Class $10^{th}$

## CHEMISTRY
## CARBON AND ITS COMPOUNDS

**Introduction:**

The earth's crust has only 0.02% carbon in the form of minerals (like carbonates, hydrogencarbonates, coal and petroleum) and the atmosphere has 0.03% of carbon dioxide. Food, cloths, medicines, books etc. are all based on this versatile nature of element carbon.

**Bonding in Carbon:**

The atomic number of carbon is 6. Its electronic configuration is 2, 4. It requires, 4 electrons to achieve the inert gas electronic configuration.

Carbon cannot form $C^{4-}$ anion because it would be difficult for the nucleus with six protons to hold on to ten electrons, that is, four extra electrons.

Carbon cannot form $C^{4+}$ cation because 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 to just two electrons.

Carbon share its valence electrons with other atoms of carbon or with atoms of other elements. Not just carbon, but many other elements form molecules by sharing electrons in this manner.

**Physical Properties of Organic Compounds:**

Most of the organic compounds have low boiling and melting point, due to the weak force of attraction (i.e., the inter-molecular force of attraction) between these molecules.

Most carbon compounds are poor conductors of electricity, due to the absence of free electrons and free ions.

| Compounds | M.P. (K) | B.P.(K) |
|---|---|---|
| Acetic acid ($CH_3COOH$) | 290 | 391 |
| Chloroform ($CHCl_3$) | 209 | 334 |

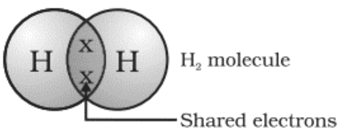
**Covalent Bond:**

The bond formed by mutual sharing of electron pairs between two atoms in a molecule is known as Covalent Bond.

**Types of Covalent Bond:**

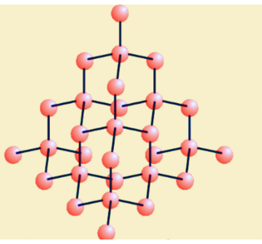
- **Single Covalent Bond:** When a single pair of electrons is shared between two atoms in a molecule.
  For example: $F_2$, $Cl_2$, $H_2$ etc.
- **Double Covalent Bond:** When two pairs of electrons are shared between two atoms in a molecule.
  For example: $O_2$, $CO_2$ etc.
- **Triple Covalent Bond:** When three pairs of electrons are shared between two atoms in a molecule.
  For example: $N_2$ etc.

Two hydrogen atoms share their electrons to form a hydrogen molecule, $H_2$. This allows each hydrogen atom to attain the electronic configuration of the nearest noble gas, helium, which has two electrons in its K shell.



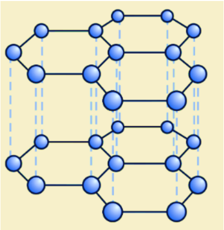

**Allotropes of carbon:**

The different physical forms of the same element which have different physical properties but the same chemical properties. Diamond, graphite and fullerene are the allotropes of carbon. Diamond is the hardest natural substance known while graphite is smooth and slippery. Graphite is also a very good conductor of electricity.



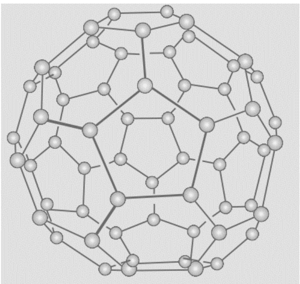
**Structure of Diamond**

In diamond, each carbon atom is bonded to four other carbon atoms forming a rigid three-dimensional structure.



**Structure of Graphite**

In graphite, each carbon atom is bonded to three other carbon atoms in the same plane giving a hexagonal array.



**Structure of C-60 Buckminsterfullerene**

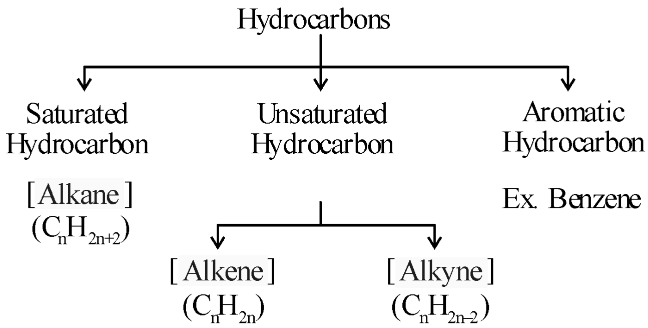
Fullerene looked like the geodesic dome designed by the US architect Buckminster Fuller, the molecule was named fullerene.

