CARBON AND ITS COMPOUNDS
Occurrence of carbon

Carbon is found in the atmosphere, inside the earth’s crust and in all living organisms.

Carbon is present in fuels like wood, coal, charcoal, coke, petroleum, natural gas, biogas, marsh gas etc.

Carbon is present in compounds like carbonates, hydrogen carbonates etc.

Carbon is found in the free state as diamond, graphite, fullerenes etc.
BONDING IN CARBON - COVALENT BOND

The atomic number of carbon is 6, its electronic arrangement is 2,4, it has 4 valence electrons. It can attain stability by gaining 4 electrons, losing 4 electrons or sharing 4 electrons with other atoms. It does not gain 4 electrons because it is difficult for the 6 protons to hold 10 electrons. It does not lose 4 electrons because it needs a large amount of energy to lose 4 electrons. So it shares 4 electrons with other atoms to attain stability resulting in the formation of covalent bonds. Since carbon atom needs 4 electrons to attain stability, its valency is 4 and it is tetravalent.

\[ \text{C} \quad -\quad \text{C} \]
Formation of covalent bonds

Covalent bond is a chemical bond formed by the sharing of electrons between atoms. The sharing of one pair of electrons results in the formation of a single covalent bond, sharing of two pairs of electrons results in the formation of a double covalent bond, and sharing of three pairs of electrons results in the formation of a triple covalent bond.

Eg: Formation of single covalent bond in Hydrogen molecule - $H_2$

The atomic number of hydrogen is 1, its electronic arrangement is 1, it has 1 valence electron. It needs 1 electron more to attain stability. So two hydrogen atoms share 1 pair of electrons resulting in the formation of a single covalent bond in hydrogen molecule $H_2$. 

\[ H^* + H^* \rightarrow H-H \rightarrow H_2 \]
Formation of double covalent bond in oxygen molecule - $O_2$

The atomic number of oxygen is 8, its EC is 2,6, it has 6 VE, it needs 2 electrons more to attain stability. So two oxygen atoms share two pairs of electrons resulting in the formation of a double covalent bond in oxygen molecule $O_2$.

Formation of triple covalent bond in Nitrogen molecule - $N_2$

The atomic number of nitrogen is 7, its EC is 2,5, it has 5 VE, it needs 3 electrons more to attain stability. So two nitrogen atoms share three pairs of electrons resulting in the formation of a triple covalent bond in nitrogen molecule $N_2$. 

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ELECTRON DOT STRUCTURES

Methane molecule – CH₄

Ethane molecule – C₂H₆
Formation of a very large number of carbon compounds

Carbon forms a very large number of compounds. The number of carbon compounds is more than three million. It is more than the number of compounds formed by all other elements. This is because:

1) Carbon atom can form bonds with other carbon atoms to form long chains, branched chains and closed rings. This property is called catenation.

2) Since the valency of carbon is 4, it can form bonds with other carbon atoms or with atoms of other elements like hydrogen, oxygen, nitrogen, halogens etc.

\[
\begin{align*}
\text{Long chain} & \quad - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \\
\text{Branched chain} & \quad - \text{C} - \text{C} - \text{C} - \text{C} - \\
\text{Closed ring} & \quad - \text{C} - \text{C} - \text{C} - \text{C}
\end{align*}
\]
Hydrocarbons, Saturated and Unsaturated hydrocarbons

i) Hydrocarbons :- are compounds containing carbon and hydrogen atoms.

ii) Saturated hydrocarbons :- are hydrocarbons having all single covalent bonds between the carbon atoms.
   Eg : Alkanes :- have all single covalent bonds between the carbon atoms and their names end with – ane.

   ![Methane - CH4 and Ethane - C2H6 Chemical Structures](image)

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iii) Unsaturated hydrocarbons :- are hydrocarbons having a double or triple covalent bond between two carbon atoms. Eg : Alkenes and Alkynes.

Alkenes :- have a double covalent bond between two carbon atoms and their names end with – ene.

\[
\begin{align*}
\text{Ethene - C}_2\text{H}_4 & \quad \text{C} = \text{C} \\
\text{Propene - C}_3\text{H}_6 & \quad \text{H} - \text{C} - \text{C} - \text{C} \\
\text{Alkynes :- have a triple covalent bond between two carbon atoms and their names end with – yne.}
\end{align*}
\]

\[
\begin{align*}
\text{Ethyne - C}_2\text{H}_2 & \quad \text{H} - \text{C} \equiv \text{C} - \text{H} \\
\text{Propyne - C}_3\text{H}_4 & \quad \text{H} - \text{C} \equiv \text{C} - \text{C} - \text{H}
\end{align*}
\]
**ISOMERISM**

Carbon compounds having the same molecular formula but different structural formulae are called isomers. This property is called isomerism.

Eg: Butane – $C_4H_{10}$ has 2 isomers. They are Normal butane and Iso butane.

- Normal butane
  - $\text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H}$
  - $\text{H} - \text{H} - \text{H} - \text{H}$

- Iso butane
  - $\text{H} - \text{C} - \text{C} - \text{C} - \text{H}$
  - $\text{H} - \text{H} - \text{H}$

Eg: Pentane – $C_5H_{12}$ has 3 isomers. They are Normal pentane, Iso pentane and Neo pentane.

