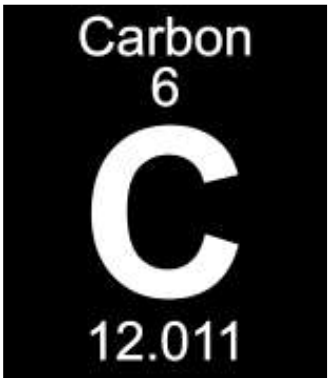
Carbon & It's Compounds

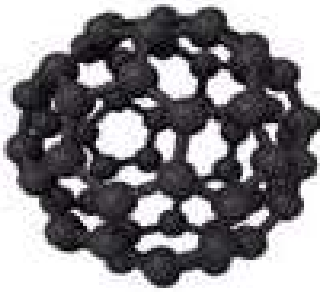
Chapter Outline

- Bonding in Carbon : The Covalent Bond
- Allotropes of Carbon
- Versatile nature of Carbon
- Organic Chemistry
- Classification of Organic Compounds
- Hydrocarbons and Functional Groups
- Homologous Series
- Nomenclature of Organic Compounds
- Chemical Reaction of Carbon Compounds
- Some Important Organic Compounds
- Soaps & Detergents



Diamond

Graphite



Fullerene

INTRODUCTION

Carbon is a very important non-metal. The name carbon is derived from the Latin word 'carbon' which means 'coal'. This is because it is the main constituent of coal. Carbon is the major chemical of most organic matter from fossil fuels to complex molecules (DNA and RNA) that control genetic reproduction in organisms. The earth's crust has only 0.02 % carbon in the form of minerals (like carbonates, hydrogen carbonates, coal and petroleum) and the atmosphere has 0.04 % carbon dioxide. Inspite of this small amount of carbon available in nature, the importance of carbon seems to be immense because carbon forms innumerable compounds by combining with other elements.

BONDING IN CARBON – THE COVALENT BOND

In the previous chapter, we have studied the properties of ionic compounds we saw that compounds have high melting and boiling points and conduct electricity in solution or in the molten state. Further all these properties were explained on the basis of nature of bonding in ionic compounds. Let us now study the properties of some carbon compounds. Melting and boiling points of some carbon compounds are given in Table.

Compound	Melting Point (K)	Boiling Point (K)
Acetic acid (CH_3COOH)	290	391
Chloroform ($CHCl_3$)	209	334
Ethanol (CH_3CH_2OH)	156	351
Methane (CH_4)	90	111

From the above data it is clear that the boiling and melting points of carbon compounds are very low. This is due to the reason that the forces of attraction between the molecules of these compounds are not strong. Since these compounds are largely non-conductors of electricity, we can conclude that the bonding in these compounds does not give rise to any ions.

The atomic number of carbon is 6. So, its electronic configuration is : ${}_6C \underset{2}{K} \underset{4}{L}$ $(1s^2, 2s^2\ 2p^2)$

The configuration shows that carbon is an element of 2^{nd} period and 14^{th} group, in the p-block.

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- 14^{th} group in the periodic table is called the carbon family. Other members of this group are Si, Ge, Sn, Pb.

Formation of Covalent Bond :

We know that the reactivity of elements is explained as their tendency to attain a completely filled outer shell, i.e., attain noble gas configuration. Elements forming ionic compounds achieve this by either gaining or losing electrons from the outermost shell. In case of carbon, it has four electrons in its outermost shell and need to gain or lose four electrons to attain noble gas configuration. If it were to gain or lose electrons :

(i) It could gain four electrons forming C^{4-} anion but it would be difficult for the nucleus with six protons to hold on to ten electrons, i.e., four extra electrons.

(ii) It could lose four electrons forming C^{4+} cation but it would require a large amount of energy to remove four electrons leaving behind a carbon cation with six protons in its nucleus holding on the just two electrons.

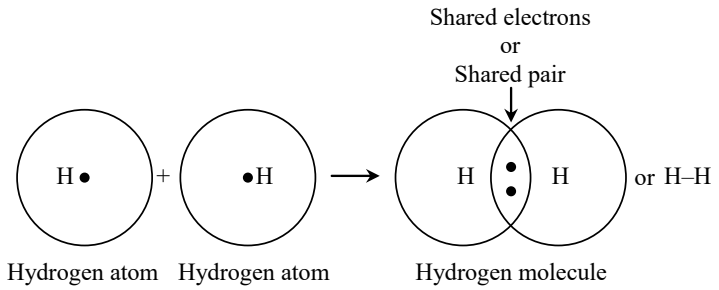
Thus, carbon can neither gain nor lose 4 electrons to acquire the nearest noble gas configuration. The only way by which it can acquire the nearest noble gas configuration is by sharing of its valence electrons with electrons of other carbon atoms or atoms of other element. Not just carbon, many other elements also form molecules by sharing of valence electrons.

Concept of Covalent Bond :

Formation of covalent bond involves the sharing of electrons between the bonding atoms which may be either same or different. Each atom contributes equal number of electrons for sharing. These shared electrons form common pairs or shared pairs which belong to the outermost shells of both the combining atoms. As a result, both the combining atoms acquire the stable configuration of the nearest noble gas. Such bonds which are formed by mutual sharing of electrons between two atoms are called covalent bonds. Thus, a chemical bond formed between two atoms by mutual sharing of valence electrons between two atoms so that each atom acquires the stable electronic configuration of the nearest noble gas is called a covalent bond and the compounds formed by sharing of electrons are called covalent compounds.

Examples of formation of covalent bonds :

1. **Formation of hydrogen (H_2) molecules :** The atomic number of hydrogen is 1. Hence, hydrogen has one electron in its K-shell and thus requires one more electron to complete the K-shell,. So, two hydrogen atoms share one electron each to form a molecule of hydrogen, H_2. By doing so, each hydrogen atom attains the stable electronic configuration of the nearest noble gas, helium, which has two electrons in its K-shell. We can depict the formation of diatomic molecule of H_2 using dots or crosses to represent the valence electrons involved in sharing. Such structures of molecules are called electron dot structures. The electrons dot structure of H_2 molecule is shown in figure.



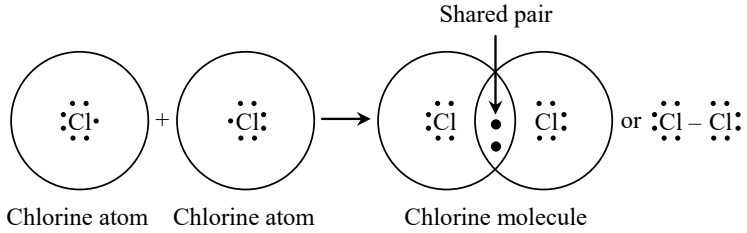
Electron dot structure of Hydrogen (H_2) molecule

The shared pair is said to constitute a single covalent bond between two hydrogen atoms and is represented by a single line between the two hydrogen atoms.

Shared pairs are also called bond pairs since they bind the combining atoms together.

2. **Formation of chlorine (Cl_2) molecule :** The atomic number of chlorine is 17. So its electronic configuration is : $_{17}Cl = \underset{2}{K}\ \underset{8}{L}\ \underset{7}{M}$ $(1s^2, 2s^2\ 2p^6, 3s^2\ 3p^5)$

Thus, chlorine has 7 electrons in its valence shell, i.e., M-shell. Therefore, it needs one more electron to complete the M-shell. So, two chlorine atoms share one electron each to form a diatomic molecule of chlorine (Cl_2). By doing so, each chlorine atom attains the stable electronic configuration of the nearest noble gas, argon. The electron dot structure of chlorine molecule is shown in figure.



Electron dot structure of chlorine (Cl_2) molecule

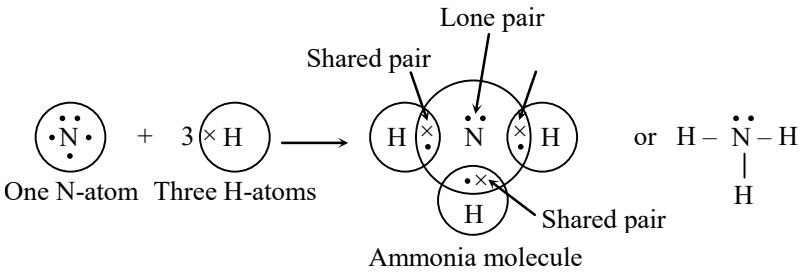
The shared pair constitutes a single covalent bond between the two chlorine atoms and is represented by a single line between the two chlorine atoms. The three pair of electrons on each chlorine atom which were not involved in bond formation are called unshared pairs or lone pairs of electrons.

3. **Formation of ammonia (NH_3) molecule :** The atomic number of nitrogen is 7. So, its electronic configuration is : $_7N = \underset{2}{K}\ \underset{5}{L}$ $(1s^2, 2s^2\ 2p^3)$

Thus, nitrogen has 5 electrons in its valence shell, i.e., L-shell. Therefore, it needs three more electrons to acquire the stable electronic configuration of the nearest noble gas, neon.

On the other hand, atomic number of hydrogen is 1. Therefore, its has one electron in the K-shell and thus needs one more electron to acquire the stable electronic configuration of the nearest noble gas, helium.

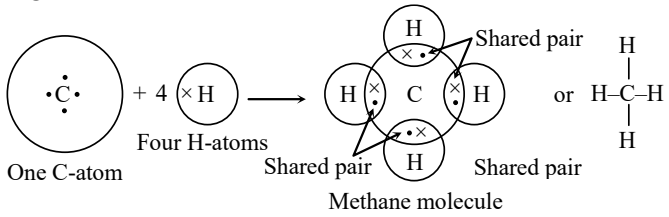
In order to complete its octet, nitrogen shares three of its valence electrons, with one electron each of three hydrogen atoms to form a molecule of ammonia. By doing so, each hydrogen atom completes its duplet. The three shared pairs of electrons form three N–H, single covalent bonds. The electron dot structure of ammonia is shown in figure. The pair of electrons on the nitrogen atom in NH_3 molecule which is not involved in bond formation is called the lone pair.



Electron dot structure of ammonia (NH_3) molecule

4. **Formation of methane (CH_4) molecule :** Methane is the simplest carbon compound. Its formula is CH_4. It is widely used as a fuel and is the major component of Bio-gas, Compressed Natural Gas (CNG).
The atomic number of carbon is 6 and its electronic configuration is : ${}_6C = \underset{2}{K}\ \underset{4}{L}$ $(1s^2, 2s^2\ 2p^2)$

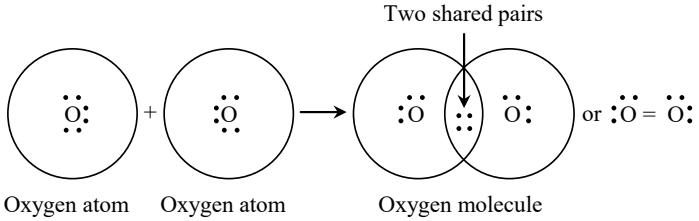
Thus, carbon has 4 electrons in the valence shell (i.e., L-shell) and hence, needs four more electrons to complete its octet by acquiring the stable electronic configuration of the nearest noble gas, neon. Thus, the valency of carbon is 4. In other words, carbon is tetravalent.
On the other hand, the atomic number of hydrogen is 1. In other words, hydrogen has one electron in the K-shell (i.e., valence shell) and thus needs one more electron to complete its duplet by acquiring the stable electronic configuration of the nearest noble gas, helium.
In order to complete its octet, carbon shares its four valence electrons, with one electron each of four hydrogen atoms to form a molecule of methane. By doing so, each hydrogen atom completes its duplet. The four shared pairs of electrons form four C–H single covalent bonds. The electron dot structure of methane molecule is shown in figure.



