General Organic Chemistry

Organic Chemistry

The hydrides of carbon (hydrocarbons) and their derivatives are called **organic compounds.** The branch of chemistry which deals with these compounds is called **organic chemistry**.

Berzelius (1808) defined organic chemistry as the chemistry of substances found in living matter and gave the vital force theory. Synthesis of urea, the first organic compound synthesised in laboratory, by Wohler, gave death blow to the vital force theory.

$$(NH_4)_2SO_4 + 2KCNO \xrightarrow[-\,K_2SO_4]{} 2NH_4CNO \xrightarrow{\Delta} \underset{\text{urea}}{NH_2CONH_2}$$

Acetic acid is the first organic compound synthesised from its elements.

Reasons for Large Number of Organic Compounds

(a) **Catenation** It is the tendency of self combination and is maximum in carbon. A carbon atom can combine with other carbon atoms by single, double or triple bonds. Thus, it forms more compounds than the others.

(b) **Tetravalency and small size** Carbon being tetravalent, is capable of bonding with four other C-atoms or some other monovalent atoms. Carbon can form compound with oxygen, hydrogen, chlorine, sulphur, nitrogen and phosphorus. These compounds have specific properties depending upon the nature of the element or group attached with the carbon.
Furthermore, these compounds are exceptionally stable because of the small size of carbon.

General Characteristics of Organic Compounds

1. These are the compounds of carbon with H, O, N, S, P, F, Cl, Br and I.

2. These are generally found in living organisms.
   e.g. carbohydrates, proteins etc.
3. These may be gases, liquids or solids.
4. Being covalent in nature, these have low boiling point and melting point and soluble in organic solvents.
5. These are generally volatile and inflammable.
6. They do not conduct electricity because of the absence of free ions.
7. They posses distinct colour and odour.

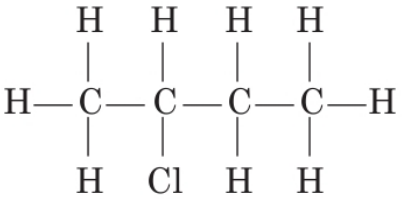
Representation of Different Formula

An organic compounds can be represented by the following ways :

1. Complete formula

In it, all the bonds present between any two atoms are shown clearly.

e.g.



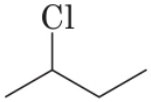
2. Condensed Formula

In it, all the bonds are not shown clearly.

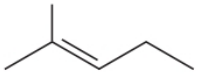
e.g. $CH_3\underset{\underset{Cl}{|}}{CH}CH_2CH_3$ or $CH_3CH(Cl)CH_2CH_3$

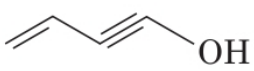
3. Bond Line Formula

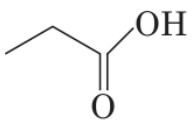
In it, every fold and free terminal represents a carbon and lines represent the bonds. e.g.



In such formulae, it is assumed that required number of H-atoms are present, **wherever**, they are necessary (to satisfy tetravalency of carbon), e.g.

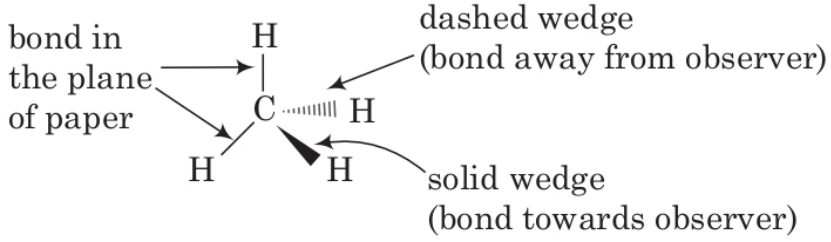
$CH_3—\underset{\underset{CH_3}{|}}{C}=CH—CH_2CH_3 \equiv$ 