- Normal pentane
  - $\text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H}$
  - $\text{H} - \text{H} - \text{H} - \text{H}$

- Iso pentane
  - $\text{H} - \text{C} - \text{C} - \text{C} - \text{H}$
  - $\text{H} - \text{H} - \text{H}$

- Neo pentane
  - $\text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H}$
  - $\text{H} - \text{H} - \text{H}$
FUNCTIONAL GROUPS

An atom or a group of atoms which decides the properties of a carbon compound is called a functional group.

i) Halide (Halo group): - Cl, - Br, etc. (Names end with - ane)
   Eg: - CH₃Cl - Chloro methane, C₂H₅Br - Bromo ethane

ii) Alcohol: - OH (Names end with - ol)
    Eg: - CH₃OH - Methanol, C₂H₅OH - Ethanol

iii) Aldehyde: - CHO - C (Names end with - al)
     Eg: - HCHO - Methanal, CH₃CHO - Ethanal

iv) Carboxylic acid: - COOH - C - OH (Names end with - oic acid)
   Eg: - HCOOH - Methanoic acid, CH₃COOH - Ethanoic acid

v) Ketone: - CO - C - (Names end with - one)
   Eg: - CH₃COCH₃ - Propanone, CH₃COC₂H₅ - Butanone
Homologues Series

Homologus series is a group of carbon compounds having similar structures, similar chemical properties and whose successive members differ by a –CH$_2$ group. Eg: Alkanes, Alkenes, Alkynes etc.

**Alkanes**: have general molecular formula $\text{C}_n\text{H}_{2n+2}$. Their names end with –ane and the members are as follows:

- Methane: $\text{CH}_4$
- Ethane: $\text{C}_2\text{H}_6$
- Propane: $\text{C}_3\text{H}_8$
- Butane: $\text{C}_4\text{H}_{10}$
- Pentane: $\text{C}_5\text{H}_{12}$

**Methane**: $\text{CH}_4 \quad \text{H} - \text{C} - \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H}$

**Ethane**: $\text{C}_2\text{H}_6 \quad \text{H} - \text{C} - \text{C} - \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H}$

**Propane**: $\text{C}_3\text{H}_8 \quad \text{H} - \text{C} - \text{C} - \text{C} - \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H}$
Alkenes have general molecular formula $C_nH_{2n}$. Their names end with – ene and the members are as follows:

- Ethene: $C_2H_4$
- Propene: $C_3H_6$
- Butene: $C_4H_8$
- Pentene: $C_5H_{10}$
Alkynes have general molecular formula $\text{C}_n\text{H}_{2n-2}$. Their names end with – yne and the members are as follows :-

Ethyne :- $\text{C}_2\text{H}_2$


Propyne :- $\text{C}_3\text{H}_4$


Butyne :- $\text{C}_4\text{H}_6$
CHEMICAL PROPERTIES OF CARBON COMPOUNDS

a) Combustion :-
Carbon compounds burn in oxygen to form water, carbon dioxide, heat and light.

Eg :- \( \text{C} + \text{O}_2 \rightarrow \text{CO}_2 + \text{heat} + \text{light} \)
\( \text{CH}_4 + 2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{CO}_2 + \text{heat} + \text{light} \)
\( \text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 3\text{H}_2\text{O} + 2\text{CO}_2 \text{ heat} + \text{light} \)

b) Oxidation :-
Carbon compounds like alcohols are oxidised to carboxylic acids on heating with oxidising agents like alkaline Potassium permanganate – \( \text{KMnO}_4 \) or acidic potassium dichromate – \( \text{K}_2\text{Cr}_2\text{O}_7 \).

Eg:- Alcohols are oxidised to Carboxylic acids

\[ \text{C}_2\text{H}_5\text{OH} + \text{alkaline KMnO}_4 + \text{heat} \rightarrow \text{CH}_3\text{COOH} \]

\[ \text{Ethanol} + \text{acidic K}_2\text{Cr}_2\text{O}_7 + \text{heat} \rightarrow \text{Ethanoic acid} \]
c) **Addition reaction** :-

Unsaturated hydrocarbons undergo addition reaction with hydrogen in the presence of nickel or palladium as catalyst to form saturated hydrocarbons.

Eg:- Ethene undergoes addition reaction with hydrogen to form ethane in the presence of nickel or palladium as catalyst.

\[
\begin{align*}
C_2H_4 + H_2 & \rightarrow C_2H_6 \\
H & \quad H & \quad H & \quad H \\
= & \quad = & Ni or Pd catalyst & \quad = \\
C & \quad C + H_2 & \rightarrow H - C - C - H \\
H & \quad H & \quad H & \quad H \\
\end{align*}
\]

The addition of hydrogen to unsaturated hydrocarbons to form saturated hydrocarbons is called **hydrogenation**. Hydrogenation is used to convert unsaturated oils and fats to saturated oils and fats.

d) **Substitution reaction** :-

Saturated hydrocarbons undergo substitution reaction with halogens to form substitution products.