Electron dot structure of methane (CH_4) molecule

5. **Formation of oxygen (O_2) molecule :** The atomic number of oxygen is 8. So, its electronic configuration is: ${}_8O = \underset{2}{K}\ \underset{6}{L}$ $(1s^2, 2s^2\ 2p^4)$

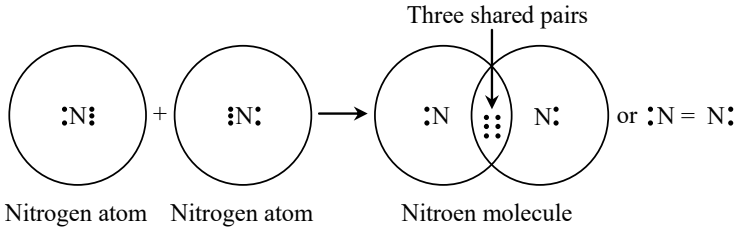
Thus, oxygen has 6 electrons in the L-shell (i.e., valence shell). Therefore, its needs two more electrons to complete its octet. So each atom of oxygen shares two electrons with another atom of oxygen to form a diatomic molecule of oxygen. By doing so, each oxygen atom acquires the stable electronic configuration of the nearest noble gas, neon. The two electrons contributed by each oxygen atom give rise to two shared pairs of electrons. These two shared pairs of electrons constitute a double bond between the two oxygen atoms which is represented by a double line. Further, since each oxygen atom shares two electrons to form O_2 molecule, therefore, the valency of oxygen is two. In other words, oxygen is divalent.
The electron dot structure of oxygen molecule is shown in figure.



Electron dot structure of oxygen (O_2) molecule

6. **Formation of nitrogen (N_2) molecule:** The atomic number of nitrogen is 7. So, its electronic configuration is: ${}_7N = \underset{2}{K}\ \underset{5}{L}$ $(1s^2, 2s^2\ 2p^3)$

Thus, nitrogen has 5 electrons in the L-shell (i.e., valence shell). Therefore, it needs three more electrons to complete its octet. By doing so, each nitrogen shares three electrons with another atom of nitrogen to form a diatomic molecule of nitrogen. By doing so, each nitrogen atom acquires the stable electronic configuration of the nearest noble gas, neon.
The three electrons contributed by each nitrogen atom give rise to three shared pair of electrons. These three shared pairs of electrons constitute a triple bond between the two nitrogen atoms which is represented by a triple line. One pair of electrons on each nitrogen atom in N_2 molecule which is not involved in bond formation is called the lone pair. Further since each nitrogen atom shares three electrons to form a molecule of N_2, therefore, the valency of nitrogen is three. In order words, nitrogen is trivalent. The electron dot structure of a diatomic molecule of nitrogen is shown in figure.



Electron dot structure of nitrogen (N_2) molecule

Homoatomic and Heteroatomic Molecules :

Molecules which are made up of only one kind of atoms such as H_2, Cl_2, O_2, N_2, etc., are called homoatomic molecules while those which are made up of more than one type of atoms such as CH_4, NH_3, HCl, etc., are called heteroatomic molecules

Boost your knowledge

☛Covalency : Covalency of an element may be defined as the number of electrons which an atom of an element shares. In H_2 molecules both the atoms share one electron each hence, have a covalency of one. In O_2 molecule both the atoms share two electrons and hence, have a covalency of two while in nitrogen molecule both the atom share three electrons and hence, have a covalency of three.

Properties of covalent compounds :

1. Physical State : Covalent compounds exist as gases, liquids or solids. For example, NH_3, CH_4, SO_2, etc, exist as gases, while H_2O exist as liquid and $C_{12}H_{22}O_{11}$ exist as solids.
2. Melting and boiling points : Since, no ions are present in the covalent molecules, the attractive forces in them are weak. Therefore, these compounds have usually low melting and boiling points.
3. Electrical conductivity : Covalent compounds do not conduct electricity. This means that covalent compounds are bad conductor of electricity due to absence of free ions. For example, covalent compounds like glucose, sugar, urea, alcohol and carbon tetrachloride, etc., do not conduct electricity because they do not contain ions. Some polar covalent compounds like hydrogen chloride gas, however, conduct electricity when dissolved in water since it dissociates into H^+ (aq) and Cl^- (aq) ions and hence, it becomes a good conductor of electricity.
4. Nature of reactions: Covalent compounds generally undergo molecular reactions.
5. Solubility: Covalent compounds are usually insoluble in water but they are soluble in organic solvents. For example, naphthalene is insoluble in water but dissolves in organic solvents like ether. Some of the covalent compounds like glucose, sugar and urea, etc., are however, soluble in water. The polar covalent compounds like hydrogen chloride and ammonia are also soluble in water.

Difference in the properties of ionic and covalent compounds

S.No.	Ionic Compounds	Covalent Compounds
1.	These are formed by the transfer of one or more electrons from one atom to the other.	These are formed by mutual sharing of electrons between the bonded atoms.
2.	These are formed between atoms of metals and non-metals	These are formed between the atoms of non-metals.
3.	They are high melting and boiling points due to strong forces of attraction between oppositely charged ions.	They have low melting and boiling points because no ions are involved in their formation.
4.	They are soluble in polar solvents like water but are insoluble in organic solvents like alcohol, benzen, petrol, ether, chloroform, etc.	They are generally insoluble in polar solvents like water but are soluble in non-polar solvents like alcohol, benzene, petrol, ether, chloroform, etc.
5.	They do not conduct electricity in the solid state but do so in the molten state or in their aqueous solution.	They do not contain ions and hence, are generally bad conductors, of electricity.
6.	They undergo ionic reactions which are very fast.	They undergo molecular reactions which are slow.

ALLOTROPES OF CARBON

Allotropes : When an element is found in different forms having different physical properties but almost similar chemical properties, the phenomenon is known as allotropy and different forms are called allotropic forms of that element.

Elements such as carbon, oxygen, phosphorus and sulphur display allotropy.

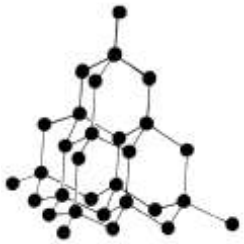
Carbon exists in both crystalline and amorphous allotropic forms.

(A) Crystalline Allotropes of Carbon :

The crystalline varieties of carbon are diamond, graphite and fullerene.

1. **Diamond :**

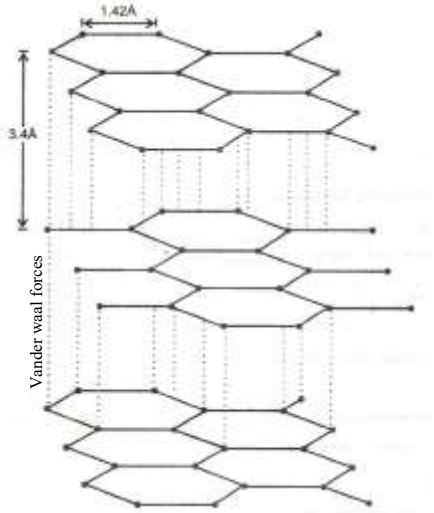
Diamond possesses a three dimensional network of carbon atoms joined together tertrahedrally through strong covalent bonds. Each carbon atom is linked tetrahedrally to four neighbouring carbon atoms extended in three dimensions such that each carbon atom lies at the centre of regular tetrahedron with the vertices occupied by other carbon atoms. All C–C bonds are of equal lengths 154 pm (1.54 Å) with bond angle 109º 28'.



Structure of diamond

The three electrons contributed by each nitrogen atom give rise to three shared pair of electrons. These three shared pairs of electrons constitute a triple bond between the two nitrogen atoms which is represented by a triple line. One pair of electrons on each nitrogen atom in N_2 molecule which is not involved in bond formation is called the lone pair. Further since each nitrogen atom shares three electrons to form a molecule of N_2, therefore, the valency of nitrogen is three. In order words, nitrogen is trivalent. The electron dot structure of a diatomic molecule of nitrogen is shown in figure.

Each carbon atom in graphite is covalently attached to three neighbouring carbon atoms lying in the same plane giving rise to planar hexagonal rings. The C–C bond length in these rings is 142 pm (1.42 Å), and are separated by a distance of 340 pm (3.4 Å). Due to weak Van der Walls' forces, the sheets are not firmly attached and can slide over one another. This is why graphite is soft and possesses lubricating properties.



Structure of graphite

Table : Difference in the properties of diamond and graphite.

S.No.	Diamond	Graphite
1.	Crystalline, transparent with extra brilliance.	Crystalline, opaque and shiny substance.
2.	Hardest form	Soft having soapy touch.
3.	Bad conductor of electricity.	Good conductor of electricity.
4.	High density (3.51 g/cm^3)	Low density (2.25 g/cm^3)
5.	Colourless.	Greyish white.
6.	Tetrahedral structure	Two dimensional layer structrure with regular hexagonal sheets.
7.	Less stable, more energy	More stable, less energy.
8.	Melting point is about 3527ºC	Melting point is about 4027ºC

2. Fullerenes :

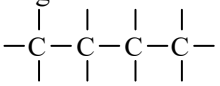
The name Buckminster fullerene was given to C_{60} in the honour of Robert Buckminster fuller whose geodesic dome structure incorporated patterns of hexagons with sufficient pentagons to give clusters. The structure of Buckminster fullerene (C_{60}) is shown in figure. Its shape resembles to that of a soccer ball (football). Fullerenes containing carbon clusters upto 600 carbon atoms have been observed.

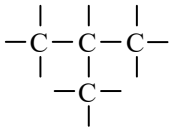
The soccer ball structure of Buckminster Fullerene (C_{60})

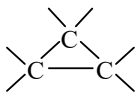
VERSATILE NATURE OF CARBON

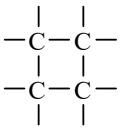
Many of the things we use in our day to day life are made up of carbon compounds. In fact, we ourselves are made up of carbon compounds. The number of carbon compounds known today is approximately three million. This number far exceeds the total number of compounds formed by all other elements. Why is it that this property is seen in carbon and in no other element ? The nature of the covalent bond enables carbon to form a large number of compounds. The four main characteristic properties of carbon atom which lead to formation of a very large number of organic compounds are :

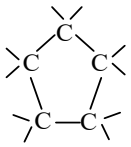
1. **Catenation :** The main reason as to why carbon forms a large number of organic compounds is that carbon can combine with other carbon atoms to form straight or branched chains of varying lengths or rings of different sizes as shown below :

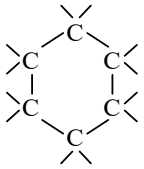

Straight chain


Branched chain


Three-membered ring


Four-membered ring


Five-membered ring


Six-membered ring

This unique property of self-linking of carbon atoms through covalent bonds to form long straight or branched chains and rings of different sizes is called catenation.

The property of catenation is probably due to

(i) small size

(ii) unique electronic configuration and

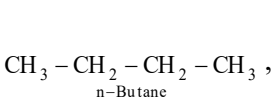
(iii) great strength of carbon-carbon bonds.

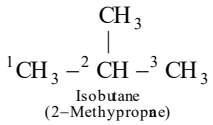
No other element exhibits the property of catenation to the extent seen in carbon atoms. Silicon forms compounds with hydrogen which have chains of upto seven or eight atoms, but these compounds are very reactive. The carbon-carbon bond is very strong and hence, stable. This gives us the large number of compounds with many carbon atoms linked to each other.