$CH_2=CH—C\equiv C—OH \equiv$ 

$CH_3—CH_2—COOH \equiv$ 

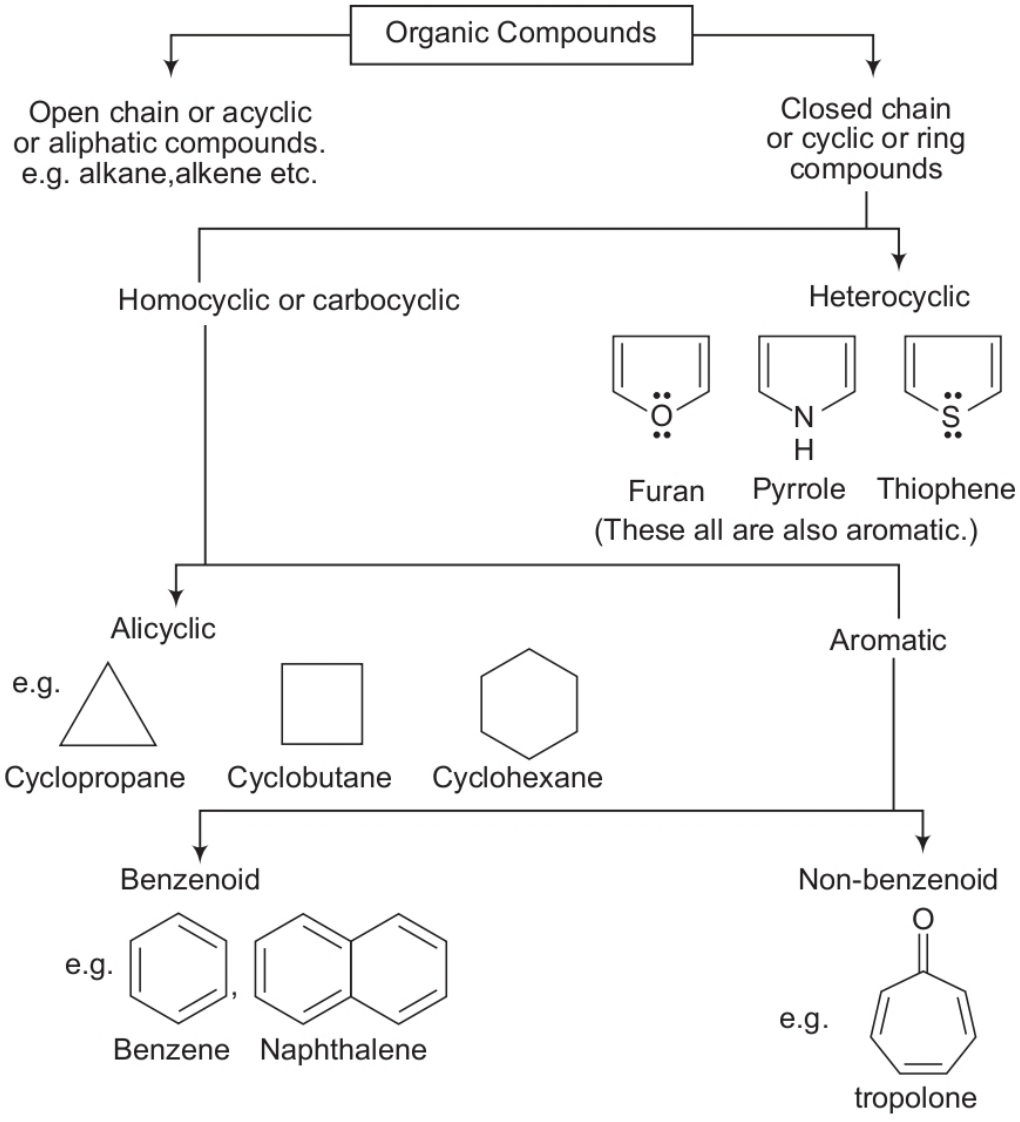
Three-dimensional Representation of Organic Molecule

The three-dimensional (3-D) structure of organic molecule can be represented on paper by using certain convention, e.g. by using solid (◄) and dashed (┈┈)wedge formula, the 3-D image of a molecule from a two-dimensional picture can be perceived. 3-D representation of methane molecule on paper has been shown below :



wedge-and-dash representation of CH_4.

Classification of Organic Compounds



Classification of Carbon Atoms

1. On the Basis of Number of C Attached

(i) **Primary carbon atom** When carbon atom is attached with one other carbon atom only, it is called primary or 1° carbon atom.