## VERSATILE NATURE OF CARBON:

**(i) Catenation:** The unique ability of carbon to form bonds with other atoms of carbon, giving rise to large molecules. These compounds may have long chains of carbon, branched chains of carbon or even carbon atoms arranged in rings. Only Silicon also forms compounds with hydrogen which have chains of upto seven or eight atoms, but these compounds are very reactive.

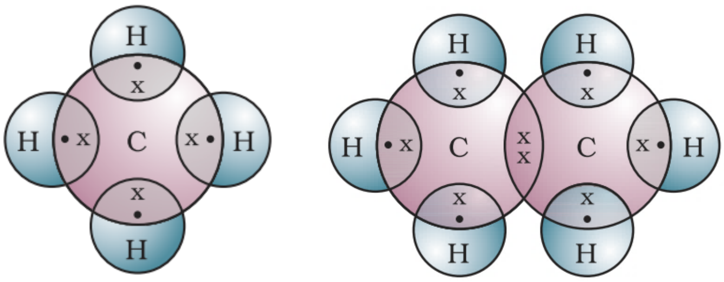
**(ii) Tetravalency:** With the valency of four, carbon is capable of bonding with four other atoms.
The compounds formed by carbon are exceptionally stable because the bonds that carbon forms with most other elements are very strong because of its small size.

**(iii) Multiple Bond formation:** Carbon can form multiple bonds (C=C, C≡C, C≡N) with other carbon atoms and with atoms of another elements.



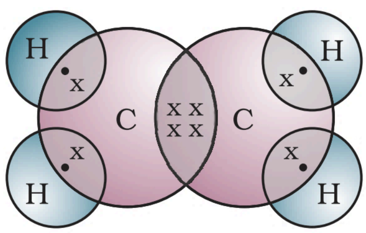

**Hydrocarbons:** Compounds of carbon and hydrogen are known as hydrocarbons.
For example: Methane ($CH_4$), Ethane ($C_2H_6$), Ethene ($C_2H_4$), Ethyne ($C_2H_2$) etc.

**Saturated Hydrocarbon (Alkanes):** General formula is $C_nH_{2n+2}$.
n = number of carbon atoms.
In this, the carbon atoms are connected by only a single bond.
For example: Methane ($CH_4$), Ethane ($C_2H_6$) etc.



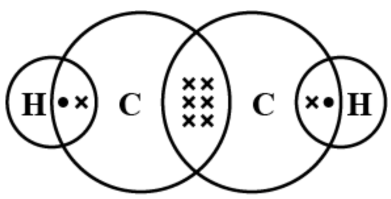
**Electron dot structure of Methane and Ethane**

**Unsaturated Hydrocarbons**
**Alkenes:** General formula is $C_nH_{2n}$, where n = number of carbon atoms.
In this, the two carbon atoms are connected by double bond.
For example: Ethene ($C_2H_4$)



**Electron dot structure of Ethene**

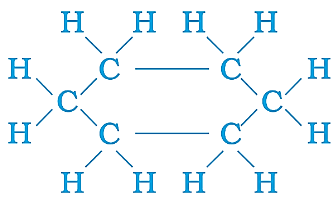
**Alkynes:**
General formula is $C_nH_{2n-2}$, where n = number of carbon atoms. In this, the two carbon atoms are connected by triple bond.
For example: Ethyne ($C_2H_2$)



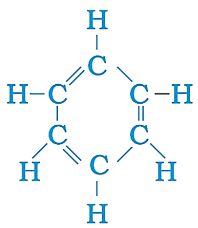
**Electron dot structure of Ethyne**

Some compounds have carbon atoms arranged in the form of a ring.

For example, cyclohexane has the formula $C_6H_{12}$ and the following structure:



Aromatic cyclic compound: Benzene



Benzene — $C_6H_6$

**Homologous Series:** Series of organic compounds having the same functional group and chemical properties and successive members differ by a $CH_2$ unit or 14 mass units are known as Homologous series.

