

Introduction to Organic Chemistry

Organic chemistry is the major branch of chemistry which deals with the scientific study of preparation, structure, properties, composition and reactions of carbon containing compounds. In organic chemistry, not only hydrocarbons are studied but also compounds in which carbon is bonded with any other atoms like oxygen, halogens, nitrogen, phosphorus and sulfur etc. Almost all organic compounds contain at least one carbon hydrogen bond (C-H) in it.

Origin of Organic Chemistry

The history of organic chemistry can be traced back to ancient times when the tribes extracted chemicals from plants and animals to treat their ailments. But they did not name it as organic chemistry. The records what they kept are useful in the development of modern organic chemistry.

In 1700s, the French noble man and chemist, *Antonie-Laurent De Lavoisier* showed that nearly all substances of plant origin are composed of carbon, hydrogen and oxygen. Organic compounds of animal's origin also consist of similar three elements but frequently contain nitrogen, phosphorous or sulphur either alone or in combination.

The German scientist *John Jakob Berzelius*, was the first scientist who defined organic chemistry as a branch of modern science in early 1800's. He had classified the chemical compounds into organic and inorganic compounds with the following definition.

Organic compounds: Compounds derived from living organisms were believed to contain an immeasurable vital force and the essence of life called organic compounds.

Inorganic compounds: Compounds derived from minerals and those lacking of that vital force were called inorganic compounds.

The Vital Force Theory "Essence of Life"

According to the *Berzelius* discovery, the chemists could create a life in the laboratory; they assumed that they could not create any compound with a vital force. This vital force theory put forwarded by *Berzelius* had no scientific background but held the field till 1828. A German chemist *Friedrich Wohler* synthesized an organic compound named urea by heating ammonium cyanate, a compound that did not come from a living organism.



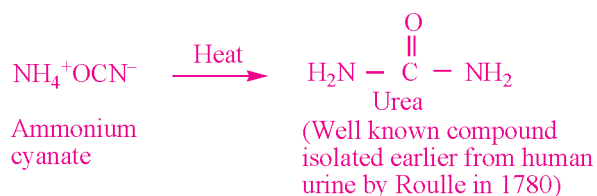
JOHN-JAKOB BERZELIUS (1779-1848)



A German scientist not only coined the term "inorganic and organic" but also invented the system of chemical symbols used even today. He discovered or purified the elements silicon, cerium, lithium, titanium, thorium and zirconium. He published the first list of accurate atomic weights and proposed the idea that atoms carry an electric charge.

For the first time an “organic compound” is obtained from something other than living system without the aid of any kind of vital force.

The synthesis of urea was indicated by the leading chemists of the day. The vital force concept (essence of life) did not die quickly. It was only after the synthesis of acetic acid by *Kolbe* in 1845 and the synthesis of methane in 1856 the belief in the essence of life theory was abandoned. Thus, we see that the vital force theory died only a lingering death.



FRIEDRICH-WOHLER (1800-1882)



A German chemist discovered the fact that two different chemicals could have the same molecular formula and also developed methods for purification of aluminium and beryllium “the most expensive metals on earth”.

Definition of Organic Chemistry

From the beginning of synthesis of urea, methane and acetic acid in the laboratory, chemists needed a new definition for organic compounds.

Organic compounds are now defined as “compounds that contain carbon”. Then the next question arises “Why is an entire branch of organic chemistry devoted to the study of carbon containing compounds? The so called organic compounds have been found to be mainly compounds of carbon and hydrogen (called hydrocarbons) and their derivatives. Finally, organic chemistry is defined today as “The chemistry of hydrocarbons and their derivatives”. There is no sharp line of demarcation between organic and inorganic chemistry, the difference between **organic and inorganic** compounds is still being retained as a matter of convenience than of principle.

Reasons for Treating Organic Chemistry as a Separate Branch of Chemistry

The following number of characteristics of organic compounds justifies the treatment of organic chemistry as a separate branch of chemistry.

