as liquids or gases at room temperature.
- Polar covalent compounds: A covalent bond formed between two different atoms, with different electronegativities is known as **polar covalent bond.** For example, hydrogen chloride molecule
- **$H^{\delta+}$----$Cl^{\delta-}$**
- Non-polar covalent compounds: A covalent bond formed between two like atoms, is known as **Non-polar bond**. For example, hydrogen molecule
- **H------H**
- **Cordinate bond**: It is formed when the shared pair of electrons is provided by one of the two atoms and shared by both.
- Conditions for formation of cordinate bond:
    - Presence of at least one lone pair of electrons on any of the two atoms. This atom acts like a donor.
    - Shortage of a lone pair of electron on the second atom. This atom acts like an acceptor.

Catenation

- Catenation is the ability of an element to combine with itself through covalent bonds.
- Carbon shows extensive catenation, giving rise to large number of compounds.
- It can form strong single, double, and triple bonds with other atoms of carbons. Carbon can combine with itself to form chain, branched, and ring structures.

- **Covalent bonds**
- The bonds formed by the sharing of electrons are known as covalent bonds.
- In covalent bonding, both the atoms (that are participating in the bonding) share electrons, i.e., the shared electrons belong to both the atoms.
- Carbon contains four electrons in its valence shell. It always forms covalent bonds as it is difficult for it to lose or gain four electrons in order to complete its octet.

Classification of hydrocarbons based upon the carbon chain:

1. Open chain compounds

2. Ring or cyclic compounds

Classification of hydrocarbons based upon the nature of bonds:

1. Saturated or single bond compounds

2. Unsaturated or multiple bond compounds

I. Open chain hydrocarbons - An open chain is an arrangement of atoms that does not form a ring.

(i) **Saturated open chain hydrocarbon –** These are the hydrocarbon which contain only single bonds.

For example: Butane

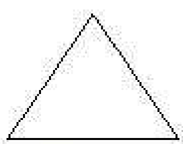
Bond line structure of butane

(ii) **Unsaturated open chain hydrocarbon** – These are the hydrocarbons which contain only double or triple bonds.
For example: 2-Butene

Bond line structure of 2-Butene

II. Closed Chain Hydrocarbons – These are the hydrocarbons which contain closed chain of carbon atoms. They are also known as cyclo hydrocarbons.

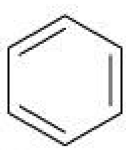
For example: Cyclopropane



Bond line structure of cyclopropane

III. Aromatic Compounds- Those are the organic compounds which contain at least one benzene ring in them. Aromatic compounds have alternate single and double bonds.

For example: Benzene



Benzene

- **Aliphatic compounds**
  - Organic compounds that have a straight chain or branched chain structures.
  - Example, methane, ethane, propane, 2-methylpropane etc.
  - They are classified as:
    - Alkanes (contain only single bonds): General molecular formula is $C_nH_{(2n+2)}$ where, n = number of carbon atoms.
    - Alkenes (contain atleast one double bond): General molecular formula is C_nH_{2n} where, n = number of carbon atoms.

        - Alkynes (contains atleast one triple bond): General molecular formula is C_nH_{2n-2} where, n = number of carbon atoms.
- **Alicyclic Saturated Hydrocarbons:**
    - Saturated organic compounds in which carbon atoms form a closed chain.
- **Aromatic Compounds**
    - Organic compounds that contain a ring system and have characteristic odour.
    - First member is Benzene.
- **Structural Isomerism**
    - Organic compounds which have same chemical formula but differ in their structures are known as isomers and this phenomenon is known as isomerism.
    - For example, 2-methylpropane is the isomer of n-butane.
    - Types of structure isomerism:
        - Chain/ skeletal/ nuclear isomerism: difference in the structure of the carbon chain that forms the nucleus of the molecule
        - Position isomerism: difference in the position of the functional group, the carbon–carbon multiple bonds or the substituent group
        - Functional group isomerism: presence of different functional groups
        - Metamerism: difference in the number of carbon atoms on either side of the functional group
- **Functional groups**
    - Carbon also forms covalent bonds with oxygen, nitrogen, and sulphur atoms.
    - Presence of any of these elements in a compound confers specific properties to the compound.
    - A group of atoms that imparts specific properties to hydrocarbons is called a functional group.
    - Some functional groups in carbon compounds are shown in the given table.

