CHAPTER-4
CARBON COMPOUNDS

Topic-1

Carbon and its Properties, Homologous Series and IUPAC Names

Concepts Covered • *Covalent bonding in carbon compounds,* • *Versatile nature of carbon,* • *Homologous series,* • *Nomenclature of carbon compounds containing functional groups,* • *Difference between saturated and unsaturated hydrocarbons,* • *Chemical properties of carbon compounds*

Revision Notes

Properties of Carbon

- The element carbon is non-metal. Its symbol is C.
- Carbon is a versatile element. The percentage of carbon present in earth's crust in form of mineral is 0.02% and in atmosphere as CO_2 is 0.03%.
- All the living things, like plants and animals are made up of carbon based compounds.
- Carbon always forms covalent bonds.
- The atomic number of carbon is 6.
- **Electronic configuration:**

	K	L
C (6)	2	4

How carbon attain noble gas configuration ?

(i) Carbon is tetravalent in nature. It does not form ionic bond because it has 4 valence electrons, half of an octet. To form ionic bonds, carbon molecules must either gain or lose 4 electrons. It is because, that is difficult to hold four extra electron and would require large amount of energy to remove four electrons. So, carbon can form bond by sharing of its electron with the electrons of other carbon atom or with other element and attain noble gas configuration.

(ii) The atoms of other elements like hydrogen, oxygen, nitrogen and chlorine also form bonds by sharing of electrons.

(iii) The bond formed by sharing of electrons between same or different atoms is covalent bond.

Key Word

Covalent Bond is formed by sharing of electrons between atoms. In a covalent bond, the shared pair of electrons belongs to the valence shell of both the atoms.

- **Conditions for formation of a covalent bond:**
  - **(i)** The combining atoms should have 4 to 7 electrons in their valence shell.
  - **(ii)** The combining atoms should not lose electrons easily.
  - **(iii)** The combining atoms should not gain electrons readily.
  - **(iv)** The difference in electronegativity of two bonded atoms should be low.
- **Properties of covalent compounds:**
  - **(i) Physical state:** They are generally liquids or gases. Some covalent compounds may exist as solid.
  - **(ii) Solubility:** They are generally insoluble in water and other polar solvents but soluble in organic solvents such as benzene, toluene, etc.
  - **(iii) Melting and boiling points:** They generally have low melting and boiling points.
  - **(iv) Electrical conductivity:** They do not conduct is more apt word instead of electrical current.
- **Steps for writing the Lewis dot Structures of a covalent compound:**
  - **(i)** Write the electronic configuration of all the atoms present in the molecule.
  - **(ii)** Identify how many electrons are needed by each atom to attain noble gas configuration.
  - **(iii)** Share the electrons between atoms in such a way that all the atoms in a molecule have noble gas configuration.
  - **(iv)** Keep in mind that the shared electrons are counted in the valence shell of both the atoms sharing it.

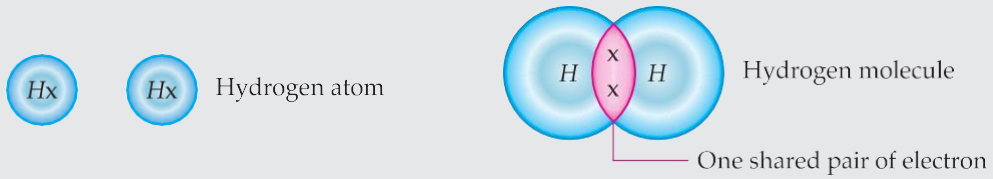
Key Word

Lewis dot structures reflect the electronic structures of the elements, including how the electrons are paired. In Lewis dot structures each dot represents an electron. A pair of dots between chemical symbols for atoms represents a bond.

Let us understand this with the help of examples:

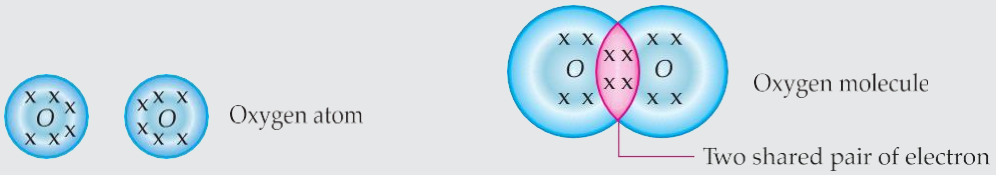
Example 1

(i) H_2



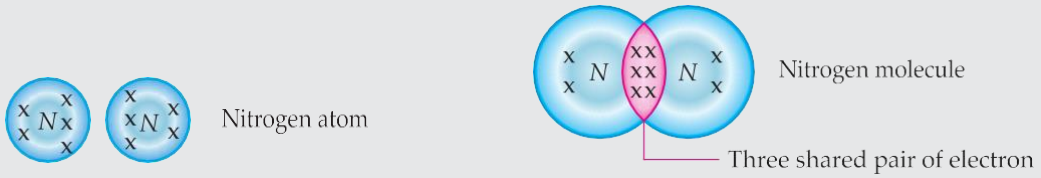
H – H: Single bond between hydrogen atoms