Homologous series of Alkane, Alkene and Alkyne:

**Alkane:** Methane ($CH_4$)

Ethane ($CH_3 - CH_3$)

Propane ($CH_3 - CH_2 - CH_3$)

**Alkene:** Ethene ($CH_2 = CH_2$)

Propene ($CH_3 - C \equiv CH_2$)

**Alkyne:** Ethyne ($CH \equiv CH$)

Propyne ($CH_3 - C \equiv CH$)

**Characteristic of Homologous Series:**

- The successive members in homologous series differ by $CH_2$ unit or 14 mass unit.
- Members of given homologous series have the same functional group.
- All the members of homologous series show similar chemical properties.

**Functional Groups:**

An atom or group of atoms present in a molecule which largely determines its chemical properties is called Functional Group.

| *Hetero atom* | *Class of compounds* | *Formula of functional group* |
|---|---|---|
| Cl/Br | Halo- (Chloro/bromo) alkane | —Cl, —Br (substitutes for hydrogen atom) |
| Oxygen | 1. Alcohol | —OH |
| | 2. Aldehyde | $-C\begin{smallmatrix} \diagup H \\ \diagdown\!\!\diagdown O \end{smallmatrix}$ |
| | 3. Ketone | $-\underset{\underset{\displaystyle O}{\|}}{C}-$ |
| | 4. Carboxylic acid | $-\overset{\overset{\displaystyle O}{\|}}{C}-OH$ |

**Nomenclature of Organic Compounds:**

It is difficult to remember millions of compounds by their individual common name. Thus, to systematize the nomenclature of organic compounds IUPAC (International Union of Pure and Applied Chemistry) has given certain rule which are as follows:

(i) Identify the number of carbon atoms in the compound.

| S.No. | Number of Carbon Atoms | Word Root(-)(Suffix) | Single bond |
|---|---|---|---|
| 1. | One carbon atoms (1-C) | Meth | + ane |
| 2. | Two carbon atoms (2-C) | Eth | + ane |
| 3. | Three carbon atoms (3-C) | Prop | + ane |
| 4. | Four carbon atoms (4-C) | But | + ane |
| 5. | Five carbon atoms (5-C) | Pent | + ane |
| 6. | Six carbon atoms (6-C) | Hex | + ane |

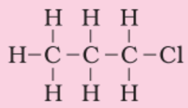
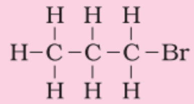
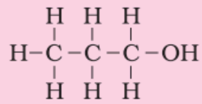
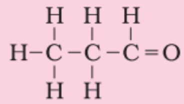
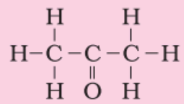
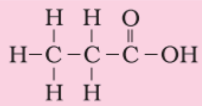
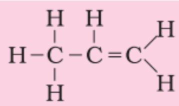
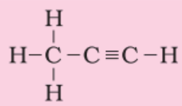
(ii) In case a functional group is present, it is indicated in the name of the compound with either a prefix or a suffix.

| S.No. | Function Group | Prefix | Suffix |
|---|---|---|---|
| 1. | Double bond (=) | – | ene |
| 2. | Triple bond (≡) | – | yne |
| 3. | Chlorine (–Cl) | Chloro | – |
| 4. | Bromine (–Br) | Bromo | – |
| 5. | Alcohol (–OH) | – | ol |
| 6. | Aldehyde (–CHO) | – | al |
| 7. | Ketone(–CO–) | – | one |
| 8. | Carboxylic acid (–COOH) | – | oic acid |

(iii) If the name of the functional group is to be given as a suffix, and the suffix begins with a vowel a, e, i, o, u, then the name of the carbon chain is modified by deleting the final 'e' and adding the appropriate suffix.
For example, a three carbon chain with a ketone group would be named in the following manner:
Propane – 'e' = Propan + 'one' = Propanone

(iv) If the carbon chain is unsaturated, then the final 'ane' in the name of the carbon chain is substituted by 'ene' or 'yne'. For example, a three-carbon chain with a double bond would be called propene and if it has a triple bond, it would be called propyne.

