CHAPTER – 4

CARBON AND ITS COMPOUNDS

Carbon is a versatile element.

In earth's crust, carbon is 0.02% and found in form of minerals.

Atmosphere has 0.03% of Carbon dioxide.

All living structures are carbon based.

Covalent Bond in Carbon

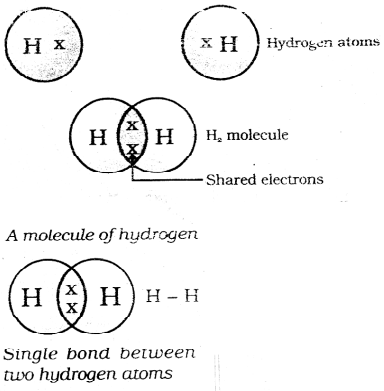
– The atomic number of carbon is 6 and its electronic configuration is 2, 4. To attain a noble gas configuration it can

1. Gain 4 electrons. But it would be difficult for nucleus to hold 4 extra electrons.
2. Lose 4 electrons. But it would require a large amount of energy to remove 4 electrons.

– It is difficult thus for an atom of carbon to either gain or lose electrons.

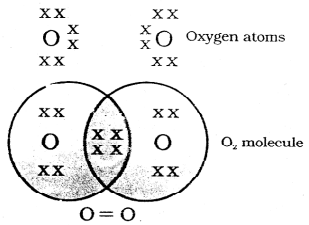
– Carbon attains the noble gas configuration by sharing its valence electrons with other atoms. Atoms of other elements like hydrogen, oxygen, nitrogen, chlorine also show sharing of valence electrons.

– Formation of H_2, O_2 and N_2 is shown as below :

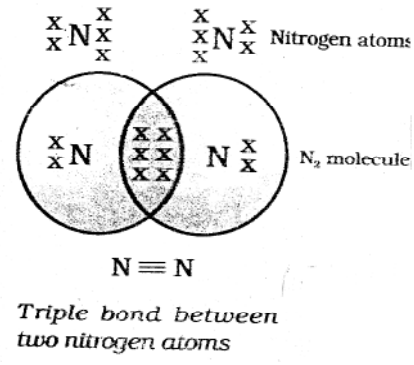


A molecule of hydrogen

Single bond between two hydrogen atoms



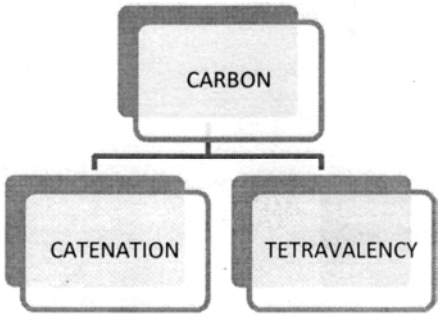
Double bond between two oxygen atoms



- It is evident that the number of shared pair of electrons can be one, two or three. Try making the structures of H_2O and CH_4.
- Bond formed by the sharing of an electron pair between two atoms is called covalent bond.
- Covalently bonded molecules have low melting and boiling points because of comparatively weaker intermolecular forces, unlike ionic compounds.
- These molecules are generally poor conductor of electricity since no charged particles are formed.

Versatile Nature of Carbon Atoms:

Two important properties of carbon atom enable carbon to form enormously large number of compounds.

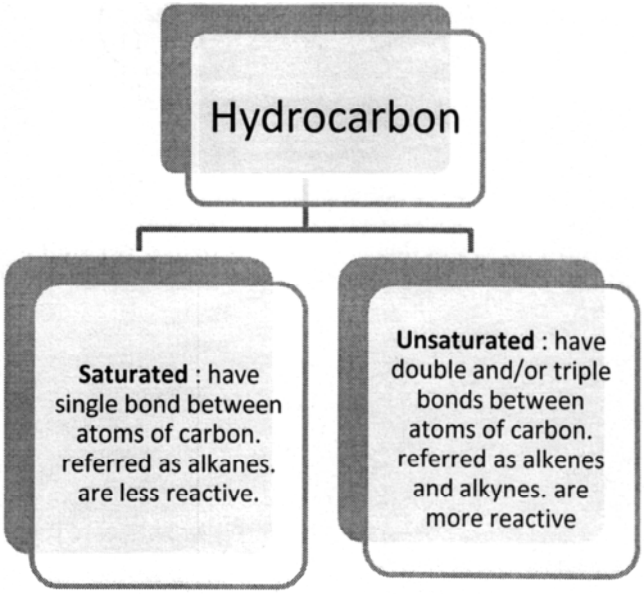


CATENATION : property of carbon atom to form bond with other atoms of carbon is called catenation. Like carbon, silicon forms compounds with hydrogen upto seven or eight atoms of silicon.

