

Organic Chemistry

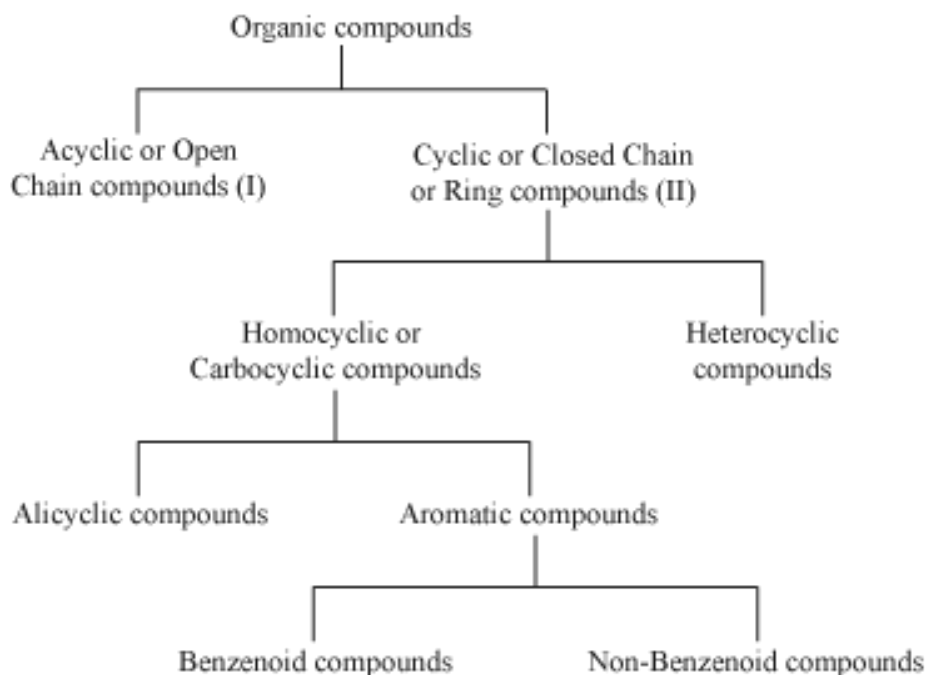
- Branch of chemistry dedicated only to the study of carbon and its compounds is known as **organic chemistry**.
- Carbon has a unique tendency of catenation. It binds with itself via a series of covalent bonds. This is the basis of organic chemistry.
- The bonds that are formed by sharing electrons are known as covalent bonds.

Characteristics of organic compounds are:

- They are covalent compounds of carbon.
- They can exist in all three states i.e., solid, liquid, and gas.
- They are soluble in organic solvents.
- They are poor conductors of electricity.

Organic compounds can be classified into the following categories.

- Open chain or aliphatic compounds
- Closed chain or cyclic compounds
- Carbocyclic or homocyclic compounds have ring comprising only of carbon atoms.
- Heterocyclic compounds contain other elements besides carbon in the ring.



- Acyclic or open chain compounds consist of straight or branched chain compounds.
- Alicyclic or closed chain or ring compounds contain carbon atoms joined in the form of ring (homocyclic). In some rings (heterocyclic), atoms other than carbon are present.
- Benzenoid aromatic compounds (include benzene and other related compounds)
- Non-benzenoid compounds (do not contain benzene ring)
- Functional group: An atom or group of atoms joined in a specific manner which is responsible for the characteristic chemical properties of the organic compound. For example, alcohol, aldehyde etc.
- Homologous series: A group or a series of organic compounds each containing a characteristic functional group. Successive members differ from each other in molecular formula by a $-\text{CH}_2$ unit.
- **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
	Alcohol	–OH
Oxygen	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.

Alkanes:

- General formula is C_nH_{2n+2} .
- Occurrence:
 - Methane is the main constituent of marsh gas.
 - Methane is exhaled by animals that feed on food containing cellulose.
 - Methane is found in the intestinal gas of humans and animals.
 - Methane is found in cavities in coal.
- Prepared by:
 - Reduction of unsaturated hydrocarbons
 - Reduction of alkyl halides
 - Wurtz reaction
 - Decarboxylation reaction
 - Kolbe's electrolysis
- Properties
 - Non-polar, colourless and odourless
 - Hydrophobic
 - Combustion reaction produces carbon dioxide
 - Controlled oxidation converts them to alcohols, aldehydes or carboxylic acids
 - Undergo isomerisation in the presence of $AlCl_3$ and HCl
 - Aromatization reaction takes place at 773 K at 10–20 atmospheric pressure in the presence of the oxides of V, Mo, or Cr supported over alumina
 - On heating to a higher temperature, higher alkanes decompose into lower alkanes or alkenes (**Pyrolysis and cracking**)
 - Alkyl halides can be prepared by substitution reaction of alkanes
- Uses:
 - Preparation of acetylene, formaldehyde, methanol, chloromethane and tetrachloro methane
 - Domestic fuel
 - Preparation of a useful solvent in dry cleaning

Alkenes:

- General formula is C_nH_{2n} .
- Alkenes are unsaturated hydrocarbons containing at least one double bond.