(ii) O_2



O = O: Double bond between oxygen atoms

(iii) N_2



N ≡ N: Triple bond between nitrogen atoms

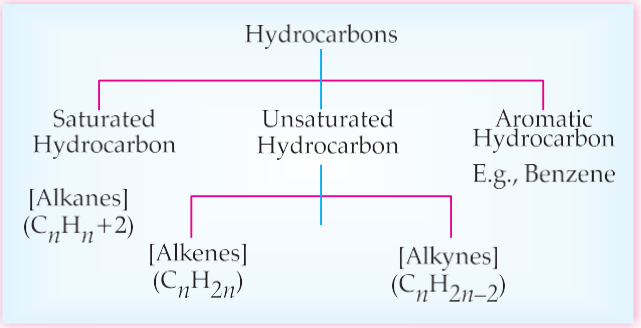
- **Versatile Nature of Carbon:** Carbon can form large number of carbon compounds. The factors that enable carbon to form large number of compounds are **catenation** and **tetravalency**.

Key Words

Catenation: It is the unique ability of elements to form long, straight or branched chains and rings of different sizes. Carbon shows maximum catenation in the periodic table.

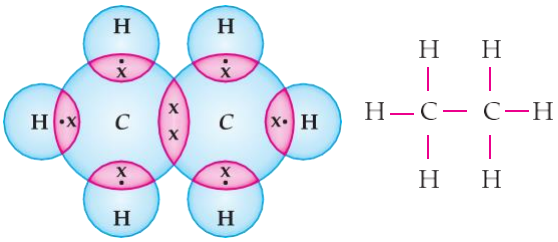
Tetravalency: It is the state of an atom in which there are four electrons available with the atom for covalent chemical bonding.

- **Hydrocarbon:** Compounds made up of hydrogen and carbon are called hydrocarbon.



- **Electron dot structure of saturated hydrocarbons:**

Ethane C_2H_6



Mnemonics

Concept: Saturated and unsaturate compounds

Mnemonics: **T**hank **Y**ou **D**e**S**a.

Interpretation:

T: Triple bond

Y: Alk**y**ne

D: Double bond

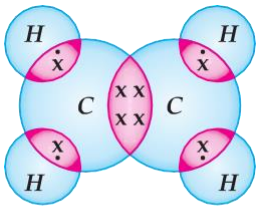
e: Alk**e**ne

S: Single bond

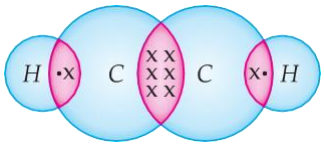
A: Alkane

- **Electron dot structure of unsaturated hydrocarbons:**

Ethene: C_2H_4



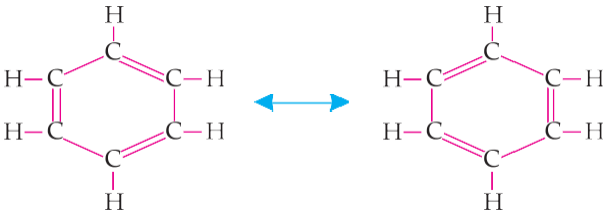
Ethyne: C_2H_2



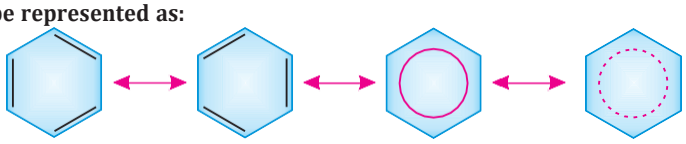
H – C ° C – H

- **On the basis of structures, hydrocarbons can be:**
  - (i) **Straight chain hydrocarbons:** Propane, butane, etc.
  - (ii) **Branched chain hydrocarbon:** Iso-butane, iso-pentane, etc.
  - (iii) **Cyclic hydrocarbons:** Cyclohexane C_6H_{12}, benzene C_6H_6, etc.
- **Cyclic or Closed Chain Hydrocarbons:** These are the hydrocarbons which have carbon - carbon closed chain. They are classified as:
  - (i) **Alicyclic hydrocarbons:** These are the hydrocarbons which do not have benzene ring in their structures.
  - (ii) **Aromatic hydrocarbons:** The hydrocarbons which have benzene ring in their structures. When hydrogen bonded to carbon of benzene is substituted with halogens, radicals or other functional groups, the derivatives are called aromatic compounds.