(v) Name the Compounds by Following Order: **Prefix + Word Root + Suffix**

| Class of compounds | Prefix/Suffix | Example | |
|---|---|---|---|
| 1. Halo alkane | Prefix-chloro, bromo, etc. |  | Chloropropane |
| | |  | Bromopropane |
| 2. Alcohol | Suffix - ol |  | Propanol |
| 3. Aldehyde | Suffix - al |  | Propanal |
| 4. Ketone | Suffix - one |  | Propanone |
| 5. Carboxylic acid | Suffix - oic acid |  | Propanoic acid |
| 6. Alkenes | Suffix - ene |  | Propene |
| 7. Alkynes | Suffix - yne |  | Propyne |

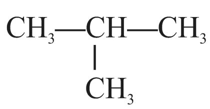
**Isomerism:**

Compounds having the same molecular formula but different structural formula and properties are known as isomers and this phenomenon is known as Isomerism.

Structural Isomers: Compounds having the same molecular formula but different structures are called Structural isomers.

Example: Isomers of butane ($C_4H_{10}$)

(i) $\underset{\text{n-Butane}}{CH_3-CH_2-CH_2-CH_3}$

(ii) 
2-Methylpropane (Isobutane)

Isomers of Pentane ($C_5H_{12}$):

(i) $CH_3-CH_2-CH_2-CH_2-CH_3$
n−Pentane

(ii) $CH_3-CH(CH_3)-CH_2-CH_3$
2-Methyl butane (Isopentane)

(iii) $CH_3-C(CH_3)_2-CH_3$
2,2-Dimethylpropane (Neopentane)

**Chemical Properties of Carbon Compounds:**

The important chemical properties are as follows:

**1. Combustion:** The complete combustion of carbon compounds in the air gives carbon dioxide water, heat and light.

$CH_3CH_2OH(l) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$ + Heat and light

Carbon burns in air or oxygen to give carbon dioxide and heat and light.

$C(s) + O_2(g) \rightarrow CO_2(g)$ + Heat and light

Saturated hydrocarbons burn with a blue flame in the presence of a sufficient supply of air or oxygen.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ + Heat and light

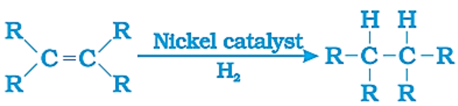
In presence of limited supply of air, saturated hydrocarbon forms a sooty flame.
Unsaturated hydrocarbons burn with a yellow smoky flame.
The gas and kerosene stove used at home has inlet for air so that, burnt to given clean blue flame.
Due to presence of small amount of nitrogen and sulphur, coal produces carbon dioxide with oxides of nitrogen and sulphur which are major pollutant.

**2. Oxidation:** Oxidation of ethanol in presence of oxidizing agents gives ethanoic acid.

$$CH_3-CH_2OH \xrightarrow[\text{Or acidified } K_2Cr_2O_7 \text{ + Heat}]{\text{Alkaline } KMnO_4 \text{ + Heat}} CH_3COOH$$

Alkaline potassium permanganate or acidified potassium dichromate are oxidising alcohols to acids, that is, adding oxygen to the starting material. Hence they are known as oxidising agents.

**3. Addition Reaction:** Addition of dihydrogen with unsaturated hydrocarbon in the presence of catalysts such as nickel or platinum or palladium are known as Hydrogenation (addition) reaction.




Process of converting vegetable oil into solid fat (vegetable ghee) is called Hydrogenation of Oil.

Vegetable oil + $H_2 \longrightarrow$ Vegetable ghee

Animal fats contain saturated fatty acids which are harmful for health.
Vegetable oil containing unsaturated fatty acids are good for health.

**4. Substitution Reaction:** Replacement of one or more hydrogen atom of an organic molecule by another atom or group of the atom is known as Substitution Reaction.

$$\underset{\text{Methane}}{CH_4(g)} + Cl_2(g) \xrightarrow{\text{Sunlight}} \underset{\text{Chloromethane}}{CH_3Cl(g)} + HCl(g)$$

**SOME IMPORTANT CARBON COMPOUNDS:**

**Ethanol ($CH_3CH_2$–OH):**

Commonly known as Ethyl Alcohol.

**Physical Properties**

- It is colourless, inflammable liquid.
- It is miscible with water in all proportions.
- It has no effect on the litmus paper.

**Chemical Properties**

- Reaction with sodium

$$\underset{\text{Ethanol}}{2CH_3CH_2OH} + \underset{\text{Sodium}}{2Na} \longrightarrow \underset{\text{Sodium ethoxide}}{2CH_3-CH_2-O^-Na^+} + \underset{\text{Hydrogen gas}}{H_2\uparrow}$$

- Reaction with concentrated $H_2SO_4$ (Dehydration Reaction)

$$CH_3–CH_2–OH \xrightarrow[H_2SO_4]{\text{Hot conc.}} CH_2 = CH_2 + H_2O$$

Dehydrating agent:

Substances which remove water from other substance (alcohols) is known as Dehydrating agent.