- (i) **Large number or Catenation (making bond with all other atoms easily) property of carbon:** Compared with the compounds of other elements, the number of organic compounds is very large. About more than one million organic compounds are already known and more being added to the list everyday by chemists all over the world. Why are so many organic compounds present? What makes carbon so special? The answer is the position of carbon in the periodic table. In periodic table, carbon is present in the centre of the second row of elements. The atoms to the left of carbon have a tendency to give up electrons, whereas the atoms to the right of carbon have a tendency to accept electrons (Fig. 1.1).

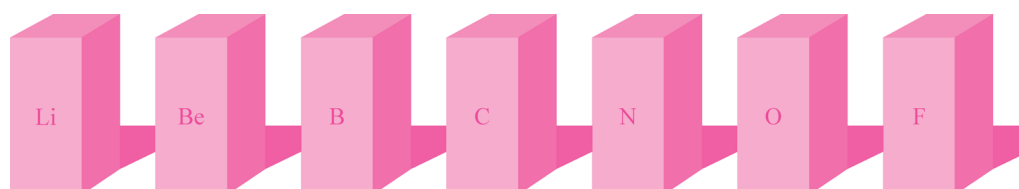


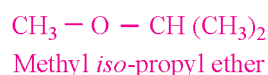
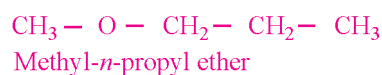
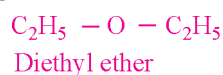
Figure 1.1 Shows the position of carbon atom in periodic table (second row elements).

Since carbon is in the middle, it neither readily gives up nor readily accepts electrons, instead it shares the electrons. Carbon not only can share the electrons with different kind of atoms, it can also share electrons with other carbon atoms which allow it to form the vast variety of chain like molecules. Because carbon can share electrons with atoms other than carbon also adds to the range of stable carbon containing compounds. Consequently it also forms millions of more stable compounds with various ranges of chemical properties by sharing its electrons.

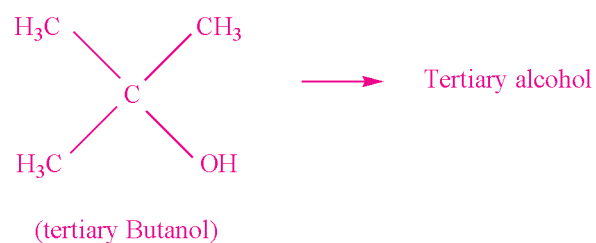
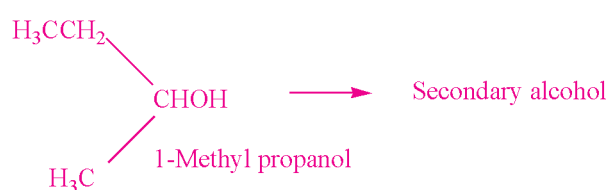
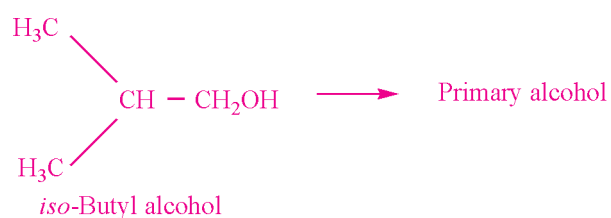
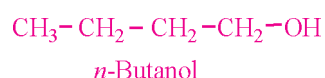
This peculiar property of carbon is known as *Catenation* (ability of carbon atom to make a bond with all atoms). It is not possible to add all these huge carbon compounds in the chapter on carbon in any textbook and hence organic compounds need to be studied separately.

- (ii) **Complexity of molecules:** Some types of organic molecules have more complex structures and possess high molecular weight than inorganic molecules. For example, molecular weight of proteins ranges from several thousands to million.
- (iii) **Isomerism:** Representation of more than one organic compound for the same molecular formula is called as isomers and this phenomenon is known as isomerism. For example, the molecular formula $C_4H_{10}O$ stands for three types of ether and four types of alcohol.

Different type of ethers



Different type of alcohols



All the above isomers possess different properties due to different arrangement of an atom. In contrast, in inorganic chemistry, one molecular formula stands for only one compound. For example H_2SO_4 indicates only sulphuric acid and nothing else (only a few inorganic complex compounds also show isomerism).