TETRAVALENCY : Having a valency of 4, carbon atom is capable of bonding with atoms of oxygen, hydrogen, nitrogen, sulphur, chlorine and other elements.

The smaller size of carbon atom enables nucles nucleus to hold the shared pair of electrons strongly, thus carbon compounds are very stable in general.

Saturated and Unsaturated Carbon Compounds

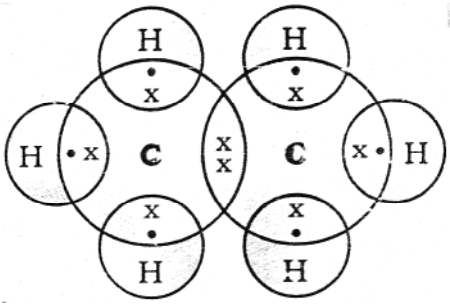


– ALKANE : C_nH_{2n+2}

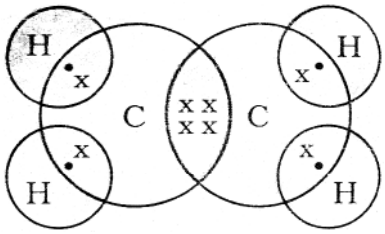
– ALKENE : C_nH_2n

– ALKYNE : C_nH_{2n-2}

– Electron dot structure of a saturated carbon compound, ethane is as follows:

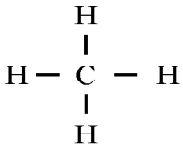
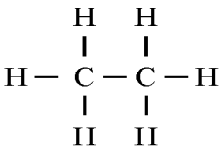
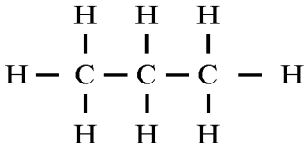
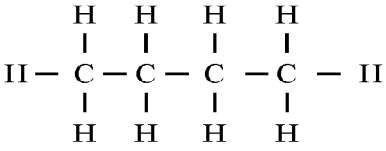
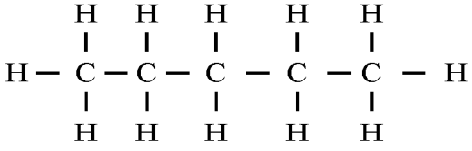


– Electron dot structure of an unsaturated cabon compound, ethene is as follows:

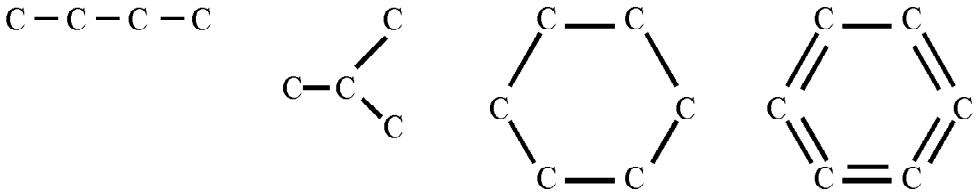


TRY DRAWING THE ELECTRON DOT STRUCTURE OF ETHYNE

Formulae and Structures of Saturated Compounds of Carbon and Hydrogen

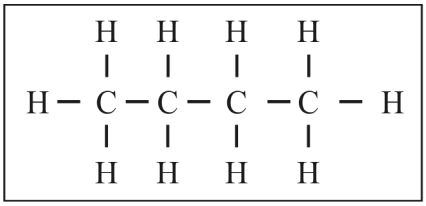
No. of Carbon Atoms	Name	Formula	Structure
1	Methane	CH_4	
2	Ethane	C_2H_6	
3	Propane	C_3H_8	
4	Butane	C_4H_{10}	
5	Pentane	C_5H_{12}	

On the basis of structures the hydrocarbons can be:

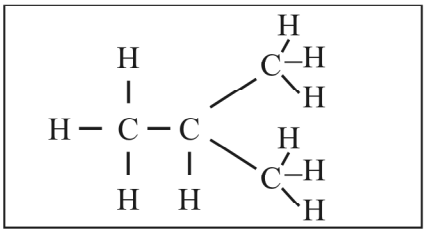


Straight chain **Branched** **Cyclic saturated** **Cyclic unsaturated**

Structural isomers : these are the compounds having identical molecular formula but different structures. For example, isomers of butane.



Straight Chain Isomer

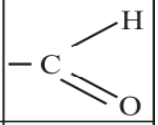
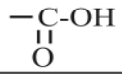


Branched Isomer of Butane

Heteroatom and Functional Group :

*In hydrocarbon chain, one or more hydrogen atoms can be replaced by other atoms in accordance with their valencies. The element that replaces hydrogen is called a heteroatom.