2. **Tetra-valency of carbon :** Carbon has a valency of four. Therefore, it is capable of bonding with four other atoms. The bonds formed by carbon with other atoms are very strong and hence the molecules are very stable. This further increases the number of carbon compounds.
3. **Tendency to form multiple bonds :** Due to small size, carbon also forms multiple (double and triple) bonds with other carbon atoms, oxygen, sulphur and nitrogen. This multiplicity of carbon-carbon, carbon-oxygen and carbon-nitrogen bonds further increases the number of carbon compounds.
4. **Isomerism :** Another reason for huge number of carbon compounds is the phenomenon of isomerism. Isomerism is defined as follows :

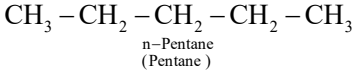
   If a given molecular formula represents two or more structures having different properties, the phenomenon is called isomerism and the different structure structures are called isomers.

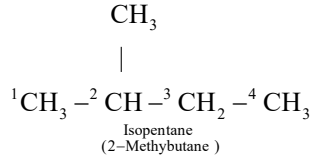
   For example, Isomers of Butane-C_4H_{10} are :


n–Butane (Butane)

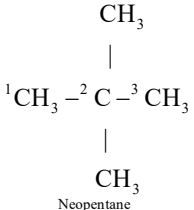

Isobutane (2–Methypropane)

Isomers of Pentane-C_5H_{12} are :


n–Pentane (Pentane)


Isopentane (2–Methybutane)

and


Neopentane (2,2–Dimethylpropane)

Thus, the number of different structures with the same molecular formula further increases the number of carbon compounds.

ORGANIC COMPOUNDS

Two characteristic features of carbon i.e., tetravalency and catenation put together, give rise to a large number of compounds. Many have the same non-carbon or group of atoms attached to different carbon chains these compounds were initially extracted from natural substances and it was thought that these carbon compounds or organic compounds could only be formed within a living system. Thus these carbon compounds were named organic compounds and were defined as- 'Those compounds of carbon that are directly or indirectly obtained from organism.'

Berzelius Hypothesis or Vital Force theory :

Organic compounds cannot be synthesized in the laboratory because they require the presence of a mysterious force (called vital force) which exists only in living organisms.

Wohler's Synthesis :

In 1828, Friedrich Wohler synthesized urea (a well known organic compound) in the laboratory by heating ammonium cyanate.

$$\underset{\text{Ammonium sulphate}}{(NH_4)_2SO_4} + \underset{\text{Potassium cyanate}}{2KCNO} \rightarrow \underset{\text{Ammonium cyanate}}{NH_4CNO} + \underset{\text{Potassium sulphate}}{K_2SO_4}$$

$$\underset{\text{Ammonium cyanate}}{NH_4CNO} \xrightarrow[\text{Rearrangement}]{\text{Heat}} \underset{\text{Urea}}{NH_2-\overset{\overset{O}{\|}}{C}-NH_2}$$

Boost your knowledge

- Urea is the first organic compound synthesized in the laboratory.

MODERN DEFINITION OF ORGANIC CHEMISTRY

With the downfall of the Vital force theory, the word organic pertaining to life lost its significance. An analysis of these compounds revealed that all them contain carbon as their essential constituents. Therefore, the organic compounds were regarded as the carbon compounds. This definition was little confusing because according to this, typical inorganic compounds like carbon monoxide, carbon dioxide and carbonates of certain metals should also be regarded as organic compounds.

However, a detailed investigation of the structure of the organic compounds revealed that almost all of them essentially contain both carbon and hydrogen (hydrocarbons) and some of them also contain the atoms of a few other elements such as nitrogen, oxygen, phosphorus, halogens, etc. These are regarded as the derivatives of hydrocarbons since, they can be formed by replacing the hydrogen atoms in the hydrocarbons by these atoms.

Thus :

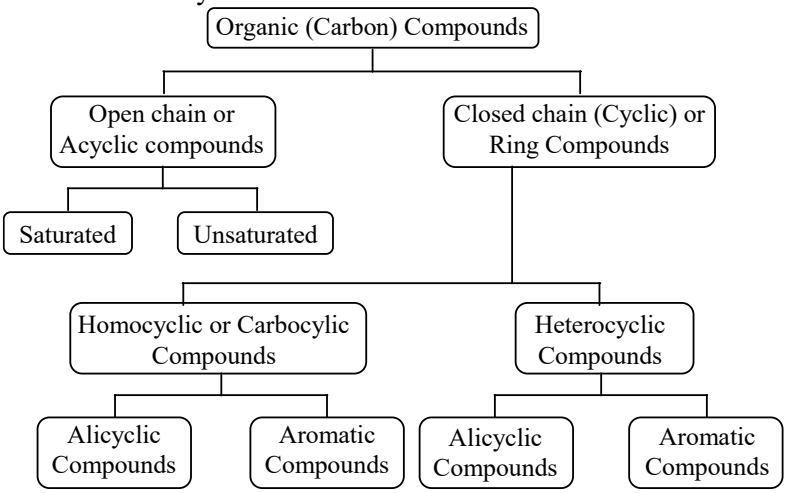
Organic compounds are the hydrocarbons and their derivatives and the branch of chemistry that deals with the study of these compounds in known as organic chemistry.

Boost your knowledge

- Oxides of carbon (like carbon monoxide and carbon dioxide), carbonates and hydrogen carbonate salts are not considered to be organic compounds. This is because their properties are very different from those of the common organic compounds.

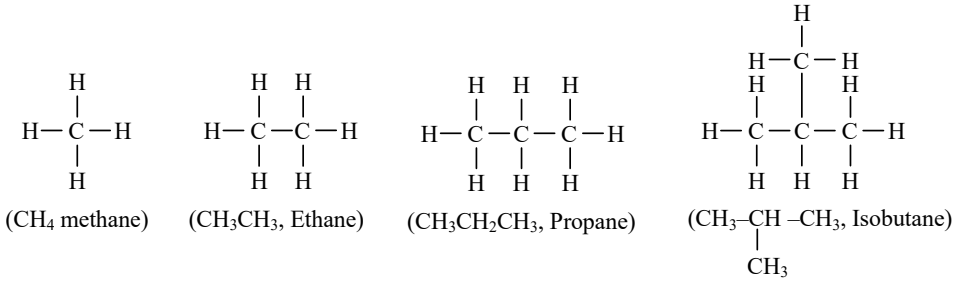
CLASSIFICATION OF ORGANIC COMPOUNDS

The organic compounds can broadly be classified as follows :



1. Open chain or Acyclic Compounds :

Compounds containing open chains of carbon atoms are referred to as open chain compounds or acyclic compounds or aliphatic compounds. The carbon chains may be either straight or branched e.g.,



(CH_4 methane) (CH_3CH_3, Ethane) ($CH_3CH_2CH_3$, Propane) (CH_3–CH(CH_3)–CH_3, Isobutane)

(a) Saturated compounds :

A saturated compound is a chemical compound that have a chain of carbon atoms linked together by single bonds.

(b) Unsaturated compounds :

A unsaturated compound is a chemical compound that have a chain of carbon-carbon atoms linked together by double or triple.

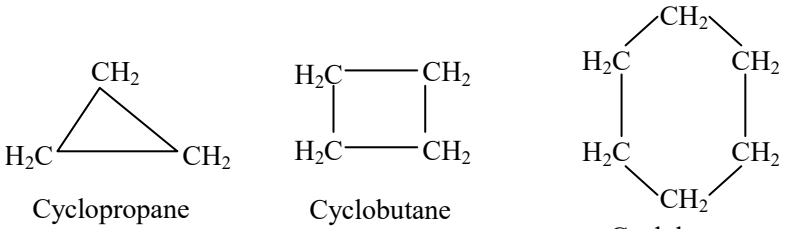
2. Closed Chain (Cyclic) or Ring Compounds :

The compounds containing closed rings of carbon atoms are referred to as cyclic or ring compounds. These are further classified into following categories.

(a) Homocyclic or Carbocyclic Compounds :

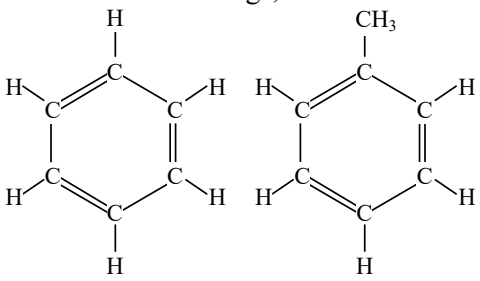
When the ring is entirely made up of carbon atoms, the compound is said to be carbocyclic compound. Carbocyclic compounds are of two types.

(i) Alicyclic compounds : These compounds contain a ring of three or more carbon atoms only and possess properties almost similar to those of aliphatic compounds e.g.,



Cyclopropane Cyclobutane Cyclohexane

(ii) Aromatic compounds: These compounds also possess one or more rings made up of carbon atoms only and have are characteristic aroma (smell). The parent aromatic compound, benzene, has a ring of six carbon atoms joined together by alternate single and double bonds. In general, when the compound contains one or more benzene rings, its is said to be an aromatic compounds e.g.,



Benzene Toluene

Aromatic compounds possess properties quite different from those of aliphatic compounds.

(b) Heterocyclic compounds : These are also cyclic compounds but the ring contains one or more atoms other than those of carbon. The atoms usually present in ring are of nitrogen, oxygen or sulphur.

HYDROCARBONS AND FUNCTIONAL GROUPS

(A) Hydrocarbons :

The organic compounds made up of carbon and hydrogen atoms only are called hydrocarbons. Hydrocarbons are the simplest organic compounds. Other compounds derived from them are regarded as the derivatives of their parent hydrocarbons. These compounds are obtained when one or more hydrogen atoms of a hydrocarbon are replaced by active atoms or groups of atoms called functional groups.

Hydrocarbons may have straight chains, branched chains or rings.

1. Saturated hydrocarbons or Alkanes :

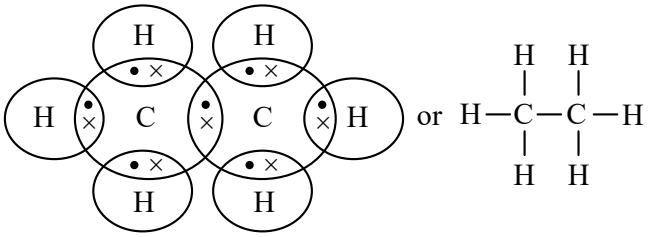
The hydrocarbons in which all the carbon atoms are linked together by single covalent bonds are called saturated hydrocarbons.

The saturated hydrocarbons are called alkanes. They can be represented by general formula C_nH_{2n+2}, where n is an integer having values 1, 2, 3 …. etc. These are the parent hydrocarbons of all aliphatic compounds. Some examples of alkanes are as follows.

CH_4 (CH_4, Methane) CH_3-CH_3 (C_2H_6, Ethane) $CH_3-CH_2-CH_3$ (C_3H_8 Propane)

$CH_3-CH_2-CH_2-CH_3$ (C_4H_{10} Butane)

Structure of ethane (C_2H_6) : In ethane (C_2H_6), the two carbon atoms are linked together by a single bond leaving each carbon with three valencies unsatisfied. These valencies are satisfied by hydrogen atoms to form an ethane molecule. Thus ethane has one C–C single bond and six C–H single bonds as shown below.



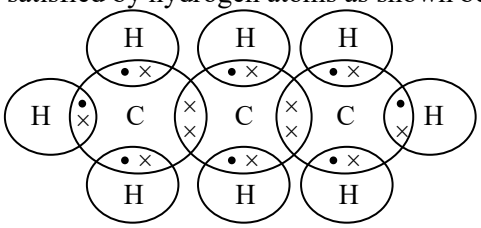
Structure of ethane

(× → electron of carbon)

(• → electron of hydrogen)

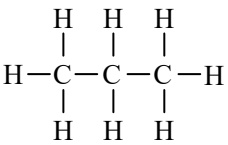
Structure of propane (C_3H_8) :

In propane (C_3H_8), all the three carbon atoms are linked together by single bonds leaving three valencies each on the first and third carbon atoms unsatisfied and two valencies on the second carbon atom unsatisfied. These valencies are satisfied by hydrogen atoms as shown below.



