Organic Chemistry

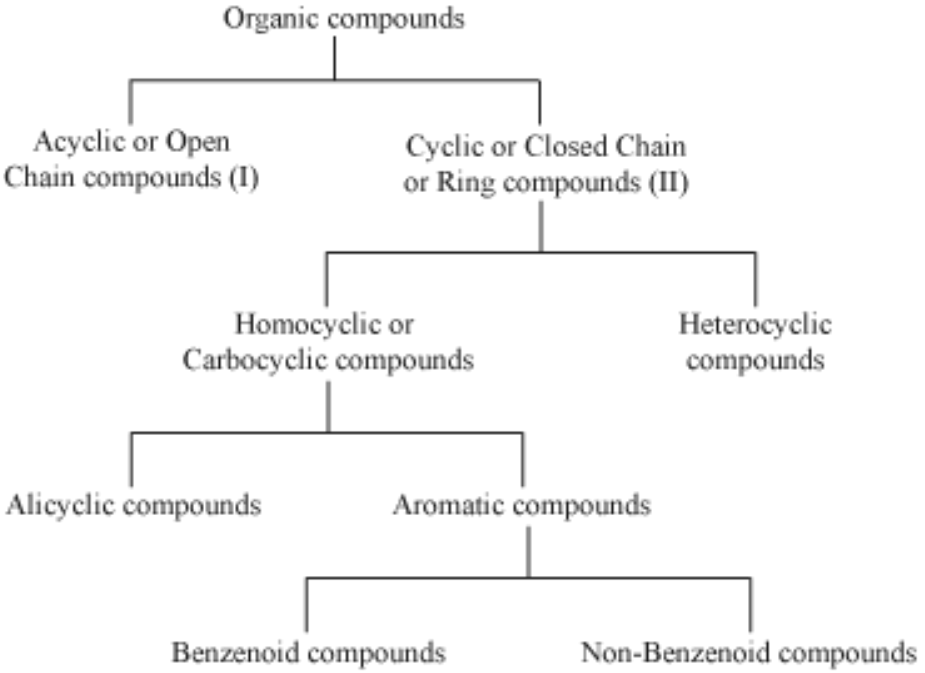
- Branch of chemistry dedicated only to the study of carbon and its compounds is known as **organic chemistry.**
- Carbon has a unique tendency of catenation. It binds with itself via a series of covalent bonds. This is the basis of organic chemistry.
- The bonds that are formed by sharing electrons 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 $-CH_2$ 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
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.

Alkanes:

- General formula is C_nH_{2n+2}.
- Occurence:
  - 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 acloholic 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 $K_2Cr_2O_7$ 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 ripeninng of fruits
  - producing oxy-ethylene

Alkynes

- General formula is CnH_{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
  - Immisicible 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 (CH_3OH)

- **Preparation**
    - Earlier produced by destructive distillation of wood
    - Nowdays 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 (C_2H_5OH)

- Also known as spirit of wine and grain alcohol
- **Preparation**
    - By fermentation of mollases
    - By hydrolysis of alkyl halides with dilute hot alkali
    - By hydration of ethene using:
    - Concentrated H_2SO_4 at 80 ^oC and 30 atm
    - H_3PO_4 at 300 ^oC 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 calles methylated spirit
        - Contains 5% methyl alcohol
        - Used for industrial purposes
    - Spurious alcohol:
        - Illicit liqour 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.