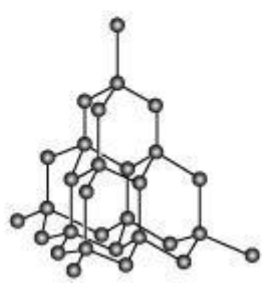
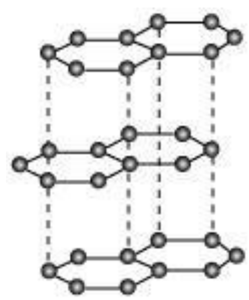
Carbon and its Compounds

- **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.

- Allotropes of Carbon
  - Allotropes have different appearances and physical properties, but chemically they are the same.
  - There are three allotropes of carbon: diamond, graphite, and buckminsterfullerene.



Diamond



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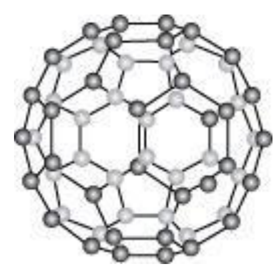


Buckminsterfullerene

Amorphous Solid:

- An amorphous solid is a non-crystalline solid with no well-defined ordered structure.
- Amorphous forms of carbon are: Charcoal, Lampblack or soot; Coal; Coke

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.

Hydrocarbons

- The compounds made up of only carbon and hydrogen are called hydrocarbons.
- The compounds of carbon that contain only single bonds among carbon atoms are called saturated compounds
- Compounds containing double and triple bonds among carbon atoms are called unsaturated compounds.

- If the hydrocarbons are saturated (like methane and ethane), then they are called alkanes; if they are unsaturated, then they are alkenes (containing double bonds) and alkynes (containing triple bonds).

- **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.

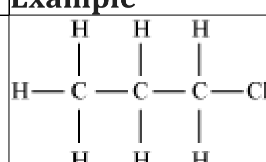
- **Nomenclature of organic compounds**
- **In IUPAC (International Union of Pure and Applied Chemistry)** system of nomenclature, the names are correlated with the structures such that the learner can deduce the structure from the name.
- Before the IUPAC system of nomenclature, organic compounds were 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.

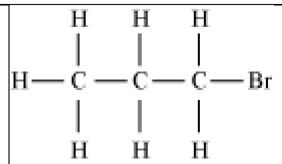
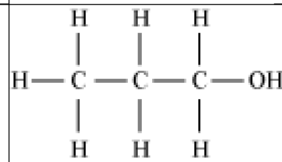
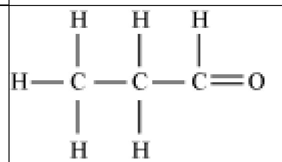
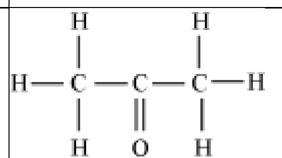
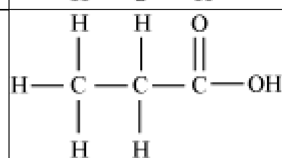
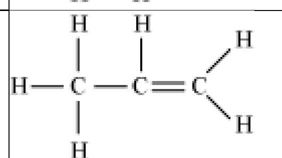
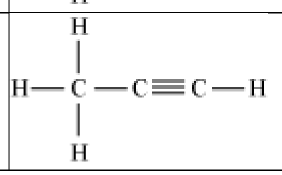
1. **Alkanes:** General formula C_nH_{2n+2}, Suffix-*ane*
2. **Alkenes:** General formula C_nH_{2n}, Suffix -*ene*
3. **Alkynes:** General formula C_nH_{2n-2}, Suffix -*yne*
4. **Alkyl halides:** General formula $C_nH_{2n+1}X$, Prefix *halo-*
5. **Alcohols:** General formula $C_nH_{2n+1}OH$, Suffix -*ol*
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.

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

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  - **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.

Preparation of soaps and detergents:

- **Soaps:** Prepared by reacting oil/fats with sodium hydroxide, then boiling the solution and adding sodium chloride to obtain soap.
- **Detergents:** Prepared by treating hydrocarbons obtained after refining of petroleum with concentrated sulphuric acid followed by sodium hydroxide solution.

Cleansing action of soaps and detergents

- The two ends of molecules of soaps and detergents are different. Their one end is hydrophilic (the cationic part) and the other is hydrophobic (the hydrocarbon chain part).
- When soap molecules are present in water, the molecules arrange themselves in the form of a cluster called a micelle.
- Soap does not work properly when water is hard. This is primarily because hard water contains salts of calcium and magnesium. When soap is added to hard water, it reacts with these salts to form an insoluble substance called **scum.**

Advantages of detergents over soaps

- Detergents clean efficiently in hard water whereas soaps are rendered inactive in hard water.
- Detergents are more soluble in water than soaps.
- Detergents have strong cleansing action than that of soaps.
- Detergents can work well in acidic medium, whereas soaps do not work in acidic medium.