*These heteroatoms and the group containing them impart chemical properties to the compound and hence are called functional groups.

Heteroatom	Functional Group	Formula
Cl/Br	Halo-(Chloro/Bromo)	$-Cl_2$, -Br
Oxygen	1. Alcohol	–OH
	2. Aldehyde	
	3. Ketone	
	4. Carboxylic acid	

Homologous Series:

– It is a series of compounds in which the same functional group substitutes for hydrogen in a Carbon chain.

– For instance, the ALCOHOLSs: CH_3 OH, C_2H_5 OH, C_3H_7 OH, C_4H_9 OH.

– The successive member differs by $-CH_2-$; unit and 14 units of mass.

– The chemical properties are imparted by the functional group thus all members have similar chemical properties. But the members have different physical properties.

– The physical properties vary among the members of homologous series due to difference in their molecular mass.

– Melting point and boiling point increases with increasing molecular mass.

Nomenclature of Carbon Compounds:

1. Identify the number of carbon atoms in the compound.
2. Functional group is indicated either by prefix or suffix.

Functional Group	Suffix	Prefix
Alkene	ene	
Alkyne	yne	
Alcohol	ol	
Aldehyde	al	
Ketone	one	
Carboxylic acid	oic acid	
chlorine		chloro

3. If a suffix is added, then final 'e' is removed from the name eg. methanol (methane-e = methan + ol).

Chemical properties of Carbon compounds :

1. COMBUSTION :

*Carbon compounds generally burn (oxidize) in air to produce carbon dioxide and water, and release heat and light energy.

$$CH_4 + O_2 \longrightarrow CO_2 + H_2O + \text{heat and light}$$

*Saturated hydrocarbon burns generally with a blue flame in good supply or air and with a yellow sooty flame in limited supply of air.

*Sooty flame is seen when unsaturated hydrocarbons are burnt.

*Burning of coal and petroleum emits oxides of sulphur and nitrogen which are responsible for acid rain.

2. OXIDATION :

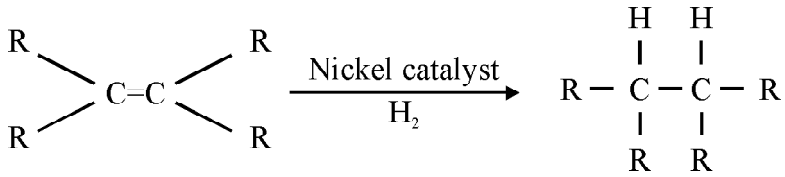
*Alcohols can be converted to carboxylic acids by oxidizing them using alkaline potassium permanganate or acidified poatassium dichromate (they add oxygen to the reactant, thus are called oxidizing agents).

$$CH_3\text{-}CH_2OH \xrightarrow[\text{Acidified } K_2Cr_2O_7 + \text{heat}]{\text{Alkaline } KMnO_4 + \text{heat}} CH_3COOH$$

3. ADDITION REACTION:

Hydrogen is added to unsaturated hydrocarbon in presence of palladium or nickel as catalyst.

Vegetable oils are converted into vegetable ghee using this process.



Saturated fatty acids are harmful for health and oils with unsaturated fatty acids should be used for cooking.

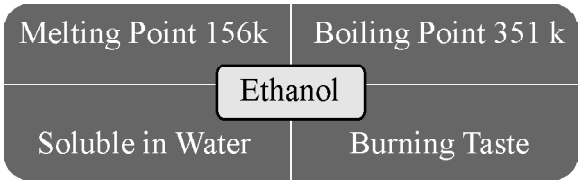
4. SUBSTITUTION REACTION :

In saturated hydrocarbons, the hydrogen attached to carbon can be replaced by another atom or group of atoms in presence of sunlight.

$CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl$ (sunlight required)

IMPORTANT CARBON COMPOUNDS : Ethanol and Ethanoic Acid

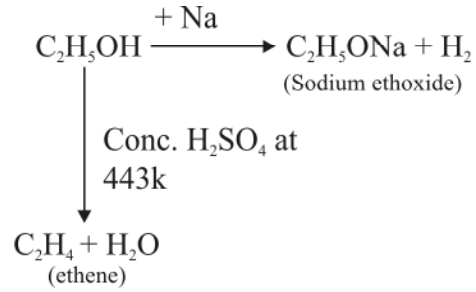
Ethanol :

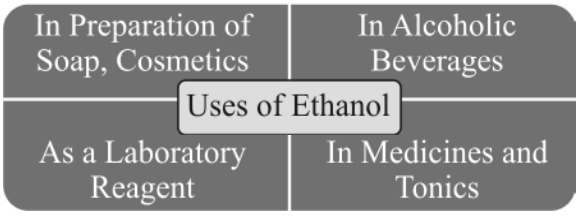


*Consumption of dilute ethanol causes serious health issues and intake of pure alcohol is lethal.