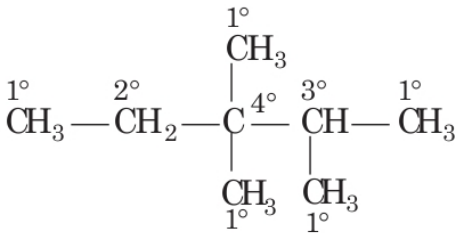
(ii) **Secondary carbon atom** When carbon atom is attached with two other carbon atoms, it is called secondary or 2°carbon atom.

(iii) **Tertiary carbon atom** When carbon atom is attached with three other carbon atoms, it is called tertiary or 3° carbon atom.

(iv) **Quaternary carbon atom** When carbon atom is attached with four other carbon atoms, it is called quaternary or 4° carbon atom.

Reactivity order of carbon atoms is as follows 3° > 2° > 1°.

e.g.



On the Basis of Position of Functional Group

(i) **α-carbon** Carbon which is directly attached to the functional group.

(ii) **β-carbon** Carbon which is directly attached to the α-carbon.

Classification of Hydrogen Atoms

1°-hydrogen (primary) attached to 1°-carbon.

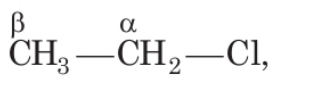
2°-hydrogen (secondary) attached to 2°-carbon.

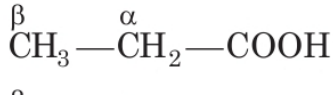
3°-hydrogen (tertiary) attached to 3°-carbon.

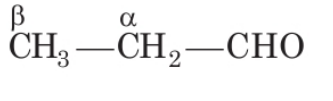
α-hydrogen(s) Hydrogens which are attached to α-carbon atom.

β-hydrogen(s) Hydrogens which are attached to β-carbon atom.

e.g.







Functional Group

The atom, e.g. —Cl, —Br etc., or group of atoms e.g. —COOH, —CHO, which is responsible for the chemical properties of the molecule, is called functional group.

Double and triple bonds are also functional groups.

$$R\text{—OH}$$

R is called alkyl group, it contains only single bond; alkenyl group contains double bond and alkynyl group contains triple bond.

Homologous Series

The series in which the molecular formula of adjacent members differ by a —CH_2 unit, is called **homologous series** and the individual members are called **homologues**. e.g. The homologous series of alkene group is

$$\left.\begin{array}{l} C_2H_4 \\ C_3H_6 \\ C_4H_8 \\ C_5H_{10} \end{array}\right\} \text{difference of } —CH_2 \text{ unit or 14 unit mass}$$

The general characteristics of this series are :

1. All the homologues contain same functional group. That's why their chemical properties are almost similar.
2. All the members of a series have same general formula, e.g.

Series	General formula
Alkanes	C_nH_{2n+2}
Alkenes	C_nH_{2n}
Alkynes	C_nH_{2n-2}
Alcohol and ether	$C_nH_{2n+2}O$
Aldehyde and ketone	$C_nH_{2n}O$
Acid and ester	$C_nH_{2n}O_2$

3. All the members can be prepared by almost similar methods.
4. With increase in the molecular weight of a series, the physical properties varies gradually.

Nomenclature of Organic Compounds

Trivial System

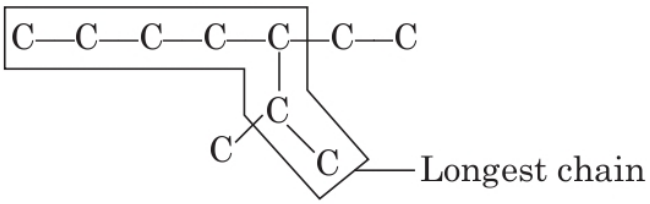
It is the oldest system in which names are derived from source or some property. These are mainly derived from Latin or Greek names. e.g. acetic acid (acetum = vinegar), oxalic acid (oxalus), malic acid (pyrus malus), citric acid (citrum), formic acid (obtained from red ant (formicus)].

IUPAC System

The IUPAC (International Union of Pure and Applied Chemistry) system, given in 1957, is superior and widely used. IUPAC amends these rules from time to time. Here, we are following the 1993 recommendations of IUPAC nomenclature. Following rules are used to write the IUPAC name of an organic compound.