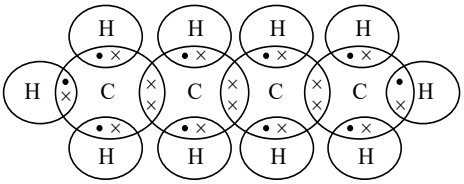
Structure of ethane

or



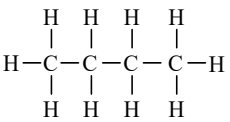
Thus, a molecule of propane has two C–C and eight C–H single covalent bonds.

Structure of butane (C_4H_{10}) : In butane (C_4H_{10}), all the four carbon atoms are linked together by single covalent bonds and the remaining valencies of each carbon are satisfied by hydrogen atoms as shown below.



Structure of Butane

or



Thus, a molecule of butane has three C–C and ten C–H single covalent bonds.

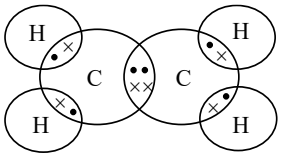
2. Unsaturated hydrocarbons :

The hydrocarbons which contain one or more double or triple bonds i.e. multiple bonds between carbon atoms are called unsaturated hydrocarbons.

(a) Alkenes : Unsaturated hydrocarbons having only one carbon-carbon double bonds are called alkenes. These can be represented by the general formula C_nH_{2n} where n is an integer having value 2, 3 ….. etc.

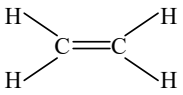
Structure of ethene (ethylene, C_2H_4) :

In ethene (C_2H_4), the two carbon atoms share their two electrons each to form a C = C double bond. Each carbon is now left with two electrons which it share with the electrons of two hydrogen atoms to form two C–H single bonds as shown below.



Structure of Ethene or Ethylene

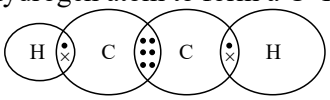
or



Thus in C_2H_4, there is one C = C double bond and four C–H single bonds.

(b) Alkynes : The unsaturated hydrocarbons having only one carbon-carbon triple bond are called alkynes. These can be represented by the general formula C_nH_{2n-2} where n is an integer having values 2, 3 ….. etc.

Structure of ethyne (acetylene, C_2H_2) : In ethylene (C_2H_2), the two carbon atoms share their three electrons each to form a C ≡ C triple bond. Each carbon is thus left with one unshared electron only which it shares with the electron of a hydrogen atom to form a C–H single bond as shown below.



Structure of Ethyne (Acetylene)

or

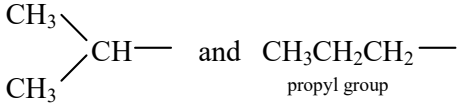
H–C≡C–H

Therefore in C_2H_2 there is one C≡C triple bond and two C–H single bonds

Boost your knowledge

☛ Alkyl Groups :

When a hydrogen atom is removed from an alkane, the group obtained is called an alkyl group or alkyl radical e.g. on removing a hydrogen atom from methane (CH_4) the resultant left is CH_3– or methyl group. In methane (CH_4), all the four hydrogen atoms are identical. Therefore, removal of any of the H-atom results in the formation of the same type of methyl group. Similarly in ethane on removal of one H-atom gives only one ethyl group (i.e., $CH_3 – CH_2$ –) because all the six hydrogen atoms present in it are of the same type. However in propane ($CH_3CH_2CH_3$) two types of alkyl groups are formed on removing H-atom e.g.,

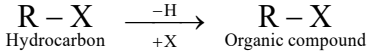


Isopropyl group

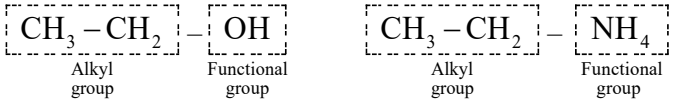
An alkyl group, in general, is represented by R. Therefore, an alkane can also be written as RH.

(B) Functional Groups :

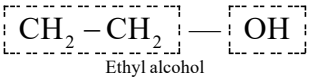
The chemical nature of an organic compound depends on the presence of a particular active atom or a group of atoms which largely decides the mode of reactivity of a given compound. The formation of an organic compound from parent hydrocarbon having functional group X can be shown as follows.



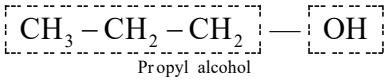
In the molecule R – X, R represents an alkyl group in aliphatic compounds, whereas in aromatic compounds, R stands for a aryl group. The group X is called functional group and decides the chemical nature of the compound. For example, the chemical behaviour of ethyl alcohol (C_2H_5OH) and ethylamine ($C_2H_5NH_2$) are altogether different although they contain the same alkyl group.



On the other hand, the properties of ethyl alcohol are almost similar to those of propyl alcohol due to the presence of the same functional group, although they contain different alkyl groups.



Ethyl alcohol

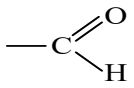
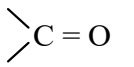
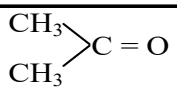
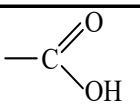
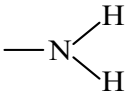
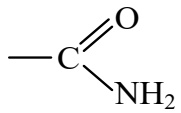
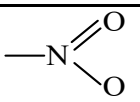


Propyl alcohol

Similarly propanol ($CH_3CH_2CH_2$–OH), Propanal (CH_3CH_2CHO), Propanone (CH_3COCH_3), Propanoic acid (CH_3CH_2COOH) have altogether different nature on account of different functional groups i.e., –OH, –CHO, $>CO$ and – COOH groups respectively.

Organic compounds have been divided into different families on the basis of functional groups present. This makes the study of organic compounds much easier, otherwise it would have been a Herculean task to study five million of organic compounds individually.

Table : Some Important Functional Groups and Corresponding Families

Hetero atom	Functional Group	Structure	Name of the Functional Group	Corresponding Family	Common Example
Halogen (Cl, Br, or I)	–X	–X	Halo	Halogen Compounds	CH_3–CH_2–Br (Ethyl bromide or Bromoethane)
Oxygen	–OH	–O–H	Hydroxyl (–ol)	Alcohols	CH_3–CH_2–OH (Ethyl alcohol or Ethanol)
	–O–R	–O–R	Alkoxy	Ethers	CH_3–CH_2–O–CH_2–CH_3 (Diethyl ether or Ethoxy ethane)
	–CHO		aldehydic (–al)	Aldehydes	CH_3–CHO (Acetaldehyde or Ethanal)
	$>CO$		ketonic (–one)	Ketones	 (Acetone or Propanone)
	–COOH		Carboxylic (–oic acid)	Carboxylic acids	CH_3–COOH (Acetic acid or Ethanoic acid)
Nitrogen	–NH_2		Amino (amine)	Amines	CH_3–CH_2–NH_2 (Ethylamine or Aminoethane)
	–$CONH_2$		Amide	Amides	CH_3–$CONH_2$ (Acetamide or Ethanamide)
	–CN	–C≡N	Nitrile	Cyanides	CH_2CN (Methyl cyanide or Ethane nitrile)
	–NO_2		Nitro	Nitro compounds	C_2H_5–NO_2 (Nitroethane)

HOMOLOGOUS SERIES

The members of a family of organic compounds possess similar or almost similar chemical properties. Their molecular formulae can be given by a general molecular formula e.g. $C_nH_{2n+1}OH$ represents alcohol family i.e., if n = 1 CH_3OH is methyl alcohol, n = 2 C_2H_5OH is ethyl alcohol.

The members of a family arranged in the order of increasing molar mass gives homologous series. The various members of a particular homologous series are called homologues.

Homologous Series of Alkanes (C_nH_{2n+2})

Value of n	Molecular formula	Strcutural Formula	Molar Mass	IUPAC Name
1.	CH_4	CH_4	16	Methane
2.	C_2H_6	$CH_3–CH_3$	30	Ethane
3.	C_3H_8	$CH_3–CH_2–CH_3$	44	Propane
4.	C_4H_{10}	$CH_3–CH_2–CH_2–CH_3$	58	Butane
5.	C_5H_{12}	$CH_3–CH_2–CH_2–CH_2–CH_3$	72	Pentane

Characteristics of Homologous Series :

The characteristics of a homologous series are as follows :

(i) All the members of a homologous series are represented by the same molecular formula. For example, all the members of alkane, alkene and alkyne series can be represented by the general formula C_nH_{2n+2}, C_nH_{2n} and C_nH_{2n-2} respectively where n may have the value 1, 2, 3, …. For alkanes and n = 2, 3, 4, …. For alkenes and alkynes.

(ii) The two successive members of a homologous series differ by $–CH_2$ group in their molecular formulae.

(iii) The molecular mass of a compound in the series differs by 14 amu ($CH_2 = 12 + 2 \times 1 = 14$) from that of its nearest neighbour.

(iv) All the members of a series have the same functional group.

(v) The physical properties such as density, melting point, boiling points, solubility, etc., of the members of a homologous series show almost regular variation in ascending or descending the series.

(vi) Homologues show similar chemical properties.

NOMENCLATURE OF ORGANIC COMPOUNDS

Boost your knowledge

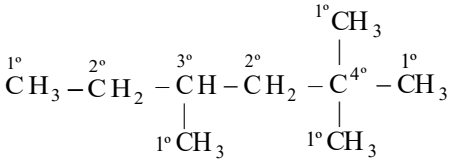
☛ Primary, secondary, tertiary and quaternary carbon atoms :

(i) C atom attached with one carbon atom is primary C atom or 1º carbon atom.

(ii) C atom attached with two carbon atoms is secondary C atom or 2º carbon atom.

(iii) C atom attached with three carbon atoms is tertiary C atom or 3º carbon atom.

(iv) C atom attached with four carbon atoms is quaternary C atom or 4º carbon atom.

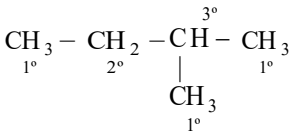


☛ Primary, Secondary and Tertiary H-atoms :

(i) H-atoms attached on 1ºC atom are primary H-atoms or 1ºH.

(ii) H-atoms attached on 2ºC atom are secondary H-atoms or 2ºH.

(iii) H-atoms attached on 3ºC atom are tertiary H-atoms or 3ºH.



☛ Reactivity order of primary, secondary and tertiary H-atoms :

Relative reactivity order : 3ºH > 2ºH > 1ºH

IUPAC Name :

In 1969, IUPAC (International Union of Pure and Applied Chemistry) convention led out the following rules to name organic compounds. In 1993, on the basis of recommendations of IUPAC, some changes were also made at basic level which have also been incorporated.

(A) General Rules for IUPAC Nomenclature :

According to the IUPAC system, the name of an organic compound, in general, has the following three parts :

(i) Word root (ii) Suffix (iii) Prefix

1. Word root :

The word root, a basic unit of the name represents the number of carbon atoms in the parent chain Parent chain is the longest possible continuous chain of carbon atoms containing maximum possible functional groups and multiple bonds present in the molecules. For organic compounds containing parent chains upto four carbon atoms (C_1 – C_4) special word roots are used, while for compounds containing parent chains having more than four carbon atoms Greek number roots are used.

Table : Word Roots for Carbon Chains

Chain Length	Word root	Chain length	Word root
C_1	Meth–	C_6	Hex–
C_2	Eth–	C_7	Hept–
C_3	Prop–	C_8	Oct–
C_4	But–	C_9	Non–
C_5	Pent–	C_{10}	Dec–

2. Suffix :

The suffix in word roots are added to show the main functional group (principal group). The multiple bonds present in the given compound are indicated by adding specific suffixes to the word root. The two types of suffix are used for this purpose.