- **Benzene:** It is an aromatic hydrocarbon which has the molecular formula C_6H_6. It has alternating carbon - carbon single and double bonds.



- **Benzene can also be represented as:**



- **IUPAC name of hydrocarbon consists of two parts. It involves:**

(i) Word root: Number of carbons in the longest carbon chain.

Number of carbon atoms	Word root (Greek name)
1	Meth
2	Eth
3	Prop
4	But
5	Pent
6	Hex
7	Hept
8	Oct
9	Non
10	Dec

(ii) Suffix: It depends on the type of carbon - carbon bond, for single bond suffix is – ane; for double bond, suffix is – *ene*; and for triple bond suffix is – *yne*.

- **Types of Formula for Writing Hydrocarbons:**

(i) Molecular formula: It involves the actual number of each type of atom present in the compound.

(ii) Structural formula: The actual arrangement of atoms is written in structural formula.

(iii) Condensed formula: It is the shortened form of the structural formula.

- In hydrocarbon chain, one or more hydrogen atom is replaced by other atoms in accordance with their valencies. These are **heteroatoms.**
- These heteroatoms or group of atoms which make carbon compound reactive and decides its properties are called functional groups.

Some important functional groups in carbon compounds are:

Hetero atom	Functional group	Formula of functional group
Cl/Br	Halo (Chloro/Bromo)	— Cl, — Br, — I
Oxygen	1. Alcohol	— OH
	2. Aldehyde	— CHO
	3. Ketone	— C — (‖ O)
	4. Carboxylic acid	O ‖ — C — OH
Double bond	1. Alkene group	> C = C <
Triple bond	2. Alkyne group	— C ≡ C —

Key Word

Heteroatoms: An atom other than carbon or hydrogen atom.

- **Isomerism:** The compounds which possess the same molecular formula but different structural formulae, are called isomers, and the phenomenon is known as isomerism. For example, butane with a molecular formula C_4H_{10} has two isomers.

- **Homologous Series:** A series of organic compounds in which every succeeding member differs from the previous one by – CH_2 or 14 a.m.u. is called homologous series. The molecular formula of all the members of a homologous series can be derived from a general formula.
- **Properties of a homologous series:** As the molecular mass increases in a series, physical properties of the compounds show a variation, but chemical properties which are determined by a functional group remain the same within a series.

Mnemonics

Concept 1: Homologous series
Mnemonics: Monkeys **E**at **P**eeled **B**ananas
Interpretations:
M: Methane (1C), **E: E**thane (2C), **P: P**ropane (3C), **B: B**utane (4C)
Concept 2: Reaction in saturated and Unsaturated compounds
Mnemonics: SaSUnA
Interpretations:
Sa: Saturated, **S: S**ubstitution, **Un: Un**saturated, **A: A**ddition

- **Homologous series of alkanes:** General formula: C_nH_{2n+2}, where n = number of carbon atoms. CH_4, C_2H_6, C_3H_8.
- **Homologous series of alkenes:** General formula: C_nH_{2n}, where n = number of carbon atoms. C_2H_4, C_3H_6, C_4H_8.
- **Homologous series of alkynes:** General formula: C_nH_{2n-2}, where n = number of carbon atoms. C_2H_2, C_3H_4, C_4H_6.
- **Chemical Properties of carbon compounds**

(a) Combustion: Carbon compounds burn in air to give carbon dioxide, water, heat and light.

$$CH_4 + 2O_2 \xrightarrow{\text{Combustion}} CO_2 + 2H_2O + \text{Heat} + \text{Light}$$

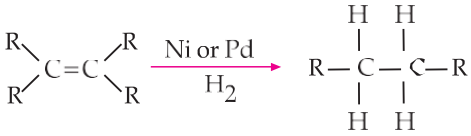
- Carbon and its compounds are used as fuels because they burn in air releasing lot of heat energy.
- Saturated hydrocarbon generally burn in air with blue and non-sooty flame.
- Unsaturated hydrocarbon burns in air with yellow sooty flame because percentage of carbon is higher than saturated hydrocarbon which does not get completely oxidized in air.