Rule I

Longest chain rule The chain containing the principal functional group, secondary functional group and multiple bonds as many as possible is the longest possible chain. In the absence of functional group, secondary group and multiple bonds, the chain containing the maximum number of C-atoms will be the longest possible chain. e.g.



Choose the word root from the table given below for the longest possible chain.

Word Root for Carbon Chain

Chain length	Word root	Chain length	Word root
C_1	Meth-	C_7	Hept
C_2	Eth-	C_8	Oct
C_3	Prop-	C_9	Non
C_4	But-	C_{10}	Dec
C_5	Pent	C_{11}	Undec
C_6	Hex-	C_{12}	Dodec

Rule 2

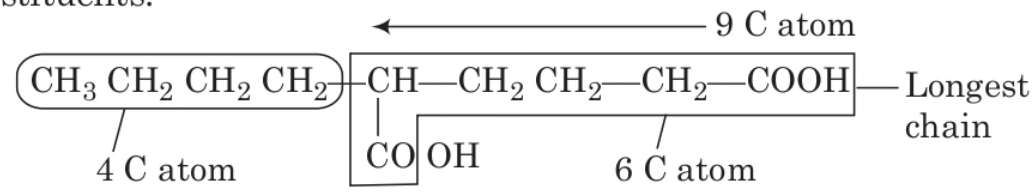
Lowest number rule Numbering is done in such a way so that

1. branching if present gets the lowest number.
2. the sum of numbers of side chain is lowest.
3. principal functional group gets the lowest number.

Select the principal functional group from the preference series :

$$-COOH > -SO_3H > -COOR > -COX > -CONH_2 > CN > -NC > -CHO > \diagup C{=}O > -OH > -SH > -NH_2 > -OR > -C(O)-C- > = > \equiv > NO_2 > X > R$$

Functional group other than the principal functional group are called substituents.



Rule 3.

Naming the prefixes and suffixes Prefix represents the substituent and suffix is used for principal functional group.

Primary prefixes are cyclo, bicyclo, di, tri, tetra, tries, tetrakis etc.

Primary suffix are ene, ane, or yne used for double, single and triple bonds respectively.

Substituent	Prefix	Substituent	Prefix
—F	Fluoro	—N=N—	diazo
—Cl	Chloro	—N=O	nitroso
—Br	Bromo	$-NO_2$	nitro

Secondary suffixes are tabulated below :

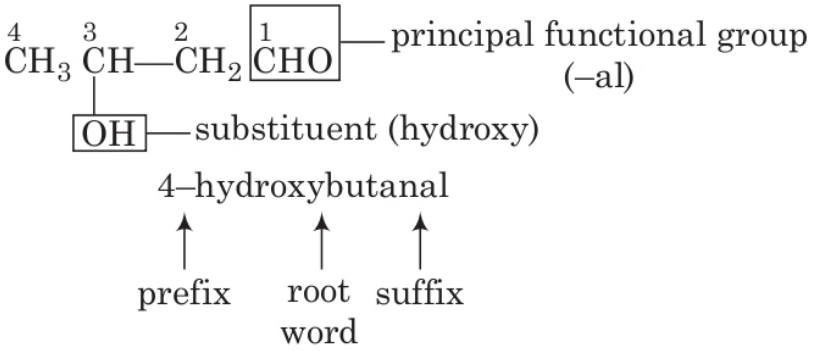
S. No.	Class	Formula	Prefix	Suffix
1.	Acid halides	$-\overset{\overset{O}{\|\|}}{C}-X$	halocarbonyl	—oyl halide —carbonyl halide
2.	Alcohols	—OH	hydroxy	—ol
3.	Aldehydes	—CHO	formyl	—al —carbaldehyde
4.	Ketones	$\diagup C{=}O$	oxo	—one

S. No.	Class	Formula	Prefix	Suffix
5.	Amides	—$CONH_2$	carbamoyl	—amide
6.	Amine	—NH_2	amino	—amine
7.	Carboxylic acid	—COOH	carboxy	—carboxylic acid
8.	Ester	—COO*R*	oxy carbonyl	—alkyl alkanoate
9.	Nitriles	—CN	cyano	—nitrile
10.	Sulphonic acid	—SO_2—OH	sulpho	—sulphonic acid

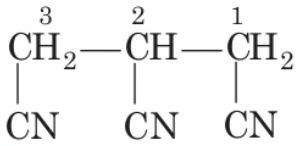
Hence, according to the rules, given above, the IUPAC name of a compound can be written as

Prefixes + root word + suffixes primary prefix + secondary prefix + root word + primary suffix + secondary suffix

e.g.