(i) Primary suffix : The suffix used to represent the multiple bonds i.e. saturation or unsaturation of carbon atoms present in the parent chain is called a primary suffix.

Table : Primary Suffixes

Nature of carbon chain	Primary suffix	General name
Saturated (C–C)	–ane	Alkane
Unsaturated, having one double boind (C=C)	–ene	Alkene
Unsaturated, having one triple bond (C≡C)	–yne	Alkyne

If the parent carbon chain contains more than one double or triple bonds, their number is indicated by numerical prefixes such as di (for two), tri (for three), tetra (for four) etc.

E.g. $CH_3 – CH=CH_2$ Propene

$CH_2 = CH – CH = CH_2$ Butadiene

(ii) Secondary suffix : Secondary suffix represents the nature of principal functional group present in the compound.

Table : Secondary Suffixes of Some Common Functional Groups

Organic Compounds	General formula	Functional group	Seconary suffix	IUPAC name word root + p-suffix + s-suffix
Alcohol	R–OH	–OH	–ol	Alkanol
Aldehyde	R–CHO	–CHO	–al	Alkanal
Ketone	R–CO–R		–one	Alkanone
Carboxylic acid	R–COOH	–COOH	–oic acid	Alkanoic acid
Acid chloride	RCOCl	–COCl	–oyl chloride	Alkanoyl chloride
Amide	$RCONH_2$	$–CONH_2$	–amide	Alkanmide
Ester	RCOOR	–COOR	–oate	Alkanoate
Nitrile	RCN	–CN	–nitrile	Alkane nitrile
Amine	RNH_2	$–NH_2$	–amine	Alkanamine
Thiol	RSH	–SH	–thiol	Alkanethiol

A secondary suffix is added to the primary suffix according to the following convention.

(i) If the secondary suffix begins with a vowel, the terminal 'e' of the primary suffix is dropped while adding secondary suffix to the primary suffix.

(ii) If the secondary suffix begins with a consonant, the terminal 'e' of the primary suffix is retained while adding secondary suffix to the primary suffix i.e. alkane nitrile and alkane thiol.

(iii) The terminal 'e' of primary suffix is also retained if some numerical prefixed like di, tri, etc., are used before the secondary suffix.

(iv) In case of more than one double (=) bonds are present, only 'ne, is replaced by diene, diyne and so on …. e.g. IUPAC name of $CH_2 = CH - CH = CH_2$ is Buta-1,3-diene.

Table : IUPAC Rules for Addition of Primary and Secondary Suffix in parent hydrocarbon.

Compound	Word root	Primary suffix	Secondary suffix	IUPAC name (Word root + P– suffix + S– suffix)
CH_3CH_2OH	Eth–	–ane [Rule (i)]	–ol	Ethanol
CH_3CH_2COOH	Prop–	–ane [Rule (i)]	–oic acid	Propanoic acid
CH_3CN	Eth–	–ane [Rule (ii)]	–nitrile	Ethanenitrile
$HOCH_2CH_2OH$	Eth–	–ane [Rule (ii)]	–diol	Ethanediol
$CH_3CH_2CH_2SH$	Prop–	–ane [Rule (iii)]	–thiol	Propanethiol
$CH_3CH=CH=CH_2$	But–	–ene [Rule (iii)]	–	Buta-1,2-diene

3. Prefix :

The alkyl groups and functional groups other than the principal functional group are regarded as substituents or side chain. Their presence is indicated by writing suitable prefixes before the word root.

Table : Some Alkyl Groups and Their Prefixes

Parent alkane	Alkyl group	Common name	Prefix used in IUPAC name
CH_4 (Methane)	CH_3–	Methyl	Methyl
CH_3–CH_3 (Ethane)	CH_3–CH_2–	Ethyl	Ethyl

Table : Some Substituents and their Prefixes

Substituent	Prefix
–Cl	Chloro–
–Br	Bromo–
–I	Iodo–
–F	Fluoro–
–NO	Nitroso–
$–NO_2$	Nitro–
–OR	Alkoxy–

Therefore in writing the complete IUPAC name of a compound following points should be obeyed.

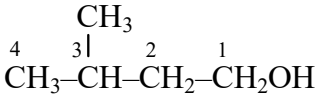
(i) The arrangement of the different parts of the name is as follows.
Prefix (es) + Word root + Primary suffix + Secondary suffix

(ii) Prefixes are arranged in alphabetical order and are separated by hyphen (–).

(iii) The position of prefixes, double bond, triple bond, or functional group is represented by putting a suitable Arabic numeral immediately before them.

(iv) In case of cyclic compounds, the prefix cyclo is written immediately before the word root.

Example :



3 – methyl ....but.... … an* ..... 1..... –ol
(Prefix) (Wordroot) (P.suffix) (Positionof Functionalgroup) (S.suffix)

i.e. IUPAC name of the given compound is 3-methybutan-1- ol

Where, * = if the secondary suffix start with a vowel then terminal 'e' of primary suffix is omitted.

(B) Nomenclature Of Open Chain Hydrocarbons :

(a) Straight Chain Alkanes :

The straight chain alkanes are named including the number of carbon atoms present in them. The names of such compounds end with –ane. Thus, the name of a straight chain alkane consists only two parts-word root and primary suffix. Thus CH_4, C_2H_6, C_3H_8 are called Methane, Ethane and Propane respectively.

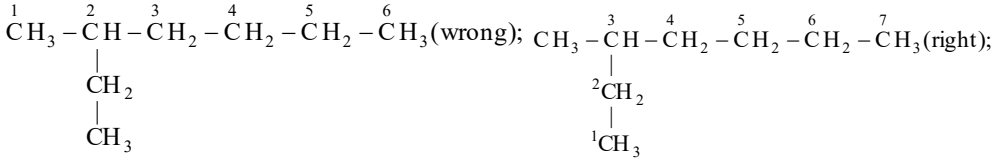
(b) Alkanes and their substituents :

In a branched chain alkane, all carbon atoms are not present in the straight chain. Some of the carbon atoms are presents in side chains at one or more positions. The side chains i.e., alkyl groups are expressed as prefixes in the IUPAC name of the compound.

(i) Longest chain rule :

- The longest continuous chain of carbon atoms is selected as the parent hydrocarbon. The compound is then named as a derivative of the parent hydrocarbon.

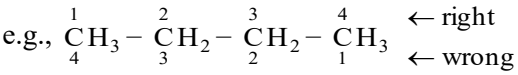
Example.



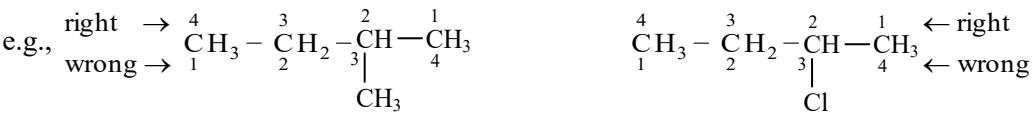
- If more than one set of longest possible chain are possible then the selected longest chain which should have maximum number of side chain

(ii) Lowest number rule :

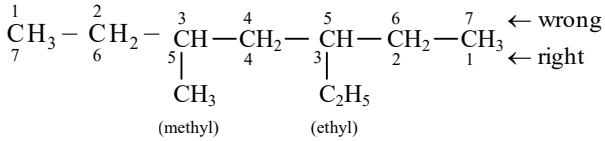
- The selected chain is numbered in terms of arabic numbers from one end to other.

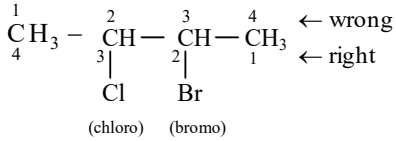
e.g., 

- Lowest number is assigned to the first side chain (alkyl group) or substitutent (–Cl, Br, –I, $–NO_2$).

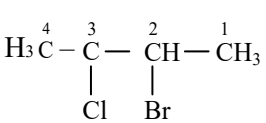
e.g., 

- If two different substituents are at the same position from opposite ends, lowest number is given in order of their alphabets.

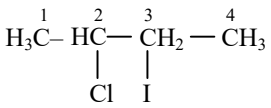
e.g., 

e.g., 

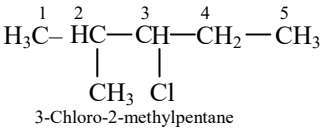
- If more than two substituents and side chains are present, the sum of their numbers should be lowest at the first preference, irrespective of the nature of side chain or substitutents,



2-Bromo-3-chlorobutane

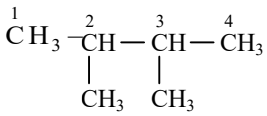


2-Chloro-3-iodobutane

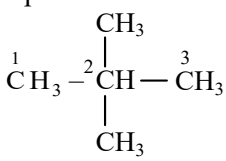


3-Chloro-2-methylpentane

- If more than one similar alkyl chains or substituents are present names are suitably modified by putting di, tri, …. terms. While arranging the substituents alphabetically, these prefixes di, tri etc. are not considered.

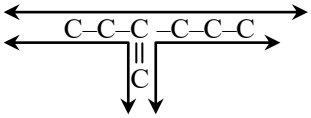
 i.e., 2,3-Dimethylbutane

- If more than one similar alkyl groups. Or substituents are present, at same position, their no. is also repeated.

 i.e., 2,2-Di methylpropane

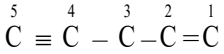
(c) Alkenes, Alkyes and their derivatives :

(i) Select the longest possible carbon chain having maximum member of unsaturated carbon atoms or maximum number of double or triple bonds, even if prior rules are violated.



- 6 with the unsaturated C atom or no double bond. (wrong).
- 5 with two unsaturated C atom or one double bond. (right).
- 4 with two unsaturated C atom or one double bond. (wrong)

(ii) If double and triple bonds are at the same position from either ends, lowest number is assigned to the double bond.



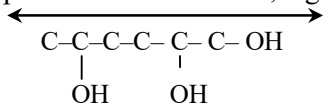
(iii) In case of unsaturation suffix name of unsaturation is used with hydrocarbon name, i.e.,
In case of double (=) bond 'ane' of hydrocarbon is replaced by 'ene' and
Triple bond (≡) bond 'ane' of hydrocarbon is replaced by 'yne'

(iv) In case of more than one multiple bond of the same kind prefixes like di, tri etc. are used with the suffix.
$CH_3–CH=C=CH_2$ Buta-1,2-diene

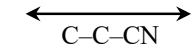
Boost your knowledge
☛ If double and triple bonds are present in a compound (i.e., two suffix are to be used for compound containing both the unsaturation), it is named as Alkenyne.

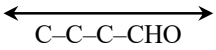
(d) For Functional groups :

(i) Select the longest possible carbon chain having maximum number of functional groups even if prior rules are violated, e.g.,

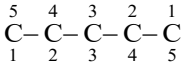


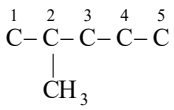
(ii) The carbon atom of functional group is to be included in deciding the longest carbon chain

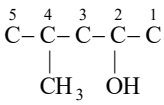
 3C atom chain

 4C atom chain

(iii) Lowest number is assigned to functional group even if prior rules are violated.

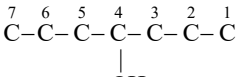


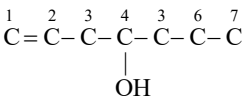


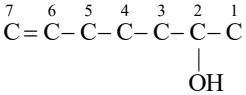


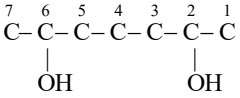
(iv) The order for numbering a carbon chain, thus, follows the order :

(a) Functional group
(b) Unsaturation
(c) Substituents and side chains (or alkyl groups)

 Lowest number to OH gp.