Eg :- Methane undergoes substitution reaction with chlorine in the presence of sunlight to form substitution products.

\[
\begin{align*}
CH_4 + Cl_2 & \rightarrow CH_3Cl + HCl & CH_3Cl + Cl_2 & \rightarrow CH_2Cl_2 + HCl \\
CH_2Cl_2 + Cl_2 & \rightarrow CHCl_3 + HCl & CHCl_3 + Cl_2 & \rightarrow CCl_4 + HCl \\
\end{align*}
\]
11) Some important carbon compounds :-

a) **ETHANOL** :-  \( C_2H_5OH \) - Ethyl alcohol

**Properties :-**

i) Ethanol is a colourless liquid with a pleasant smell and burning taste.

ii) It is soluble in water.

iii) Ethanol reacts with sodium to form sodium ethoxide and hydrogen.

\[ 2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2 \]

iv) Ethanol reacts with hot conc. \( H_2SO_4 \) to form ethene and water. Conc. \( H_2SO_4 \) is a dehydrating agent and removes water from ethanol.

\[ C_2H_5OH \rightarrow C_2H_4 + H_2O \]

**Uses :-**

i) Ethanol is used for making alcoholic drinks.

ii) It is used as a solvent.

iii) It is used for making medicines like tincture iodine, cough syrups, tonics etc.
b) **ETHANOIC ACID** :- \( CH_3COOH \) – Acetic acid

**Properties :-**

i) Ethanoic acid is a colourless liquid with a pungent smell and sour taste.

ii) It is soluble in water.

iii) A solution of 5% to 8% ethanoic acid in water is called Vinegar.

iv) **Esterification :-**

   Ethanoic acid reacts with ethanol to form the ester ethyl ethanoate in the presence of conc. \( H_2SO_4 \).

   \[
   \text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH} \xrightarrow{\text{conc.} H_2SO_4} \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}
   \]

   The reaction between carboxylic acid and alcohol to form an ester is called esterification.

v) **Saponification :-**

   When an ester reacts with sodium hydroxide solution, the sodium salt of the carboxylic acid and the parent alcohol are formed. This reaction is called saponification.

   Eg: - Ethyl ethanoate reacts with sodium hydroxide to form sodium acetate and ethanol.

   \[
   \text{CH}_3\text{COOC}_2\text{H}_5 + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + \text{C}_2\text{H}_5\text{OH}
   \]

vi) Ethanoic acid reacts with bases to form salt and water.

   \[
   \text{CH}_3\text{COOH} + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}
   \]

vii) Ethanoic acid reacts with carbonates and hydrogen carbonates to form salt, water and carbon dioxide.

   \[
   2\text{CH}_3\text{COOH} + \text{Na}_2\text{CO}_3 \rightarrow 2\text{CH}_3\text{COONa} + \text{H}_2\text{O} + \text{CO}_2
   \]

   \[
   \text{CH}_3\text{COOH} + \text{NaHCO}_3 \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O} + \text{CO}_2
   \]
Soaps and detergents

Soaps: Soaps are long chain sodium or potassium salts of carboxylic acids. Eg: Sodium stearate – $\text{C}_{17}\text{H}_{35}\text{COONa}$

Structure of soap molecule: A soap molecule has two parts. A long hydrocarbon part which is hydrophobic (water repelling) and soluble in oil and grease and a short ionic part which is hydrophilic (water attracting) and insoluble in oil and grease.

\[
\text{COO}^{-} \quad \text{Na}^{+}
\]

Hydrocarbon part (Water repelling)
Ionic part (Water attracting)

Cleansing action of soap: When soap is dissolved in water it forms spherical structures called micelles. In each micelle the soap molecules are arranged radially such that the HC part is towards the centre and the ionic part is towards the outside. The HC part dissolves the dirt, oil and grease and forms an emulsion at the centre of the micelles which can be washed away by water.
Cleansing action of soap

(a) Soap micelle

Soap molecules

Dirt particle (Oil or Grease)

Water

(a) Soap micelle entraps the dirt particle
b) **Detergents** :-

Detergents are long chain sodium salts of sulphonic acids. Soaps do not wash well with hard water because it forms insoluble precipitates of calcium and magnesium salts in hard water. Detergents wash well with hard water because it does not form insoluble precipitates of calcium and magnesium salts in hard water.

<table>
<thead>
<tr>
<th>Soaps</th>
<th>Detergents</th>
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<tbody>
<tr>
<td>Soaps are sodium salts of fatty acids.</td>
<td>Detergents are sodium salts of sulphonic acids.</td>
</tr>
<tr>
<td>Soaps clean well in soft water but do not clean well in hard water.</td>
<td>Detergents clean well with both hard and soft water.</td>
</tr>
<tr>
<td>Soaps do not clean as well as detergents.</td>
<td>Detergents clean better than soaps.</td>
</tr>
<tr>
<td>Soaps are biodegradable and do not cause pollution.</td>
<td>Some detergents are non biodegradable and cause pollution.</td>
</tr>
</tbody>
</table>