For example: Conc. $H_2SO_4$

**Ethanoic Acid ($CH_3COOH$):**

Commonly known as Acetic acid. 5-8% of ethanoic acid in water is called Vinegar. The melting point of pure ethanoic acid is 290 K and hence, it often freezes in cold climate so named as glacial acetic acid.

**Physical Properties**

- It is a colourless, pungent-smelling liquid.
- Miscible with water in all proportions.
- Turns blue litmus to red.

**Chemical Properties:**

**(i) Esterification Reaction:** Reaction of ethanoic acid with an alcohol in the presence of a few drops of conc. $H_2SO_4$ as catalyst gives a sweet-smelling substance known as Esters, called Esterification reaction.

$$\underset{\text{Ethanoic acid}}{CH_3COOH(aq)} + \underset{\text{Ethanol}}{CH_3CH_2OH(aq)} \xrightleftharpoons{\text{conc. } H_2SO_4} \underset{\text{Ethyl ethanoate (Ester)}}{CH_3COOC_2H_5(aq)} + H_2O(l)$$

Esters are used in making perfumes and flavouring agents.

**Saponification Reaction:**

Reaction of esters with sodium hydroxide, gives alcohol and sodium salt of carboxylic acid (soap). This reaction is known as Saponification Reaction.

$$\underset{\text{Ethyl ethanoate}}{CH_3COOC_2H_5} + \underset{\text{Sodium hydroxide}}{NaOH} \longrightarrow \underset{\text{Ethanol}}{C_2H_5OH} + \underset{\text{Sodium ethanoate(soap)}}{CH_3COONa}$$

**(ii) Reaction with Carbonates and Hydrogen Carbonates:** Ethanoic acid reacts with sodium carbonates and sodium hydrogen carbonates to give rise to a salt, carbon dioxide and water.

$$\underset{\text{Ethanoic acid}}{2CH_3COOH} + \underset{\text{Sodium carbonate}}{Na_2CO_3} \longrightarrow \underset{\text{Sodium ethanoate}}{2CH_3COONa} + H_2O + CO_2$$

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Sodium bicarbonate}}{NaHCO_3} \longrightarrow \underset{\text{Sodium ethanoate}}{CH_3COONa} + H_2O + CO_2$$

**(iii) Reaction with a base:** Ethanoic acid reacts with the base such as sodium hydroxide to give a salt and water.

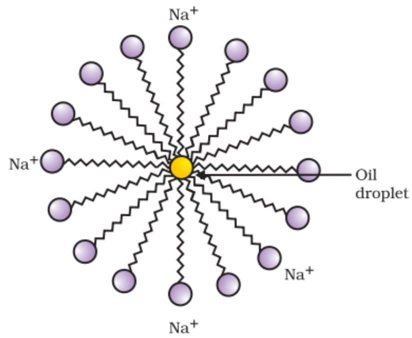
$$NaOH + CH_3COOH \longrightarrow CH_3COO^-Na^+ + H_2O$$

**Soaps:**

Sodium or potassium salts of long chain fatty acids are called Soap.
General formula: $RCOO^-Na^+$
Examples of soaps: Sodium palmitate and sodium stearate

**Formation of micelles:**

Soaps are molecules in which the two ends have differing properties, one is hydrophilic, that is, it interacts with water, while the other end is hydrophobic, that is, it interacts with hydrocarbons (oil). The soap molecules, thus form structures called micelles where cluster of molecules in which the hydrophobic tails are in the interior of the cluster and the ionic ends are on the surface of cluster. This forms an emulsion in water. The soap micelle thus helps in pulling out the dirt in water and we can wash our clothes clean.




**Detergent:**

Detergents are generally sodium salts of sulphonic acids or ammonium salts with chlorides or bromides ions, etc. Both have long hydrocarbon chain. The charged ends of these compounds do not form insoluble precipitates with the calcium and magnesium ions in hard water. Thus, they remain effective in hard water. Detergents are usually used to make shampoos and products for cleaning clothes.
Example of detergent: Sodium lauryl sulfate.