 OH at equidistant from two ends and thus, Next lowest number to unsaturated

 Lowest number to OH gp.

 Lowest number to OH gp.

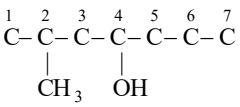
 OH at equidistant from two ends and thus, next lowest number to alkyl group.

Table : Functional groups, their prefixes and suffixes

Functional group	Prefix name	Suffix name
–COOH	carboxy	–oic acid
$-SO_3H$	sulpho	–sulphonic acid
–COOR	alkoxy carbonyl	–oate
–COX	halo carbonyl	–oyl halide
–CN	cyano	–nitrile
$-CONH_2$	carbamoyl	–amide
–NC	isocyano	–isonitrilic
–CHO	aldo or formo	–al
>CO	keto or oxo	–one
–OH	hydroxy	–ol
–SH	mercapto	–thiol
$-NH_2$	amino	–thiol
–OR	alkoxy	…\

(v) If more than one kind of functional groups are present, the functional group placed above, i.e., principal functional group decides suffix name and the others placed below decide prefix name.

$CH_3-C(=O)-COOH$ — 2–ketopropanoic acid

$CH_3-C(=O)-CH_2OH$ — 1–hydroxypropan–2–one

$CH_3-C(=O)-CHO$ — 2–ketopropanal

(vi) The last 'e' of primary suffix is replaced by the suffix name of functional group.

CHEMICAL REACTIONS OF CARBON COMPOUNDS

Combustion or oxidation in air :

The burning of a compound in the excess of oxygen or air is called combustion. It is always exothermic process and releases energy in the form of heat and light. Combustion reactions are infact the oxidation reactions. E.g.,

$$C + O_2 \rightarrow CO_2 + \text{Heat}$$

All allotropic forms of carbon burns in oxygen to give carbon dioxide, liberating heat and light. Carbon compounds being combustible evolve a large amount of heat and light. This is why carbon and several carbon compounds are used as fuels.

Saturated hydrocarbons burn with a blue, non-sooty flame due to low percentage of carbon in them and the entire carbon present in them gets completely oxidized during combustion. Higher alkanes also burn with a blue non-sooty flame and thus are used as fuels. e.g.,

$$\underset{\text{Methane}}{CH_4(g)} + \underset{\text{Oxygen(from air)}}{2O_2(g)} \rightarrow CO_2(g) + 2H_2O(\ell) + \text{Heat and Light}$$

$$\underset{\text{Ethane}}{2C_2H_6(g)} + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(\ell) + \text{Heat and Light}$$

$$\underset{\text{Propane}}{C_3H_8} + 5O_2(g) \rightarrow 3CO_2 + 4H_2O(\ell) + \text{Heat and Light}$$

Unsaturated hydrocarbons burn in air with a yellow and sooty flame with lots of black smoke, due to higher percentage carbon in them. During the process of combustion, the entire carbon present in them is not completely oxidized and the flame contains smoke due to the presence of unburnt carbon. i.e.,

$$\underset{\text{Ethene}}{C_2H_4(g)} + \underset{\text{Oxygen(from air)}}{3O_2(g)} \rightarrow 2CO_2(g) + 2H_2O(\ell) + \text{Heat and Light}$$

$$\underset{\text{Benzene}}{2C_6H_6(g)} + 15O_2(g) \rightarrow 12CO_2(g) + 6H_2O(\ell) + \text{Heat and Light}$$

Disadvantages of incomplete combustion of fuel :

(i) Fuel on burning under insufficient supply of oxygen leads to unburnt carbon in the form of black soot causing air pollution as well as block chimneys in factories.
(ii) The black soot so formed blackens the bottom of cooking utensils.
(iii) Formation of highly dangerous and poisonous carbon monoxide.
(iv) Leading to less heat generation.

Boost your knowledge

☛ Formation of coal and petroleum :

Coal and petroleum are fossil fuels formed from remains of plants and animals which has undergone many of biological and geological processes over millions of years. It is believed that coal is formed by the burial of different types of plants that lived millions of yeas ago into the earth on account of natural disturbances like earthquakes or volcanic eruptions. These underwent slow combustion under pressure between the layers of earth due to high temperature prevailing inside and changed into coal. Other carbon forms as oil and gas have been formed in the same way from the remains of dead plants and animals. The bodies of plants and animals sank in the sea bed and got covered by silt. Bacteria turned them into oil and gas under the high pressure of sea water. In due course of time, the slit slowly changed into porous rock. The oil and gas seeped into the pores of the rock and got trapped there. The natural oil and gas thus came into existence.

Oxidation :

Oxidation is a process in which oxygen is added to a substance. The substances which add oxygen to other substances are called oxidizing agents. There are many oxidizing agents such as alkaline potassium dichromate ($K_2Cr_2O_7$), nitric acid (HNO_3), acidified potassium dichromate used in organic chemistry.

$$\underset{\text{Ethyl alcohol}}{CH_3CH_2OH(\ell)} + \underset{\substack{\text{Nascent oxygen}\\ \text{(From the oxidising agent)}}}{(O)} \xrightarrow[\text{or acidified } K_2Cr_2O_7\text{, Heat}]{\text{Alkaline } KMnO_4\text{, Heat}} \underset{\substack{\text{Acetic acid}\\ \text{(a carboxylic acid)}}}{CH_3COOH(\ell)}$$

Alkaline $KMnO_4$ or acidified $K_2Cr_2O_7$ provides oxygen to ethyl alcohol and are known as oxidizing agents.

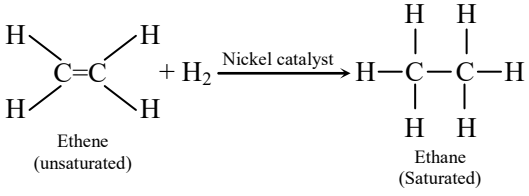
Addition Reactions :

The unsaturated molecules containing a double bond or triple bond show reactions in which they add molecules across the multiple bonds. These are called addition reactions.

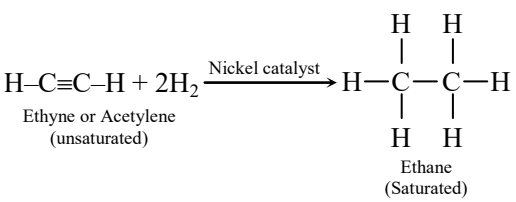
Addition reactions (e.g., addition of hydrogen, addition of chlorine, addition of HCl etc.) are the characteristic reactions of unsaturated compounds. During addition reaction cleavage of one of the bond (double bond or triple bond) takes place and an attacking species adds to the molecule of an unsaturated compound at the site of its double or triple bond.

(a) Addition of hydrogen on unsaturated hydrocarbons :

Unsaturated hydrocarbons add hydrogen in the presence of a catalyst palladium or nickel. A catalyst is the substance which alters the rate of a chemical reaction providing a new pathway for reaction without being used up in the reaction. e.g.,



Ethene (unsaturated) → Ethane (Saturated)



Ethyne or Acetylene (unsaturated) → Ethane (Saturated)

In the first reaction, the molecule of ethene adds one H-atom on each carbon by cleavage of the double bond. Thus, a hydrogen molecule is added at the site of the double bond and ethene (an unsaturated hydrocarbon) changes to ethane (a saturated hydrocarbon). In the second reaction, the ethyne molecule adds two hydrogen molecules at the site of triple bond to form ethane.

Boost your knowledge

The addition of hydrogen to an unsaturated compound to obtain a saturated compound is called hydrogenation and is largely used in the preparation of margarine (Vegetable Ghee or Vanaspati Ghee) from edible vegetable oils.

Hydrogenation of Oils :

Vegetable oils such as groundnut oil, soyabean oil, cotton seed oil, (liquids at room temperature) etc., are unsaturated organic compounds having many double bonds between the carbon atoms in their molecules.

Hydrogenation of vegetable oils is carried out by heating them with hydrogen in the presence of nickel as catalyst. In this process, double bonds present in the oil change into single bonds due to addition of hydrogen at their sites and the oil gets solidified as semi solid mass into a saturated fat called Vanspati Ghee.

$$\underset{\text{unsaturated oil (Liquid at room temp.)}}{\text{Edible oil}} + H_2 \xrightarrow[\text{Heat}]{\text{Nickel}} \underset{\text{(saturated fat) (solid at room temp.)}}{\text{Vanaspati Ghee}}$$

However saturated fats thus obtained by the hydrogenation of edible oils are not good for our health. Animal fats such as butter, butter oil, desi ghee etc., are also said to be harmful for health. Therefore, we should prefer to use those edible oils which are least saturated and contain a higher proportion of unsaturated fatty acids.

(b) Addition of Cl_2 and Br_2 on unsaturated hydrocarbon :

The addition of Cl_2 and Br_2 takes place in the same manner, but the addition of Br_2 on unsaturated hydrocarbons is a test for unsaturation in molecule. 5 % Br_2 – water, a brown solution is used in addition reaction and the colour of Br_2 – water disappears.

$$CH_2 = CH_2 + (Br_2 \text{ - water}) \xrightarrow{CCl_4} CH_2Br - CH_2Br$$

$$H_2C = CH_2 + Cl_2 \longrightarrow CH_2Cl - CH_2Cl$$

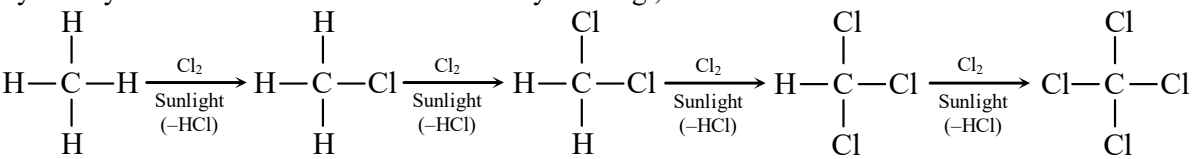
Similarly on addition of Br_2 – water to cooking oil, the colour of Br_2 – water disappears. This confirms that oils contain unsaturated molecules or compounds. On the other hand butter does not decolorizes Br_2 – water showing saturation nature.

(D) Substitution Reactions :

The reactions involving replacement of an atom or group of atoms present in a compound by some other atom or group without bringing any change in the structure of the compound, are called substitution reactions.

Saturated hydrocarbons are less reactive and remain inert for most of the reagents. However, they undergo substitution reaction under specific sets of conditions.

Substitution reactions involving replacement of one or more H-atoms of an alkane with chlorine in the presence of sunlight are also referred to as chlorination. An alkane on treating with chlorine in the presence of sunlight shows replacement of all the hydrogen atoms present in the alkane molecule one by one by chlorine atoms. The reaction is very fast. e.g.,



Chlorination of methane, therefore gives a mixture of chloromethane, dichloromethane, trichloromethane and tetrachloromethane to give a large number of products.

SOME IMPORTANT ORGANIC COMPOUNDS

(A) Ethanol (Ethyl Alcohol), C_2H_5OH

It belongs to alcoholic family of organic compounds.

(a) Physical Properties of Ethanol (Ethyl Alcohol):

(i) Ethyl alcohol is a colourless liquid having boiling point 351.3 K.

(ii) It possesses characteristic smell and a burning taste.

(iii) It is miscible in water in all proportions.

(iv) It has a stimulant effect followed by depressant and anesthetic action on the central nervous system.

(v) It is a good solvent for fats, oils, paints, etc. and for several inorganic substances like NaOH, KOH, sulphur, phosphorus, etc.

(b) Chemical Properties of Ethanol (Ethyl alcohol) :

The chemical properties of ethanol are mainly due to alcoholic (–OH group) group.