Hetero atom	Name of functional group	Formula of functional group
Chlorine/Bromine	Halo- (Chloro/Bromo)	–Cl, –Br
Oxygen	Alcohol	–OH
	Aldehyde	–CHO
	Ketone	>C=O
	Carboxylic acid	–COOH

- **Homologous series**
    - A homologous series is a series of carbon compounds having different numbers of carbon atoms, but containing the same functional group.

- **Nomenclature of organic compounds**
- **In IUPAC (International Union of Pure and Applied Chemistry)** system of nomenclature, the names are correlated with the structures such that the learner can deduce the structure from the name.
- Before the IUPAC system of nomenclature, organic compounds were assigned **trivial** or common names based on their origin or certain properties.
- A series of organic compounds containing a particular characteristic group is called a homologous group.
- While naming hydrocarbons, the first part of the name, called the root name, represents the number of carbon atoms and the last three letters represent the homologous series to which the alkane belongs.

1. **Alkanes:** General formula C_nH_{2n+2}, Suffix-*ane*
2. **Alkenes:** General formula C_nH_{2n}, Suffix -*ene*
3. **Alkynes:** General formula C_nH_{2n-2}, Suffix -*yne*

4. **Alkyl halides:** General formula $C_nH_{2n+1}X$, Prefix *halo-*
5. **Alcohols:** General formula $C_nH_{2n+1}OH$, Suffix -*ol*
6. **Aldehydes:** General formula $C_nH_{2n+1}CHO$, Suffix -*al*
7. **Carboxylic acid:** General formula $C_nH_{2n+1}COOH$, Suffix -*oic acid*

- A systematic name of an organic compound is generally derived by identifying the parent hydrocarbon and the functional group(s) attached to it.
- Functional groups are structural units within organic compounds that are defined by specific bonding arrangements between specific atoms.
- To name a compound:

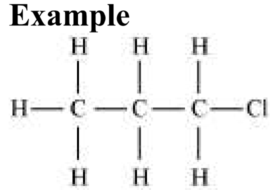
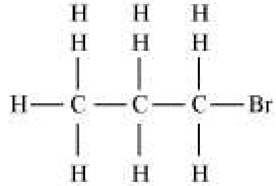
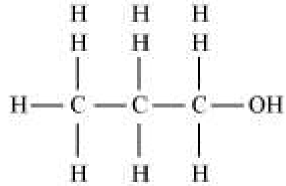
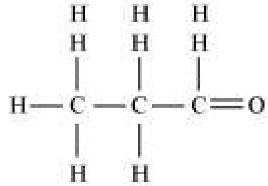
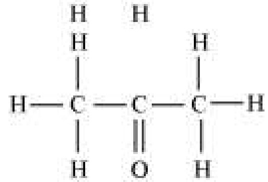
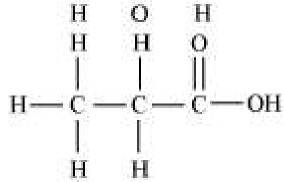
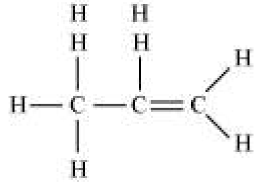
Step – I: Select the longest carbon chain.

Step – II: Assign lowest number to the side chain.

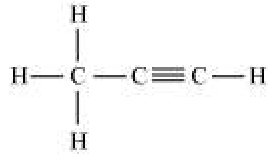
Step-III: Arrangement of prefixes

Step-IV: Lowest number for functional group

- The nomenclature of organic compounds is done by using a set of rules. Names of some common compounds are shown in the given table.

Functional group	**Prefix/Suffix**	**Example**
1. Halogen	Prefix: chloro, bromo, etc.	 
2. Alcohol	Suffix: -ol	
3. Aldehyde	Suffix: -al	
4. Ketone	Suffix: -one	
5. Carboxylic acid	Suffix: -oic acid	
6. Double bond (alkenes)	Suffix: -ene	

7. Triple bond (alkynes) Suffix: -yne



- Using the IUPAC of an organic compound, it's structure can be determined. The following rules help in accomplishing the task:

Step − I: Identify the root word. It forms the carbon skeleton in the structure.