(b) Oxidation: Alcohols can be converted into carboxylic acid in the presence of oxidizing agent like alkaline $KMnO_4$ (potassium permanganate) or acidic potassium dichromate $K_2Cr_2O_7$.

$$CH_3CH_2OH \xrightarrow[\text{Acidic } K_2Cr_2O_7]{\text{Alkaline } KMnO_4 \text{ Or}} CH_3COOH$$

Ethanol Ethanoic acid

(c) Addition Reaction: Unsaturated hydrocarbons (alkene, alkyne) undergo addition reactions.



In unsaturated hydrocarbon, hydrogen added in the presence of catalyst palladium or nickel. Vegetable oils are converted into vegetable ghee using this process. It is also called hydrogenation of vegetable oils.

(d) Substitution Reaction: Saturated hydrocarbons undergo substitution reaction in the presence of sunlight.

$$CH_4 + Cl_2 \xrightarrow{\text{Sunlight}} CH_3Cl + HCl$$

Topic-2 Ethanol, Ethanoic acid, Soaps and Detergents

Concepts Covered • *Properties and uses of ethanol and ethanoic acid,* • *Soap and Detergents.*

Revision Notes

- **Ethanol:** Ethanol is commonly known as alcohol. It is the second member of the alcohol series. The molecular formula of ethanol is C_2H_5OH.
  - **Chemical Properties:**

(i) Reaction with sodium: Formation of sodium ethoxide and hydrogen.

$$2CH_3CH_2OH + 2Na \rightarrow 2CH_3CH_2ONa + H_2$$

(ii) Reaction with acid: Formation of ester (ethyl ethanoate) – a sweet smelling ester. This process is called esterification.

$$CH_3COOH + C_2H_5OH \xrightarrow{conc.\ H_2SO_4} CH_3COOCH_2CH_3 + H_2O$$

- **Uses:** In preparation of soap, cosmetics, in alcoholic beverages, in medicines, in laboratory reagent.

Ethanoic acid: The common name of ethanoic acid is acetic acid and it belongs to the group of acids called carboxylic acid. It is the second member of the series. The molecular formula of the compound is CH_3COOH.

- Vinegar — 5-8 % solution of acetic acid in water.
- Glacial acetic acid — Pure acetic acid
- **Chemical Properties of ethanoic acid**

(i) Reaction with sodium carbonate:

$$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$$

(ii) Reaction with sodium hydrogen carbonate:

$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$$

Brisk effervescence marks the presence of carbon dioxide.

(iii) Reaction with NaOH:

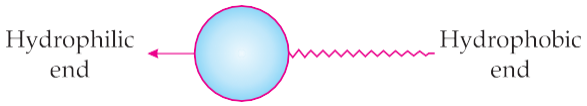
$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

(iv) Reaction with ethanol (Esterification):

$$CH_3COOH + CH_3CH_2OH \xrightarrow{conc.\ H_2SO_4} CH_3COOC_2H_5 + H_2O$$

Soap and detergents

- Soap is sodium or potassium salt of long chain carboxylic acid. e.g., $C_{17}H_{35}COONa^+$
- On hydrolysis, ester gives parent alcohol and sodium salt of carboxylic acid. Alkaline hydrolysis of ester is called saponification.
- Soaps are effective only in soft water.
- Detergents are ammonium or sulphonate salt of long chain of carboxylic acid.
- Detergents are effective in both hard and soft water.
- Soap molecule has:
  (i) Ionic (hydrophilic) part
  (ii) Long hydrocarbon chain (hydrophobic) part



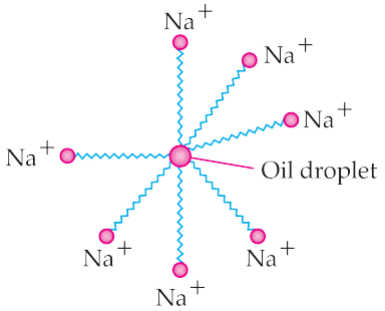
Structure of soap molecule

Key Word

Ester: Esters is generally sweet-smelling substances and is produced as a result of the reaction of an acid such as ethanoic acid and an alcohol such as ethanol in the presence of an acid catalyst. It is used in making perfumes and as flavouring agents.

Cleansing Action of Soap: Most dirt is oily in nature. The hydrophobic end of soap molecule attaches itself with dirt and the ionic end is surrounded with molecule of water. This result in formation of a radial structure called micelles.

- Soap micelles helps to dissolve dirt and grease in water and cloth gets cleaned.



- The magnesium and calcium salt present in hard water reacts with soap molecule to form insoluble product called scum. This scum create difficulty in cleansing action.
- By use of detergent, insoluble scum is not formed with hard water and clothes get cleaned effectively.