CHAPTER 6
CARBON AND ITS COMPOUNDS

NOTES

Carbon-

- Chemical element represented by symbol **C**.
- Atomic number 6.
- Non-metallic and tetravalent - making four electrons available to form covalent chemical bonds.
- Belongs to group 14 of the periodic table.
- Isotopes of Carbon are ^{12}C , ^{13}C and ^{14}C.

Allotropes of Carbon

Allotropes: Different forms of an element that has similar chemical properties but different physical properties are known as **Allotropes**.

Allotropes of carbon - diamond, graphite and fullerene.

Diamond

- Three-dimensional network with strong carbon-carbon covalent bonds.
- Hard in nature with high melting point (3500^{0}C).
- Shines in presence of light and it is a bad conductor of electricity.
- Used in making jewellery, cutting and drilling tools.

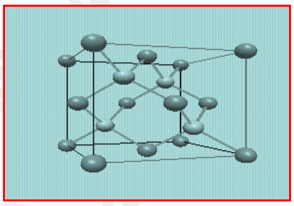


Fig.1. Structure of diamond

Graphite

- Each carbon atom is bonded with other three carbon atoms to form hexagonal networks.
- Good conductor of heat and electricity.
- Soft and greasy to touch
- Used as dry lubricant for machine parts and as pencil lead.

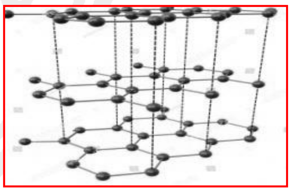


Fig.2. Structure of graphite

Fullerene

- Designed by US architect Buckminster Fuller
- Sixty carbon atoms are arranged in the shape of a football.

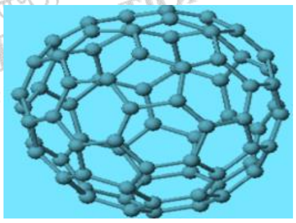


Fig.3. Structure of Fullerene

Catenation- the property of carbon by which carbon atoms can link one another via covalent bond and can form long chains, closed ring or branched chains etc. Carbon atoms can be linked by single, double or triple bonds.

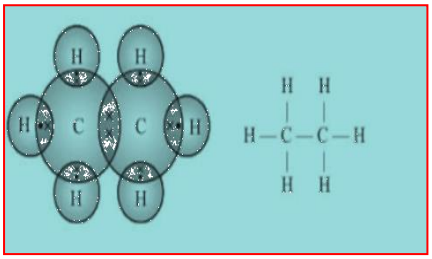


Fig.4. Electron dot and cross structure of Ethane as well as open structure

Hydrocarbons - compounds of carbon and hydrogen.
For example, Ethane, C_2H_6

Types:
1. Saturated hydrocarbons
2. Unsaturated hydrocarbons

Saturated Hydrocarbons
Saturated Hydrocarbons consist of single bonds between the carbon atoms. They are also known as Alkanes. Alkanes are represented by a formula, C_nH_{2n+2} where n = 1,2,3...etc.

Some important alkanes are
Methane - CH_4
Ethane - C_2H_6
Propane - C_3H_6
Butane - C_4H_{10}
Pentane - C_5H_{12}
Hexane - C_6H_{14}

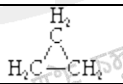
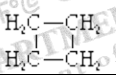
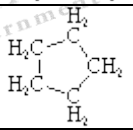
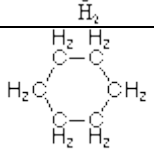
Homologous series: Alkanes when arranged in order of increasing molecular mass constitute a series in which any two consecutive alkanes differ by CH_2.Such series is known as homologous series.

Structural isomers: Compounds with the same molecular formula but different structure are called structural isomers. **e.g.** the two structures of C_4H_{10} are
(i) $CH_3CH_2CH_2CH_3$ and

(ii) $CH_3CH(CH_3)CH_3$

Cycloalkanes: Hydrocarbons which have carbon atoms in the form of a ring.
General formula representing cycloalkanes is C_nH_{2n}.

Examples of some cycloalkanes.

Name	Molecular Formula	Structural Formula	Line Formula
Cyclopropane	**C_3H_6**		
Cyclobutane	**C_4H_8**		
Cyclopentane	**C_5H_{10}**		
Cyclohexane	**C_6H_{12}**		

Unsaturated hydrocarbons

Unsaturated hydrocarbons consist of a double or a triple bond between two adjacent carbon atoms.