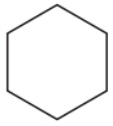
If more than two similar functional groups are present, all the groups are considered as substituent, e.g.



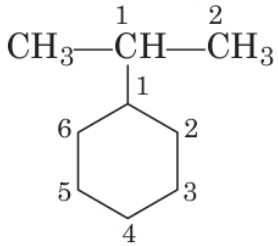
propane-1, 2, 3-cyanide

Naming Alicyclic Compounds

For alicyclic compounds, prefix cyclo is used e.g.

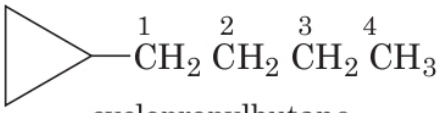


cyclohexane



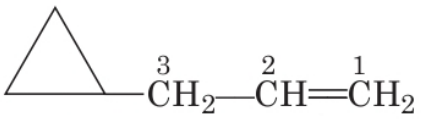
1-(1-methylethyl) cyclohexane

If the alkyl chain contains a greater number of C-atoms than the ring, the ring is designated as substituent, e.g.



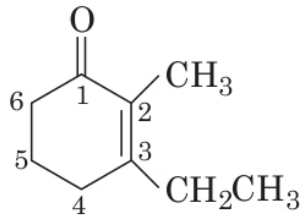
cyclopropylbutane

If side chain contains a multiple bond or a functional group, the ring is treated as a substituent e.g.



3-cyclo propylprop-1-ene

Other examples are :

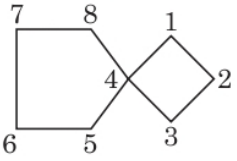


3-ethyl-2-methylcyclohex-2-en-1-one

Naming Spiro Compounds

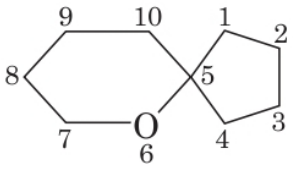
Prefix 'spiro' is used for the compounds in which one carbon is common between two rings :

Here, smaller ring is numbered first, e.g.



spiro [3.4] octane

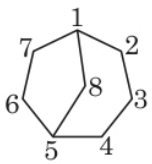
number of atoms in ring in ascending order



6-oxaspiro [4.5] decane

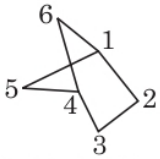
Naming Bicyclo Compounds

Prefix 'bicyclo' is used for such compounds, e.g.



bicyclo [3.2.1] octane

number of atoms in each ring in descending order



bicyclo [2.1.1] hexane

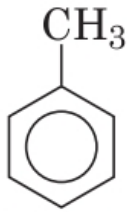
In bicyclo compounds, numbering is done first in larger ring, then in smaller ring.

Naming Aromatic Compounds

IUPAC accepted their common trivial names, e.g.

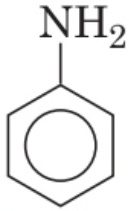
benzene

chlorobenzene



toluene

phenol

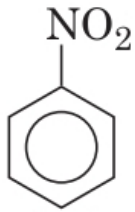


aniline

benzoic acid

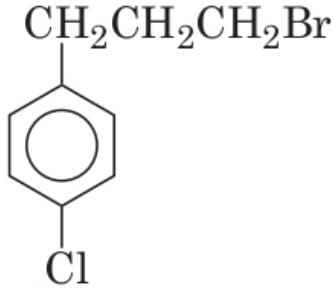
benzaldehyde

benzonitrile



nitrobenzene

1,4-dichlorobenzene



1-bromo-3-(4-chlorophenyl) propane