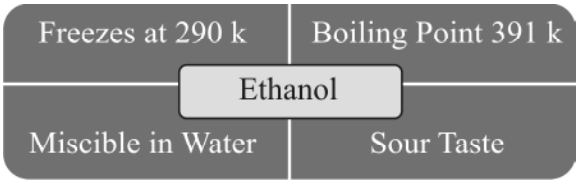
CHEMICAL PROPERTIES OF ETHANOL

C_2H_5OH Reacts with ***Sodium*** to from **Sodium Ethoxide** and **Hydrogen**	When C_2H_5OH is **Heated** with **Concentrated Sulphuric Acid** at 443 k, It is Dehydrated to **Ethene**





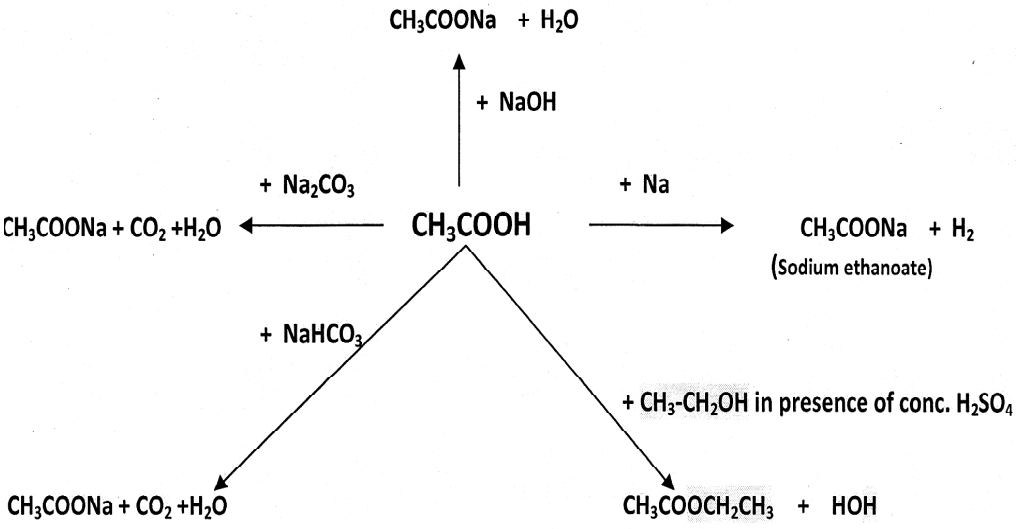
Ethanoic Acid (CH3COOH) / Acetic Acid :



*5-8% solution of acetic acid in water is called vinegar.

*Pure acetic acid is called glacial acetic acid.

		REACTS WITH	PRODUCTS
ETHANOIC ACID	1	SODIUM Na	SODIUM ETHANOATE AND HYDROGEN
	2	SODIUM CARBONATE Na_2CO_3	SODIUM ETHANOATE, CARBON DIOXIDE AND WATER
	3	SODIUM BICARBONATE $NaHCO_3$	SODIUM ETHANOATE, CARBON DIOXIDE AND WATER
	4	ETHANOL(IN PRSENCE OF CONC. SULPHURIC ACID) CH_3-CH_2OH	ESTER AND WATER



Esterification :

Carboxylic acids react with alcohols in presence of few drops of concentrated sulphuric acid as catalyst and form sweet smelling compounds called ester.

Hydrolysis :

On heating with an acid or a base the ester forms back the original alcohol and carboxylic acid.

$$CH_3COO\ CH_2CH_3 + NaOH \longrightarrow CH_3COONa + CH_3\text{-}CH_2OH$$

$$CH_3COO\ CH_2CH_3 \xrightarrow[HEAT]{Dil.\ H_2SO_4} CH_3COOH + CH_3\text{-}CH_2OH$$

*Alkaline hydrolysis of ester is also called saponification.

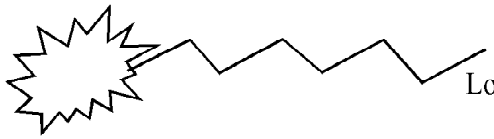
Soaps and Detergents

– Soap is sodium and potassium salt of carboxylic acids with long chain.