Step − II: Write the number of carbon atoms as per the root word and number them from any end.

Step − III: As per the suffix in the name, ascertain the type of bond present in the compound. If any multiple bond is present, place it between the carbon atoms as stated in the IUPAC name.

Step − IV: Place the substituents at the carbon atoms mentioned in the IUPAC name.

Step − V: Place the functional group at the designated carbon atom.

Step − VI: Complete the valencies of the remaining carbon atoms by attaching hydrogen atoms.

- **Chemical properties of carbon compounds**
    - **Combustion reaction**:
    - Carbon burns in air to form carbon dioxide and hydrocarbons burn in air to give carbon dioxide and water. Heat and light are also released in these processes.

$$C + O_2 \rightarrow CO_2$$
$$CH_4 + O_2 \rightarrow CO_2 + H_2O + \text{Heat and light}$$
$$CH_3CH_2OH + O_2 \rightarrow CO_2 + H_2O + \text{Heat and light}$$

    - **Oxidation reaction**:
- Combustion of carbon to form carbon dioxide is an oxidation reaction.
- When alcohols are oxidised, carboxylic acids are obtained.

$$CH_3CH_2OH \xrightarrow[\text{Heat}]{\text{Alkaline } KMnO_4} CH_3COOH$$

- **Addition reaction**:
    - Unsaturated hydrocarbons yield saturated hydrocarbons when reacted with hydrogen in the presence of catalysts.

$$RCH = CHR \xrightarrow[H_2]{\text{Nickel catalyst}} RCH_2 - CH_2R$$

- **Substitution reaction**:
    - Under specific conditions, hydrogen atoms present in hydrocarbons can be replaced by atoms of other elements like chlorine and bromine.

$$CH_4 + Cl_2 \xrightarrow{\text{in presence of sunlight}} CH_3Cl + HCl$$

- **Ethanol** (alcohol), CH_3CH_2OH:
    - Liquid at room temperature
    - It is a good solvent
    - Soluble in water in all proportions

- Chemical properties of ethanol

$$2Na + 2CH_3CH_2OH \rightarrow 2CH_3CH_2O^-Na^+ + H_2$$

Sodium ethoxide

$$CH_3CH_2OH \xrightarrow[H_2SO_4]{\text{Hot conc.}} CH_2 = CH_2 + H_2O$$

Ethene

Acetic acid

- Common name of ethanoic acid (CH_3COOH).
- Its dilute solution in water is known as vinegar.
- Preparation of acetic acid is done by the following methods:
    - Oxidation of ethanol or ethanal (acetaldehyde) using acidified potassium dichromate solution
    - From acetylene using concentrated H_2SO_4 and $HgSO_4$
    - From catalytic oxidation of ethanol over platinum rod
- Properties of acetic acid are as follows:
    - It is a colourless, pungent smelling liquid, miscible with water.
    - It is a weak acid.
    - The reaction of a carboxylic acid with an alcohol to form an ester is known as **esterification reaction**.
    - Esters react in the presence of an acid or a base to give back alcohol and carboxylic acid. This reaction is used in the preparation of soaps and is known as **saponification reaction.**
    - Ethanoic acid reacts with sodium hydroxide to form a salt, sodium ethanoate, and water.
    - Carbonates and bicarbonates are also basic in nature and react with ethanoic acid to form salt, water, and carbon dioxide.
    - Ethanoic acid reacts with phosphorous compounds like chloride and oxide to form corresponding acid derivative.
- **Uses**:
    - manufacture of polyvinyl acetate, cellulose acetate and vinegar.
    - as organic solvent.

1. Polymers are giant molecules that are formed by addition of small molecules. The process of formation of polymers is known as **polymerization**.

2. The repeating units of a polymer are called monomers.

3. For example, the repeating unit of polythene is ethene; polyvinyl chloride is vinyl chloride and polystyrene is styrene.Varieties of polymers are used for various purposes.

(i) Polythene is used in making carry bags and plastic films.

(ii) Polyvinyl chloride (PVC) is used in making electric cables, pipes, waterproof sheets.

(iii) Polystyrene is used for making disposable cutlery, outside housing for TV and computer’s cabinet.