- (iv) **Polymerism:** When the molecular formula of one organic compound is a simple multiple of the other (*i.e.*, both of them have the same empirical formula), they exhibit polymerism.

For example: benzene exhibits polymerism with acetylene (Benzene is a polymer of acetylene)

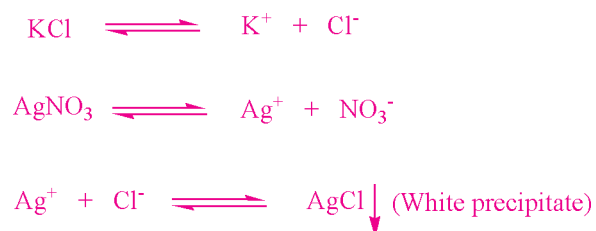


A large number of organic compounds exhibit polymerism but a very few inorganic compounds show polymerism.

- (v) **Non-ionic character of organic compounds:** Organic compounds have covalent bonds and therefore do not get ionize when dissolved in water.

For example: Chloroform (CHCl_3) is insoluble in water and does not give white precipitation with silver nitrate solution (a characteristic property of inorganic chloride salts).

On the other hand, the inorganic compounds usually ionize in water and therefore mainly all inorganic reactions undergo ionic reactions. For example; all chloride salts react with silver nitrate solution and produces white precipitate which is a characteristic reaction of chloride ions.



- (vi) **Comparative instability of organic compounds:** The covalent bond nature of organic compounds makes them more liable to heat and light. On heating the covalent bond, it easily undergoes decomposition. Hence all of the organic molecules possess low melting point and boiling point.

But all the inorganic compounds have ionic bonds which cannot be decomposed at low temperature. More amount of energy is needed for breaking the bond. Hence all inorganic compounds have high melting and boiling point.

- (vii) **Solubility:** Organic compounds, unlike inorganic compounds are mostly soluble in organic solvents such as alcohol, ether, acetone, benzene etc. and they are sparingly soluble (formation of weak hydrogen bond) or insoluble in water (lack of formation of hydrogen bond with water).
- (viii) **Homologues series:** Organic compounds are classified into families or groups called as homologues series. Different members belonging to a homologues series are known as homologues and they are characterized by the presence of a particular characteristic group so can be indicated by a general formula. The common difference between the consecutive members in the homologues series is CH_2 . These members possess similar chemical properties and regular gradation in their physical properties. They are prepared by general methods of preparation as described in the individual chapters.
- This property of organic compounds reduced the studies of over a million of organic compounds to few homologues series. Similar properties of different homologues are the properties of the functional group in each one of them.

- (ix) **Action of heat:** Most of the organic compounds burns in air to give carbon dioxide and water and some of them decompose on heating to leave a black residue (ash or charcoal). But generally inorganic compounds are stable towards heat.
- (x) **Structure:** The arrangement of atoms or structure in most of the organic molecules is well established. But it is more difficult to determine the structure of inorganic compounds. A comparatively very few of them have been completely worked out.
- (xi) **Origin:** Most of the organic compounds are obtained from animal or vegetable kingdom in comparison to the inorganic compounds which are obtained from mineral origin.
- (xii) **Rates of organic reactions:** Due to the reversibility and invariability accompanied by side reactions, most of the reactions between organic compounds are slow. It indicates the activity of molecules rather than ions. They rarely proceed to completion and their yield is generally low.

Rise of Organic Chemistry

After the various discoveries of *Wohler* (1828), *Kolbe* (1840) and *Berthelot* (1850's), chemists found that it was not the vital force which imparted uniqueness to organic chemistry rather a simple fact that organic compounds were all compounds of carbon. The perfection in technique of combustion analysis of carbon and oxygen gave new dimension to organic chemistry. Hence, the first time accurate formulae were available for a good number of fairly complicated organic compounds. Various theories were advanced in order to describe the complexities of substitution, isomerism etc.