– Soaps are effective with soft water only and ineffective with hard water.

– Detergents are ammonium or sulphonate salts of carboxylic acids with long chain. They are effective with both soft as well as hard water.

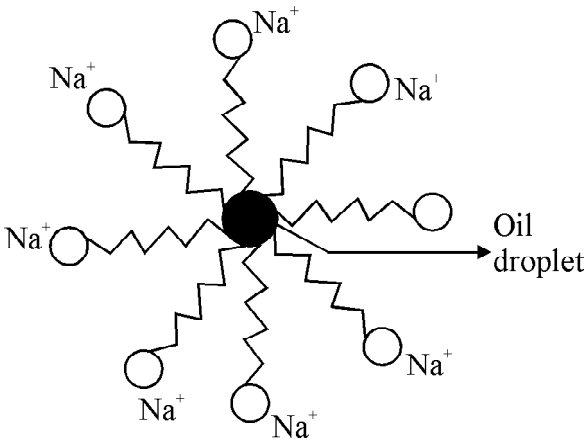
An ionic part (hydrophilic) and a long hydrocarbon chain (hydrophobic) part constitutes the soap molecule.



Structure of a Soap Molecule

Cleansing Action of Soaps :

– Most dirt is oily in nature and the hydrophobic end attaches itself with dirt, while the ionic end is surrounded with molecules of water. This result in formation of a radial structure called micelles.



– An emulsion is thus formed by soap molecule. The cloth needs to be mechanically agitated to remove the dirt particles from the cloth.

– Scum : The magnesium and calcium salts present in hard water reacts with soap molecule to form insoluble products called scum, thus obstructing the cleansing action. Use of detergents overcome this problem as the detergent molecule prevents the formation of insoluble product and thus clothes get cleaned.

EXERCISE
(Question Bank)

1MARK

1. How an atom of carbon attain noble gas configuration?
2. Draw the electron dot structure of a molecule of water.
3. Define catenation.
4. The kerosene/gas stove used at home has inlets for air. Give reason.
5. Write only the chemical equation for dehydration of ethanol by hot conc. Sulphuric acid.
6. Write the number of covalent bonds present in propane.
7. Define the term: oxidising agent.
8. Write the formula for first member of ketone.

9. Would you be able to check if water is soft by using a soap?

10. Write the molecular formula of an alkyne containing 10 atoms of hydrogen.

2 MARKS

1. Define saponification. Write a chemical equation for it.

2. Covalent compounds generally don't conduct electricity. Why?

3. Specify the condition in which ethanol undergo oxidation to form ethanoic acid. Write the chemical equation.

4. Define isomerism. Draw the structures of the two isomers of butane.

5. Identify the functional group present in the following compounds: HCOOH, HCHO, CH_3Br and $C_{10}H_{21}OH$

3 MARKS

1. What is a homologous series? Write any two characteristic features of any homologous series using one example.

2. Write any three differences between soaps and detergents.

5 MARKS

1. Differentiate between ethanol and ethanoic acid on the basis of any three physical properties and two chemical properties.

2. An organic compound 'A' is used as a preservative in pickles and has molecular formula $C_2H_4O_2$. This compound reacts with ethanol to form a sweet smelling compound 'B'.

   i) Determine the compound 'A'.

   ii) Write the chemical equation for its reaction with ethanol to form compound 'B'.

   iii) Write any two uses of compound 'B'.

   iv) Which gas is produced when compound 'A' reacts with washing soda? Write the chemical equation

   v) How can vinegar be obtained from compound 'A'?

CARBON AND ITS COMPOUNDS IN BRIEF

– Carbon is a versatile non-metal.

– Carbon atom like atoms of other non-metals like oxygen, nitrogen, hydrogen and chlorine shares electrons.

– Carbon forms large number of compounds due to catenation and tetravalency.

– Carbon can form single, double and triple covalent bonds.

– The compounds of hydrogen and carbon are called hydrocarbons, which can be saturated or unsaturated.

– Structurally hydrocarbons can have straight chain, branches or cyclic structure.

– Difference in Structural arrangement of same molecule gives rise to isomerism.

– In a hydrocarbon, a heteroatom can replace the hydrogen atom and imparts it chemical properties.

– Homologous series is a series of compounds with same general formula and same chemical properties but different physical properties.

– Carbon based compounds are excellent fuels.

– Ethanol is an important industrial compound. It reacts with reactive metals and is also dehydrated to ethene.

– Ethanoic acid is another important compound. It combines with ethanol to form sweet smelling esters.

– Soaps and detergents are used as cleansing agents. Detergents efficiently cleanses with soft and hard water.