(i) Reaction with sodium : Ethanol reacts with sodium (or potassium) to form ethoxide liberating hydrogen gas. This is a test for alcoholic group.

$$\underset{\text{Ethanol (ethylalcohol)}}{2C_2H_5OH} + 2Na \longrightarrow \underset{\text{Sod. ethoxide}}{2C_2H_5ONa} + H_2\uparrow$$

Experiment : A small piece of sodium metal is added into 100% pure ethanol (absolute alcohol) taken in a dry test tube. Rapid effervescence due to evolution of a gas are noticed. On bringing a burning splinter near the mouth of test tube the gas coming out of the test tube burns with a "pop" sound. This indicates that the gas evolved is hydrogen.

(ii) Reaction with concentrated sulphuric acid (dehydration) : Ethanol on heating with excess of concentrated sulphuric acid at 443 K eliminates a water molecule showing dehydration (removal of water molecule) to form ethene. Concentrated sulphuric acid acts as a dehydrating agent.

$$\underset{\substack{\text{Ethanol}\\(\text{ethyl alcohol})}}{CH_3CH_2OH} \xrightarrow[\substack{443\,K\\(\text{dehydration})}]{\text{conc. } H_2SO_4} \underset{\substack{\text{Ethene}\\(\text{ethylene})}}{CH_2=CH_2} + H_2O$$

(iii) Reaction with ethanoic acid (esterification) : Ethanol reacts with ethanoic acid in the presence of conc. Sulphuric acid to form ethyl ethanoate, (an ester) having fruity smell. This is an other test for alcoholic group in molecule. The reaction is called esterification as it is characterized by the formation of an ester.

$$C_2H_5O\underset{\substack{\text{Ethanoic acid}\\(\text{acetic acid})}}{\boxed{H+HO}}OCCH_3 + \xrightarrow{\text{conc. } H_2SO_4} \underset{\substack{\text{Ethyl ethanate}\\(\text{ethyl acetate})}}{CH_3COOC_2H_5} + H_2O$$

(iv) Combustion : It readily burns in air or oxygen to form carbon dioxide and water.

$$\underset{\substack{\text{Ethanol}\\(\text{ethyl alcohol})}}{C_2H_5OH} + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

Ethanol burns with a blue non-sooty flame and liberates lots of heat and is therefore used as a fuel in spirit lamps. It is a clean fuel as on burning, it gives only carbon dioxide and water which do not cause much pollution. The fossil fuels such as coal, petrol, etc. produce several harmful gases on burning which give rise to serious pollution problems.

(v) Oxidation : Oxidising agents such as acidified potassium dischromate oxidise ethanol to ethanal which further undergoes oxidation to form ethanoic acid.

$$\underset{\substack{\text{Ethanol}\\(\text{ethyl alcohol})}}{CH_3CH_2OH} + [O] \xrightarrow{\text{Alkaline } KMnO_4} \underset{(\text{Acetic acid})}{CH_3CHOOH(\ell)}$$

(c) Uses of Ethanol :

(i) in the manufacture of alcoholic beverages.
(ii) as a fuel for spirit lamps and stoves.
(iii) as a solvent for paints, varnishes, lacquers, dyes, cosmetics, perfumes, drugs, tinctures etc.
(iv) as a starting material for the manufacture of ether, chloroform, iodoform, acetaldehyde, acetic acid etc.
(v) as a substitute of petrol.
(vi) as a preservative for biological specimens.
(vii) as an antifreeze for automobile liquid in thermometers and spirit level.

(d) Commercial forms of Ethanol :

1. Rectified spirit : Rectified spirit is the commercial form of ethanol obtained by the fractional distillation of wash obtained during the manufacture of ethyl alcohol by fermentation. It is usually referred to as industrial alcohol. It contains about 95.57 % ethyl alcohol, rest being water.
2. Absolute alcohol : It is 100 % pure ethanol obtained by azeotropic distillation of rectified spirit using benzene. In azeotropic distillation, rectified spirit is mixed with a suitable quantity of benzene and the mixture is subjected to fractional distillation. The third and the last fraction obtained at 79.1ºC is absolute alcohol i.e., 100 % ethanol.

3. **Methylated spirit or denatured alcohol :** Alcoholic beverages contain ethyl alcohol. Therefore, the manufacture and sale of ethyl alcohol is controlled by the government and heavy excise duty is levied on alcoholic beverages. The alcohol used for various other industrial purposes is however duty free and is sold much cheaper. Therefore, in order to prevent the misuse of cheaper industrial alcohol for drinking purposes, the industrial alcohol is made unfit for drinking by the addition some poisonous substances to it.
   Industrial alcohol is usually made poisonous by the addition of poisonous substances like methyl alcohol, pyridine and some colouring matter. Such a sample of alcohol is called methylated spirit or denatured alcohol. It is poisonous and unfit for drinking.
   This process is known as denaturation and alcohol is known as denatured spirit.
4. Power alcohol : The alcohol used for the generation of power is called power alcohol (a mixture of petrol and alcohol in the ratio of 4 : 1 and little benzene). Since alcohol does not mix with petrol, a third solvent such as benzene, ether or tetrahydronapthalene (tetralin) is also added as a cosolvent. Power alcohol can be used as a substitute for petrol and can meet the everyday increasing demand of gasoline all over the world.

(e) Harmful Effects of Alcohols :

All alcoholic beverages (e.g., Rum, whisky, wine, beer, etc.) contains ethyl alcohol as an essential constituent. People who consume alcoholic beverages everyday become alcohol adduct.

Toxicity of alcohols :

Ethyl alcohol < isopropyl alcohol < methyl alcohol

When taken in small dose, ethanol acts as a stimulant and provides extra energy to the body. But if used in excess it develops damaging effect in human body e.g. acidity to slow down metabolic processes, a depressant and anaesthetic action on the central nervous system. This leads to lack of coordination, mental confusion, drowsiness, lowering of sense of discrimination and finally unconsciousness. Heavy drinking may even lead to death. One should not consume alcohol due to very harmful effects on human body.

(B) Ethanoic Acid (Acetic Acid) CH_3COOH

Ethanoic acid commonly known as acetic acid is the main constituent of vinegar and is known since ancient times. Vinegar widely used as a preservative in pickles, contains 5-8 % of acetic acid solution in water. Ethanoic acid belongs to the carboxylic acid family of organic compounds and has – COOH group.

(a) Physical Properties of Ethanoic acid (Acetic Acid) :

(i) Ethanoic acid is a colourless liquid (b. pt 391 K) with a pungent vinegar odour and sour in taste.
(ii) On cooling pure acid below 290 K, it forms ice-like crystals usually called glacial acetic acid (glacial : ice like).
(iii) It is miscible with water, alcohol and ether in all proportions. It dissolves in water with the evolution of heat and showing contraction in volume of mixture.
(iv) It is corrosive in nature and produces blisters on the skin.
(v) It dissolves sulphur, iodine and many organic compounds.

(b) Chemical Properties of Ethanoic Acid (Acetic Acid) :

The chemical properties of ethanoic acid are mainly due to the presence of carboxyl (–COOH) group i.e. functional group present in all carboxylic acids.

(i) Acidic nature : Ethanoic acid shows acidic nature as it turns a blue litmus paper red.
   Ethanoic acid is a much weaker acid than hydrochloric acid. All carboxylic acids (organic acids) are much weaker acids than the mineral acids (e.g., HCl, H_2SO_4, etc.)
   The mineral acids like HCl are completely ionized and furnish a large number of H^+ ions in solution. On the other hand, carboxylic acids such as CH_3COOH being covalent in nature are weakly dissociated in solution and furnish only a few H^+ ions. This is why carboxylic acids are much weaker acids as compared to the mineral acids.

$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H^+$$

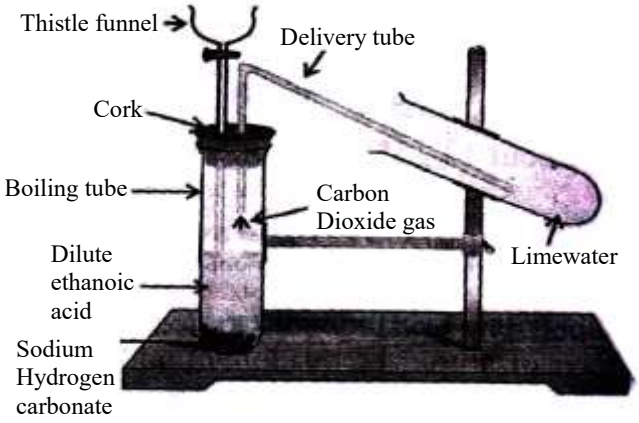
(ii) Reaction with sodium carbonate and sodium hydrogencarbonates : Ethanoic acid reacts with sodium carbonate and sodium hydrogencarbonate to yield a salt, effervescence of carbon dioxide and water.

$$\underset{\text{Ethanoic acid (acetic acid)}}{2CH_3COOH} + \underset{\text{Sodium carbonate}}{Na_2CO_3} \longrightarrow \underset{\text{Sodium ethanoate (Sodium acetate)}}{2CH_3COONa} + \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

$$\underset{\text{Ethanoic acid (acetic acid)}}{CH_3COOH} + \underset{\text{Sodium hydrogencarbonate}}{NaHCO_3} \longrightarrow \underset{\text{Sodium ethanoate (sodium acetate)}}{CH_3COONa} + \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

The evolution of carbon dioxide in the reaction of ethanoic acid with sodium carbonate or sodium hydrogencarboate is used as identification test for carboxylic group (acidic group).

Experiment : Put a little sodium hydrogen carbonate in a boiling tube and set up the apparatus as shown in figure. Now add 2 mL of dilute ethanoic acid through the thistle funnel. Brisk effervescence due to evolution of gas is noticed. On passing the gas in freshly prepared limewater through the delivery tube, the limewater turns milky. Since carbon dioxide turns limewater milky, it may be concluded that the gas evolved is carbon dioxide.



Reaction of ethanoic acid with sodium carbonate

Similar observation can be made by taking sodium carbonate in place of sodium hydrogencarbonate.

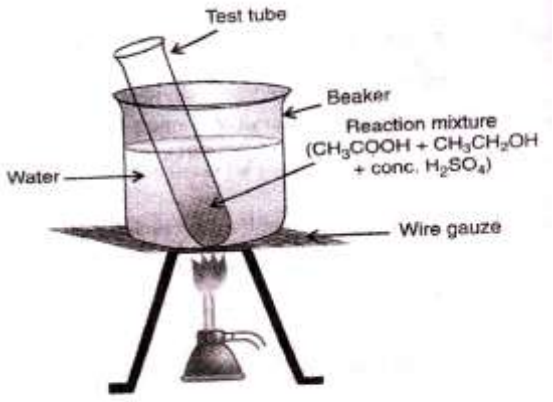
(iii) Reaction with a base (Neutralisation reaction) : Ethanoic acid with alcohols in the presence an acid (conc. H_2SO_4) forms salt and water.

$$\underset{\text{Ethanoic acid (acetic acid)}}{CH_3COOH} + \underset{\text{Sodium hydroxide}}{NaOH} \longrightarrow \underset{\text{Sodium ethanoate (sodium acetate)}}{CH_3COONa} + \underset{\text{Water}}{H_2O}$$

(iv) Reaction with alcohol (Esterification): Reaction of ethanoic acid with alcohol in the presence an acid (conc. H_2SO_4 a dehydrating agent) to form ester is called esterification reaction.

$$\underset{\text{Ethanoic aicd (acetic acid)}}{CH_3-\overset{\overset{O}{\|}}{C}-OH} + \underset{\text{Ethanol (ethyl alcohol)}}{CH_3CH_2OH} \xrightarrow{\text{conc. } H_2SO_4} \underset{\text{Ethyl ethanoate (ethyl acetate) (An ester)}}{CH_3-\overset{\overset{O}{\|}}{C}-O-CH_2-CH_3} + H_2O$$

Experiment : 1 mL of ethanol (absolute alcohol) and 1 mL of glacial acetic acid are taken in a test tube. Now few drops of concentrated sulphuric acid are added to the mixture and the test tube is warmed in a water bath as shown in figure. After sufficient warming, the test tube is taken out of water and on smelling it indicates the presence of an ester in the resulting mixture.