- Alkenes- hydrocarbons having at least one double bond between two adjacent carbon atoms .Its general formula is C_nH_{2n}. E.g. Ethene, C_2H_4
- Alkynes - hydrocarbons which contain a carbon-carbon triple bond. Its general formula is C_nH_{2n-2}.E.g. Ethyne, C_2H_2
- Aromatic hydrocarbons- ring-shaped hydrocarbons that contain delocalized pi electrons. They are relatively stable .e.g. Benzene, C_6H_6

Homologous series of alkenes:

Molecular formula	Structure	Name
C_2H_4	**$CH_2 = CH_2$**	**Ethene**
C_3H_6	**CH_3-CH=CH_2**	**Propene**
C_4H_8	**(i)CH_2=CH-CH_2-CH_3**	**But-1-ene**
	(ii)CH_3-CH=CH-CH_3	**But-2-ene**

Isomerism in alkene

- Position isomers- compounds having the same carbon chain but differ in the position of double bond

  For example :Butene

  1 2 3 4
  CH_2=CH-CH_2-CH_3
  But -1-ene (1-Butene)
  (a)

  1 2 3 4
  CH_3-CH=CH-CH_3
  But-2-ene (2-Butene)
  (b)

  The two structures of butene have the same carbon chain but differ in the position of carbon-carbon double bond. In (a) the double bond lies between C_1 and C_2 and in (b) the double bond lies between C_2 and C_3. Hence butene shows position isomers

- Structural isomers – compounds having the same molecular formula but showing different structures of carbon chains.

For example-butene, C_4H_8

CH_2=CH-CH_2-CH_3
1-Butene

$$\begin{array}{c} CH_3 \\ | \\ CH_3\text{-}C\text{=}CH_2 \end{array}$$
isobutene

In the above, 1-Butene and isobutene have the same molecular formula but structures of carbon chains are different. So they are structural isomers. Hence butene can show structural isomerism also.

Homologous series of alkynes

Formula	Structure	Name
C_2H_2	$H\text{-}C\equiv C-H$	Ethyne
C_3H_4	$CH_3\text{-}C\equiv C-H$	Propyne
C_4H_6	(i)$H\text{-}C\equiv C-CH_2-CH_3$	But-1-yne
	(ii)$CH_3\text{-}C\equiv C-CH_3$	But-2-yne

Petroleum

- Dark coloured viscous liquid found deep in the earth's crust
- Mixture of hydrocarbons along with some oxygen, sulphur and nitrogen containing compounds.
- Formed by the decay and decomposition of marine animals as well as that of plant materials of the prehistoric forests.
- Due to prolonged action of high pressure and high temperature in the interior of the earth for ages the organic matter decomposed into petroleum.
- Petroleum is pumped out through the deep wells bored into the crust.
- Crude petroleum is separated by fractional distillation.
- Products of petroleum are - gas, gasoline or petrol, kerosene, gas oil, diesel oil, lubricating oil, Vaseline, paraffin wax and asphalt.

Functional groups:

Heteroatoms and the group attached to the hydrocarbon part forms a stable molecule characterise the specific properties of the compound irrespective of the nature and length of the carbon chain. Such groups are called functional groups.

Table-2. Examples of functional groups of Carbon compounds.

Heteroatoms	Functional group	Formula	Compound Name
Cl/Br/I	Halo-(Chloro/Bromo/Iodo)	-Cl, -Br, -I	CH_3Cl Chloromethane
			CH_3Br Bromomethane
			CH_3CH_2I Iodoethane
Oxygen	i) Alcohol (-ol) (hydroxyl)	-OH	CH_3OH Methanol
			C_2H_5OH Ethanol
	ii) Aldehyde (-al) (formyl or aldehyde)	-CHO	HCHO Methanal
			CH_3CHO Ethanal
	iii) Ketone (-one)	-CO-	$CH_3\text{-}CO\text{-}CH_3$ Propanone
	iv) Carboxylic acid (-oic acid)	-COOH	HCOOH Methanoic acid
			CH_3COOH Ethanoic acid (Acetic acid)

Nomenclature of Carbon compounds

1. **Word root:** Denoted by the number of carbon atoms present in the main chain of the molecule.

Chain length	Word Root
C_1	Meth-
C_2	Eth-
C_3	Prop-

2. **Suffix:**

(i) A primary suffix is added to the word root to indicate whether the carbon chain is of single bonds or C-C multiple bonds.

Organic compound	Word Root	Primary Suffix	Name
$CH_3CH_2CH_3$	**Prop**	**-ane**	**Propane**
$CH_3CH=CH_2$	**Prop**	**-ene**	**Propene**
CH_3-C ≡CH	**Prop**	**-yne**	**Propyne**

(ii) A secondary suffix is added to the primary suffix to indicate the nature of functional group present in the molecule.

Family of Compound	Functional group	Secondary Suffix
Carboxylic Acid	**-COOH**	**-oic acid**
Aldehyde	**-CHO**	**-al**
Ketone	**-CO-**	**-one**
Alcohol	**-OH**	**-ol**

3. **Prefix:**

(i) Distinguishes open chain compound from ring compounds.