- Carbon-carbon double bond in alkenes consist of one sigma bond and one pi bond.
- **Prepared by:**
 - Partial reduction of alkynes
 - Dehydrohalogenation by heating alkyl halides with alcoholic KOH
 - Dehalogenation by reacting vicinal dihalides with Zn metal
 - Dehydration of alcohols using
 - Concentrated H_2SO_4
 - Heated Al_2O_3
- **Properties:**
 - Colourless, odourless, insoluble in water and fairly soluble in non-polar solvents
 - Undergo addition reactions:
 - Addition of hydrogen to form alkanes
 - Addition of halogen to form dihalides
 - Addition of hydrogen halide to form alkyl halides
 - Addition of H_2SO_4
 - Addition of water
 - Oxidation of alkenes with
 - Baeyer's reagent converts them to vicinal glycols
 - Acidic KMnO_4 or acidic $\text{K}_2\text{Cr}_2\text{O}_7$ oxidises them to give ketones or acids (depending upon the nature of alkenes)
 - Undergoes ozonolysis to form aldehydes
 - Polymerises at high temperature in presence of suitable catalyst
 - Undergoes combustion to form a large amount of heat
- **Uses:**
 - Manufacture of synthetic chemicals, polythene, raw materials for detergents
 - For ripening of fruits
 - producing oxy-ethylene

Alkynes

- General formula is $\text{C}_n\text{H}_{2n-2}$
- They are named as the corresponding alkanes replacing 'ane' by the suffix 'yne'.
- Each carbon atom of ethyne has two *sp* hybridised orbitals.
- **Preparation of Ethynes**
 - From calcium carbide (CaC_2)
 - From vicinal dihalides
- **Properties**
 - Colourless, odourless, weakly polar
 - Immiscible in water
 - Hydrogen attached to triply bonded carbon atom is acidic
 - Undergoes addition reactions

- Addition of dihydrogen
 - Addition of halogens
 - Addition of hydrogen halides (HX; X = Cl, Br, I)
 - Addition of water
- Undergoes linear and cyclic polymerisation
- Shows oxidation reaction
- Undergoes ozonolysis to produce ozonides
- **Uses:**
 - Oxy-acetylene welding at very high temperatures
 - Illuminant in oxy-acetylene lamp
 - Ripening and preservation of fruits
 - Manufacture of several products like polymers. artificial rubber, oxalic acid, acetaldehyde, acetic acid, etc.

Methanol (CH₃OH)

- **Preparation**
 - Earlier produced by destructive distillation of wood
 - Nowadays produced by catalytic hydrogenation of carbon monoxide
- **Properties**
 - Colourless liquid
 - Boiling point = 337 K
 - Highly poisonous – Small quantities cause blindness and large quantities cause even death.
- **Uses**
 - As a solvent in paints and varnishes
 - In the preparation of formaldehyde (HCHO)

Ethanol (C₂H₅OH)

- Also known as spirit of wine and grain alcohol
- **Preparation**
 - By fermentation of molasses
 - By hydrolysis of alkyl halides with dilute hot alkali
 - By hydration of ethene using:
 - Concentrated H₂SO₄ at 80 °C and 30 atm
 - H₃PO₄ at 300 °C and 60 atm
- **Properties**
 - Colourless liquid
 - Boiling point = 351 K
 - Pleasant odour and inflammable
 - Very good organic solvent

- Reacts with sodium
- Undergoes dehydration to form corresponding alkene
- Combustion reaction produces carbon dioxide, water and heat
- Oxidised to corresponding aldehyde and carboxylic acid by acidified $K_2Cr_2O_7$
- Undergoes esterification reaction with carboxylic acids
- Reacts with phosphorous halide to form alkyl halide
- **Uses**
 - As a solvent in manufacture of paint and a number of carbon compounds
 - Denaturation of alcohol – Making commercial alcohol unfit for drinking by mixing compounds like copper sulphate, pyridine in it.
 - Denatured alcohol:
 - Addition of poisonous substances like pyridine, methyl alcohol to pure ethanol for making it unfit for consumption
 - Also called methylated spirit
 - Contains 5% methyl alcohol
 - Used for industrial purposes
 - Spurious alcohol:
 - Illicit liquor prepared by improper distillation
 - Contains large portions of methanol
 - Fatal for human consumption
 - Used as a solvent for paints and varnishes

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.