Formation of ethyl acetate

Boost your knowledge

- All esters are sweet-smelling substances and are used in making perfumes and as flavouring agents. The esterification reaction can also be used to identify carboxylic acid.

(c) Uses of Ethanoic Acid :

(i) as a laboratory reagent and as a solvent for carrying out reactions.
(ii) as vinegar.
(iii) in medicine as a local irritant.
(iv) in the manufacture of various dyes, plastics, rayons, silk and perfumes.
(v) as a coagulating agent in rubber industry.
(vi) in the manufacture of acetates, acetone and esters.

(d) Test for Ethanoic Acid :

Ethanoic acid (acetic acid) gives following test :

(i) Its aqueous solution turns blue litmus red.
(ii) Its aqueous solution gives effervescence with sodium hydrogen carbonate.
(iii) On heating with ethyl alcohol and a small amount of sulphuric acid, a fruity smell due to formation of ethyl acetate is noticed.

(f) Hydrolysis of Ester :

(i) Acidic hydrolysis : An ester on heating with water in the presence of a mineral acid under goes hydrolysis to form the parent carboxylic acid and alcohol e.g. ethyl ethanoate on heating with water in the presence of an acid gives ethanoic acid and ethanol back. The reaction is reversible in nature.

$$\underset{\text{Ethyl Ethanoate (ethyl acetate)}}{CH_3COOC_2H_5} + H_2O \overset{H^+}{\rightleftharpoons} \underset{\text{Ethanoic acid (acetic acid)}}{CH_3COOH} + \underset{\text{Ethanol (ethyl alcohol)}}{C_2H_5OH}$$

Thus, acidic hydrolysis of an ester is the reverse of the esterification process.

(ii) Alkaline hydrolysis (Saponification) : Hydrolysis of ester carried out in the presence of an alkali such as sodium hydroxide, gives sodium salt of the parent acid and the parent alcohol.

$$\underset{\substack{\text{ethyl ethanoate}\\(\text{ethyl acetate})}}{CH_3COOC_2H_5} + \underset{\substack{\text{Sodium}\\(\text{hydroxide})}}{NaOH} \longrightarrow \underset{\substack{\text{Sodium ethanoate}\\(\text{sodium acetate})}}{CH_3COONa} + \underset{\substack{\text{Ethaol}\\(\text{ethyl alcohol})}}{C_2H_5OH}$$

The alkaline hydrolysis of esters is known as saponification and is used in the preparation of soaps.

SOAPS AND DETERGENTS

Surfactants are the substances which possess surface activity i.e., these reduce the surface tension of water. Soaps and detergents are the substances which possess surface activity as well as detergency (cleansing action). The term detergent was originated from Latin word (detergere-to wipe clean).

Soaps and synthetic detergents are commonly used cleaning agents and improve the cleansing properties of water by easily removing oily dirt present on clothes or skin.

(A) Soaps :

Soaps are anionic class of detergents. The commonly used soaps are the sodium or potassium salts of higher fatty acids such as palmitic acid, stearic acid, oleic acid, etc.

Preparation of Soaps :

The soaps are usually prepared by saponification of oils and fats i.e. the hydrolysis of an oil or fat with an alkali (sodium hydroxide or potassium hydroxide). Oils and fats are glyceryl esters of fatty acids and are mixed glycerins.

Sodium soaps are prepared by heating an oil or a gas with aqueous sodium hydroxide solution.

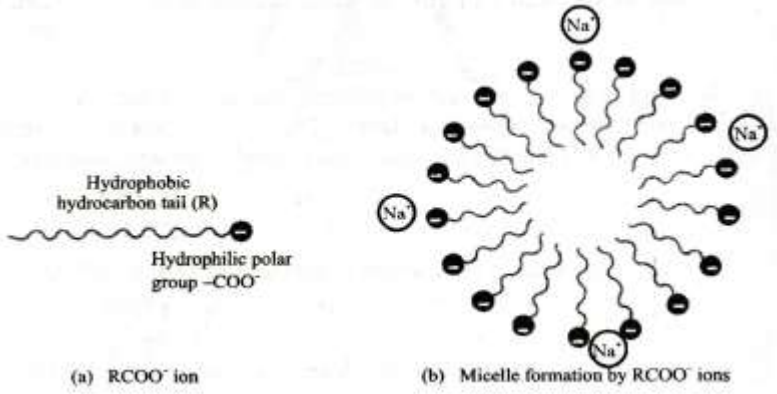
$$\underset{\substack{\text{Glyceryl ester of Steric Acid (fat)}}}{\begin{array}{l} CH_2{-}O{-}\overset{\overset{O}{\|}}{C}{-}C_{17}H_{35} \\ \quad\vert \\ HC{-}O{-}\overset{\overset{O}{\|}}{C}{-}C_{17}H_{35} \\ \quad\vert \\ CH_2{-}O{-}\overset{\overset{O}{\|}}{C}{-}C_{17}H_{35} \end{array}} + 3NaOH \longrightarrow \underset{\text{Sodium stearate (soap)}}{3C_{17}H_{35}COONa} + \underset{\substack{\text{Glycerol}\\(\text{or Glycerine})}}{\begin{array}{l} CH_2OH \\ \vert \\ CHOH \\ \vert \\ CH_2OH \end{array}}$$

(B) Cleasing Action of Soaps :

Soaps are widely used as cleansing agents. The cleansing action of a soap is mainly due to its ability to emulsify the greasy or oil dirt through micelle formation. The mechanism of micelle formation in soap solution and the cleansing action of soaps are described below.

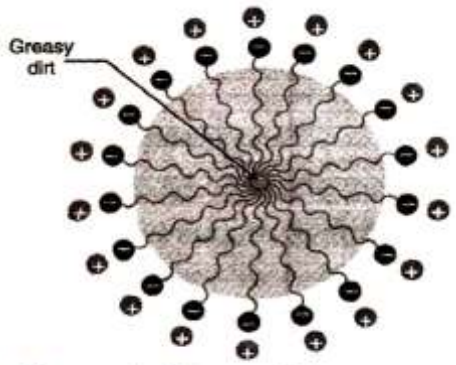
1. **Micelle formation in soap solution :** A soap can be represented as RCOONa, where R represents a long chain alkyl group. When dissolved in water soap ionises to give $RCOO^-$ ion. The $RCOO^-$ ion possesses two parts-long hydrocarbon chain R (tail) and the polar group $–COO^-$ as shown in figure. The hydrocarbon tail R being non polar and is hydrophobic i.e., water repelling whereas the $–COO^-$ group being polar is hydrophilic i.e., water loving. Therefore $RCOO^-$ ion orients itself in such a way that $–COO^-$ end dips in water and the hydrocarbon tail R orients away from water. The $–COO^-$ group of different $RCOO^-$ ions tends to stay far away from one another due to the like charges whereas the R-groups try to approach each other to form a bunch. This leads to the formation of a micelle as shown in figure.

$$RCOONa \xrightarrow{H_2O} RCOO^- + Na^+$$



Thus, a soap micelle is a negatively charged colloid particle in which the negatively charged $–COO^-$ groups present at the surface whereas the hydrocarbon chains point towards the centre. The $–COO^-$ groups present at the surface of the micelle get surrounded by Na^+ ions which tend to drag the micelle in the bulk of the solution. A micelle may contain as many as 100 molecules or more. The minimum concentration of soap at which it forms micelle may contain as many as 100 molecules or more. The minimum concentration of soap at which it forms micelle is called critical micelle concentration or CMC.

The cleansing action of soaps : Water is not capable of wetting oily or greasy substances. However, the hydrocarbon residue R of the soap anion ($RCOO^-$) can do so. When dirty cloth due to the deposition (hydrophobic) of $RCOO^-$ ion dissolves the non polar impurities of oily or greasy dirt and encapsulate it in cleaning action of soap is shown in figure.



Soap micelle containing greasy dirt

(C) Limitation of Soaps as Cleansing Agents in Hard Water :

No doubt the soaps are capable of removing greasy dirt from a dirty article and are therefore, widely used as cleansing agents. Their cleansing action with soft water is good but not with hard water.

The commonly used soaps are the sodium and potassium salt of higher fatty acids. They are soluble in water to give 100 % ionization. The $RCOO^-$ ions so formed shows micellization and give good lather in solution.

Hard water contains Ca^{2+} and Mg^{2+} ions. When a sodium or potassium soap is added to hard water, it gets converted into a insoluble calcium or magnesium soap.

$$2RCOONa + \underset{\text{(From hard water)}}{Ca^{2+}} \longrightarrow \underset{\substack{\text{Calcium soap}\\ \text{(insoluble in water)}}}{(R-\overset{\overset{O}{\|}}{C}-O^-)_2\,Ca^{2+}} + 2Na^+$$

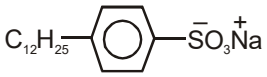
$$\underset{\substack{\text{Sodium soap}\\ \text{(soluble in water)}}}{2R-\overset{\overset{O}{\|}}{C}-O^-Na^+} + \underset{\text{(From hard water)}}{Mg^{2+}} \longrightarrow \underset{\substack{\text{Magnesium soap}\\ \text{(insoluble in water)}}}{(R-\overset{\overset{O}{\|}}{C}-O^-)_2\,Mg^{2+}} + 2Na^+$$

The conversion of soluble sodium or potassium soaps into insoluble calcium or magnesium soaps in the presence of hard water, the common soaps are unable to form micelles till all the Ca^{2+} and Mg^{2+} ions are removed by using excessive amount of soap. Therefore neither they produce lather with hard water nor they remove greasy material from cloth. The calcium and magnesium soaps thus produced, appear on the surface as insoluble sticky grey scum, resulting in decolorisation and hardening of fabrics. This is why the commonly used sodium and potassium soaps cannot be used as cleaning agents with hard water.

(D) Synthetic Detergents (Syndets) :

Now a days, the term detergent is mainly used to denote synthetic detergents or syndets.

The most commonly used synthetic detergents are either anonic such as sodium salts of long chain alkyl substituted benzene sulphonic acids or sodium salts of sulphuric acid ester of long chain aliphatic alcohols or cationic detergents as alkyl ammonium halides.



Sodium p-dodecyl benzenesulphonate

$C_{12}H_{25}-O-SO_2-\bar{O}\overset{+}{Na}$

Sodium lauryl sulphate

Detergent vs. Soaps :

Synthetic detergents are better cleaning agents than soaps due to the following reasons.

(i) Detergents can be used both in soft as well as in hard water as their calcium and magnesium salts are water soluble. On the other hand, soaps form insoluble salts with calcium and magnesium ions and cannot be used in hard water.

(ii) The aqueous solutions of detergents are usually neutral. Therefore, they do not damage delicate fabrics and can be used for washing almost all types of fabrics. On the other hand, aqueous solutions of soap are alkaline and damage delicate fabrics. Therefore, soaps cannot be used for washing delicate fabrics.

Biodegradable and Non-Biodegradable and Pollution :

The detergents having great deal of branching in the hydrocarbon tail are not biodegradable and cause pollution in rivers and waterways. The presence of side chains in the hydrocarbon tail prevents bacteria from attacking and breaking the chain. This results in slow degradation of detergent molecules leading to their accumulation in water.

Efforts are being made of minimize the branching in the detergent molecule in order to make them biodegradable easily. Since unbranched chains are more easily attacked by the bacteria, the detergents having no branching or minimum branching are easily biodegraded and pollution is prevented.