Frankland, in 1852 discovered the concept of valence. In 1858 *Kekule & Cooper* proposed the tetravalency concept of carbon and its ability to link with each other. In 1858, *Cannizzaro* and *Avogadro* discovered a hypothesis for the determination of accurate molecular weight. Chemists started thinking about molecular structure and chemical bond related terms. *Kekule* introduced the idea about a bond between atoms.

Nowadays, organic chemistry has matured as a major scientific discipline. Over 95 % the known chemical compounds are organic in nature and roughly half of the present-day chemists are organic chemists. Rapid and fast growth in the field of organic chemistry is due to the fact that organic chemical industry contributes a major role in the world economy and organic compounds are literally the “**stuff of life**”.

Need for Studying Organic Chemistry

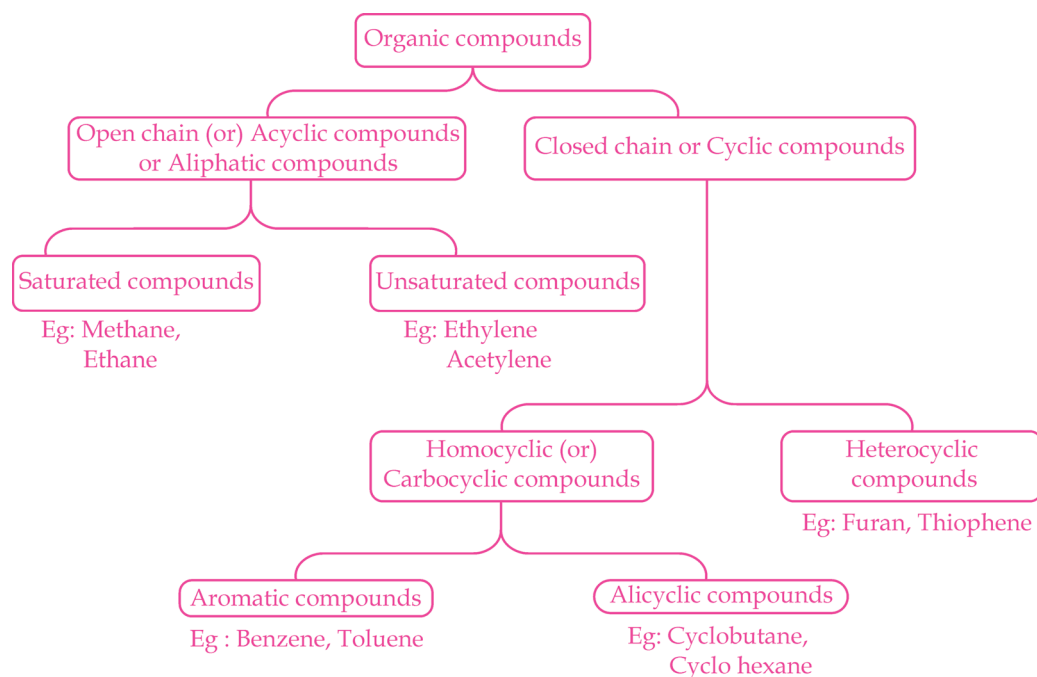
Organic chemistry is an essential aspect in biological and medical field. All the living organisms are composed of organic substances. Evolution of life postulated that life started from a single organic compound, nucleotide which polymerises or joined together to form a building blocks of life known as DNA.

In most of the chemical industries and pharmaceutical companies in and around us, we encounter organic reactions. Maximum number of life saving drugs are organic compounds only, hence any field e.g. chemical engineering, food and flavoring industry, electrical engineering (liquid crystals displays for digital watches) is surrounded by basics of organic chemistry only. Doctor or Pharmacist are surrounded by organic compounds throughout their life because maximum numbers of life saving drugs are organic compounds only.

For the discipline of biochemistry, molecular biology or another branch of life sciences, a good background of organic chemistry is essential. Specialization in any other branch of chemistry needs good knowledge of organic chemistry.