Example: $CH_2 – CH_2$ is Cyclo + but + ane = Cyclobutane
$CH_2 – CH_2$
(primary prefix) (word root) (primary suffix) (name)

(ii) **Secondary prefix:** It is substitute of functional group and added immediately before the word root or primary prefix.

Group	Secondary prefix	Example	Name
-F	**Fluoro**	**CH_3F**	**Fluoromethane**
-Cl	**Chloro**	**CH_3CH_2Cl**	**Chloromethane**

Complete name of an organic compound in the IUPAC consists of the following parts:

Secondary prefix + primary prefix + word root + primary suffix + secondary suffix

Chemical Properties of Carbon Compounds

Combustion

Carbon along with its compound is used as a fuel as it burns in presence of oxygen to release energy.

$$C + O_2 \longrightarrow CO_2 + \text{Energy}$$

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + Energy

Oxidation

Oxidation may be defined as the addition of oxygen or removal of hydrogen from a carbon compound. Potassium permanganate,$KMnO_4$ and acidified $K_2Cr_2O_7$ are oxidising agents.

Ethanol can be oxidized to aldehydes which in turn can be produces to carboxylic acid.

i) $CH_3CH_2OH + [O] \xrightarrow{\text{alk. } KMnO_4} CH_3CHO + H_2O$

Ethanol Ethanal

ii) $CH_3CHO + [O] \xrightarrow{\text{alk. } KMnO_4} CH_3COOH$

Ethanoic acid

Addition Reaction

(i)Hydrogenation (addition of hydrogen): Unsaturated hydrocarbons add hydrogen in presence of catalyst like nickel to form saturated hydrocarbons. Thus ethene adds a molecule of hydrogen to form ethane.

Example, $CH_2 = CH_2 + H_2 \xrightarrow{\text{Ni cat.}} CH_3 - CH_3$

Ethene Ethane

This reaction is commonly used in the hydrogenation of vegetable oils (contain unsaturated carbon chains) to give vegetable ghee.

(iii) Bromination (Halogenation): This reaction is used as a test for the unsaturated organic compounds (presence of double or triple bonds)

Example: On treatment with bromine water, ethene adds a molecule of bromine to form dibromoethane.(orange colour of bromine water is discharged during the reaction)

$CH_2{=}CH_2 + Br_2$ (water) $\longrightarrow CH_2Br - CH_2Br$

Ethene 1,2-dibromoethane

(iv)Addition of Hydrobromic acid: Ethene readily reacts with hydrobromic acid HBr to produce bromoethane.

$CH_2{=}CH_2 + HBr(aq) \longrightarrow CH_3CH_2Br$

Ethene Bromoethane

Substitution Reaction

When one atom in hydrocarbon is replaced by chlorine, bromine, etc. this reaction is known as **Substitution Reaction**.

Example, CH_4 + Cl_2 $\xrightarrow{\text{diffuse sunlight}}$ CH_3Cl + HCl
Methane Chloromethane

CH_3 Cl + Cl $\xrightarrow{\text{diffuse sunlight}}$ CH_2 Cl_2 + HCI
Dichloromethane

CH_2 Cl + Cl_2 $\xrightarrow{\text{diffuse sunlight}}$ CH_2 Cl_3 + HCI
(Trichioromethane chloroform)

$CHCl_2$ + Cl_2 $\xrightarrow{\text{diffuse sunlight}}$ CCl_2 + HCI
(Trichioromethane chloroform tetrachloride)

Important Carbon Compounds: Ethanol and Ethanoic Acid

Ethanol (Ethyl alcohol) is a volatile liquid with a boiling point of 78^0C. It reacts with sodium to form sodium ethoxide.

Example, $2CH_3CH_2OH$ + 2Na $\longrightarrow$ $2CH_3CH_2ONa$ + H_2

Dehydration of ethanol in presence of hot sulphuric acid forms alkene.

CH_3CH_2OH $\xrightarrow[170^0C]{\text{Conc.}H_2SO4}$ CH_2 = CH_2 + H_2O
Ethanol Ethene

Ethanoic acid is a colourless liquid. When pure ethanoic acid converted into like ice solid, it is known as **Glacial Acetic Acid**. It is formed at a temperature of about 16.6 ^{o}0

Ethanoic Acid/Acetic acid when reacts with ethanol it forms an ester, ethyl acetate. Ester is aa sweet-smelling liquid and it is used in making perfumes.

CH_3COOH + CH_3CH_2OH $\xrightarrow{H^+}$ CH_3COOC_2H5 + H_2O
Ethanoic acid Ethanol Ethyl acetate(ester)

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