Apart from these, study of organic chemistry extremely stimulate intellectual pursuit and promotes logical thinking. Organic compounds are vital for the sustenance of all life. Many medical disorders or diseases are due to disruption of organic molecules in the body. Enzymes, proteins, carbohydrates, lipids and catalysts present in our body are organic substances which play a major role in our day to day life.

Classification of Organic Compounds



Organic compounds are categorized into two major groups such as

1. Open chain or acyclic compounds or aliphatic compounds.
 2. Cyclic compounds or closed chain compounds.
1. **Open chain or acyclic compounds:** Carbon compounds having open chain of carbon atoms whether branched or unbranched are called as open chain compounds. The name aliphatic was derived from the Greek word aleipher (meaning fat) as the earliest known compounds of this type were obtained from fats.

CH_4	Methane
$\text{CH}_3 - \text{CH}_3$	Ethane
$\text{CH}_3 - \text{CH}_2 - \text{CH}_3$	Propane
$\text{CH}_3 - \text{CH}_2 - \text{CH}_2\text{Br}$	<i>n</i> -Propyl bromide
$\text{CH}_3 - \text{CH}_2 - \text{OH}$	Ethanol

Saturated compounds: A hydrocarbon (compounds that contains only carbon and hydrogen) contains only one carbon-carbon (C-C) single bond are called as saturated compounds (Four valency of carbon atom is saturated with different atoms or groups).

CH_4	Methane
$\text{CH}_3 - \text{CH}_3$	Ethane

Unsaturated compounds: A hydrocarbon having carbon-carbon double bond (C=C) or carbon-carbon triple bond (C≡C) are called as unsaturated compounds.

$\text{CH}_2 = \text{CH}_2$	Ethylene
$\text{CH} \equiv \text{CH}$	Acetylene
$\text{CH}_2 = \text{CH} - \text{CH} = \text{CH}_2$	1,3-Butadiene

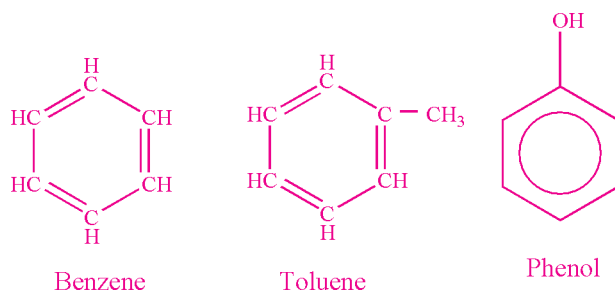
2. **Cyclic compounds or closed chain compounds:** Organic compounds with a closed chain of atoms are called as closed chain or cyclic compounds.

Polycyclic compounds: Molecules containing two or more ring system is known as polycyclic compounds.

Homocyclic or carbocyclic compounds: The cyclic compounds entirely composed of carbon atom are called as homocyclic or carbocyclic compounds.

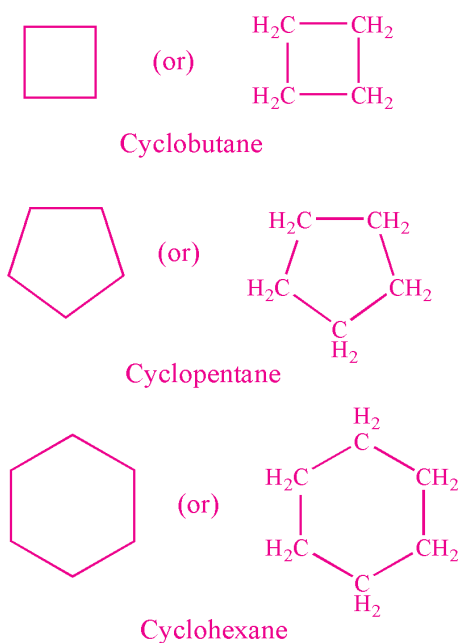
These are further sub divided in to two important groups.

Aromatic compounds: Compounds containing a ring structure of six carbon atom of benzene are known as benzenoid or aromatic compounds as shown in following examples.

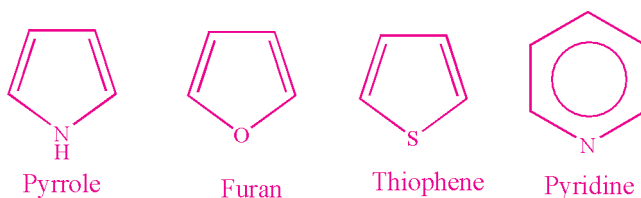


Most of the organic compounds occur in plants and many of them have fragrant odour, so they are named as aromatic compounds (Greek *aroma* = sweet smell).

Alicyclic compounds or aliphatic cyclic compounds: Some of the homocyclic compounds contain a ring structure but behave like aliphatic compounds, hence, they are named alicyclic or cyclic aliphatic compounds. It includes the important compounds of polymethylenes or their derivatives as shown below.



Heterocyclic compounds: Cyclic compounds in which one or more carbon atoms are replaced by other atoms are called as heterocyclic compounds. The non carbon atoms present in the ring are called as hetero atoms. Examples are nitrogen, oxygen and sulphur. Some of the examples for heterocyclic compounds are shown below.



Organic Chemistry in the Service of Mankind

All molecules such as proteins, amino acids, enzymes, lipids, DNA & RNA which make life possible contain carbon atoms and the great majority of the chemical reactions that occur within body or living system are organic reactions. We depend on organic compounds that occur in nature for our day to day life needs as given below:

Foods: Starch, sucrose, glucose, fats, vitamins, proteins etc.

Household and commercial articles: Soap, ointments, oils, cosmetics, flavoring agents, paints, varnishes etc.

Drugs and disinfectants: Aspirin, sulphonamides, penicillin, chloroform, dettol, lysol etc.

Poisons: Strychnine, opium and different kind of insecticides.

Perfumes: Camphor, ionone and vanillin.

Dyes: Indigo, malachite green, congo red etc.

Explosives: Trinitrotoluene, nitroglycerin, dynamite and picric acid etc.

War gases: Lewisite, mustard gas and chloropicrin.

Hence, organic compounds penetrate into each and every phase of our life. We look and count on an organic chemist for the manufacture of the above compounds and for the development of various chemical industries.

Various sources of organic compounds: As mentioned earlier, organic compounds are mainly obtained from the natural sources and synthesized in laboratory.

Plants and animal sources: By using suitable method of isolation, various types of organic compounds are obtained directly from plant and animal sources. For example: carbohydrates (sugars, starch, cellulose), proteins (silk, wool, food proteins, casein), alkaloids (morphine, quinine, strychnine), fats and oils (soybean oil, cotton seed oil, sunflower oil, butter), hormones, vitamins, resins, perfumes and flavouring agents.

- 1. Natural gas and petroleum:** These are used as fuels as well as the major source for organic compounds. Through various types of synthetic organic reaction, natural gas and fuels are used as a source for the preparation of hundreds of useful organic substances such as explosives, solvents, synthetic rubber and plastics.
- 2. Coal:** It is another major source of lot of organic compounds. Pyrolysis or the destructive distillation of coal produces coke and coal tar. Nearly more than 200 varieties of organic compounds are isolated from coal tar. The coal tar produces the starting materials for the manufacture of thousands of useful aromatic compounds such as drugs, dyes, perfumes and others.
- 3. Synthesis:** By using synthetic strategies and reactions, the simple organic compounds obtained from petroleum and coal tar have been converted in to thousands of useful materials.

Many examples can be cited of synthetic organic compounds replacing those obtained from natural sources but it need volumes. In several cases, the synthetic compounds obtained are more superior to natural compounds. We will study the basic principles of organic chemistry which will help us to learn complex organic compounds and their chemistry in further stages.

Probable Questions

1. Define vital force theory. Why was it abandoned?
2. What is meant by isomerism and polymerism? Write the various isomers of $C_4H_{10}O$.
3. Write the importance of organic chemistry in medicines or medical field.
4. Write a brief note on the rise and development of organic chemistry.
5. Define organic chemistry, and how will you justify organic compounds belongs to separate branch of chemistry?
6. Write a short note on organic chemistry in the service of mankind.