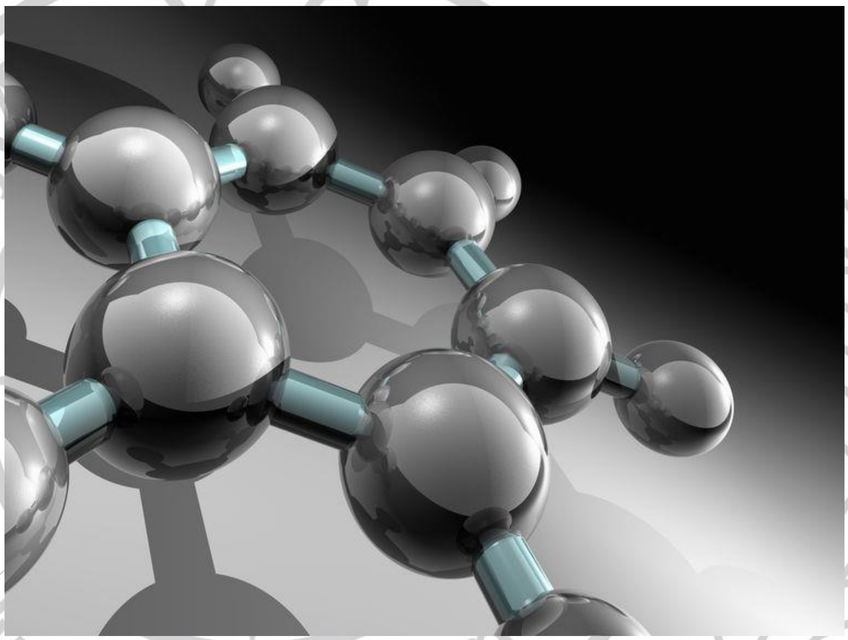
CARBON AND ITS COMPOUNDS



EDUMAX CLASSES

EDUCATION AT MAXIMUM

Bonding in Carbon: The Covalent bond, Electron dot structure, Physical properties of organic compounds, Allotropes of Carbon.

Covalent Bond: The atomic number of carbon is 6. Its electronic configuration is 2, 4. It requires, 4 electrons to achieve the inert gas electronic configuration. But carbon cannot form an ionic bond

It could gain four electrons forming C^{4-} cation. But it would be difficult for the nucleus with six protons to hold on to ten electrons.

It could lose four electrons forming C^{4+} cations. But it requires a large amount of energy to remove four electrons.

Thus, carbon overcomes this problem by sharing of its valence electrons with other carbon atoms or with atoms of other elements.

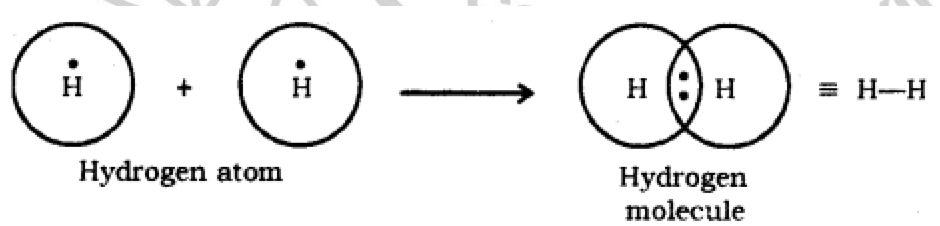
The bond formed by mutual sharing of electron pairs between two atoms in a molecule is known as Covalent Bond.

Types of Covalent Bond:

- Single Covalent Bond: When a single pair of electrons are 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.

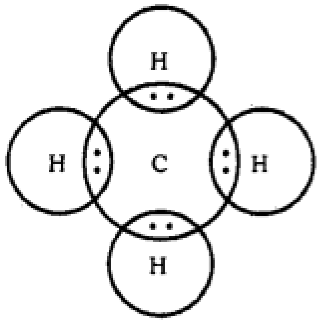
Electron Dot Structure: The electron dot structures provides a picture of bonding in molecules in terms of the shared pairs of electrons and octet rule.

Formation of Hydrogen Molecule
Atomic number of Hydrogen = 1
Number of valence electrons = 1

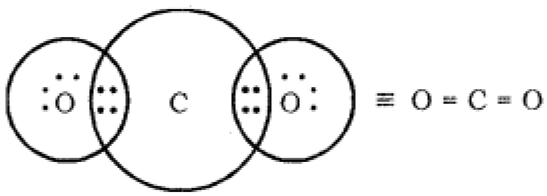


Formation of CH_4 Molecule
Atomic number of Carbon = 6 [2, 4]
Number of valence electrons = 4
Atomic number of Hydrogen = 1

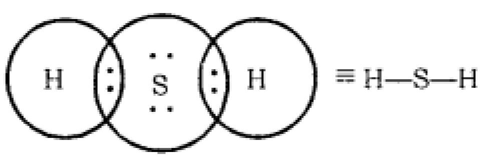
Number of valence electrons = 1



Formation of CO_2 Molecule
Atomic number of Carbon = 6 [2, 4]
Number of valence electrons = 4
Atomic number of Oxygen = 8 [2, 6]
Number of valence electrons = 6



Formation of H_2S Molecule
Atomic number of Sulphur = 16 [2, 8, 6]
Number of valence electrons = 6



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
Ethanol (CH_3CH_2OH)	156	351
Methane (CH_4)	90	111

Allotropes of Carbon
Allotropy: The phenomenon in which the element exists in two or more different physical states with similar chemical properties are called Allotropy.

Carbon has Three Main Allotropes

- **Diamond:** In this, carbon, an atom is bonded to four other atoms of carbon forming three-dimensional structures. It is the hardest substance and an insulator. It is used for drilling rocks and cutting. It is also used for making jewellery.
- **Graphite:** In this, each carbon atom is bonded to three other carbon atoms. It is a good conductor of electricity and used as a lubricant.
- **Buckminster Fullerene:** It is an allotrope of the carbon-containing cluster of 60 carbon atoms joined together to form spherical molecules. It is dark solid at room temperature.

Versatile nature of Carbon, Hydrocarbons, Isomerism, Homologous series, Functional groups, Nomenclature of functional groups.

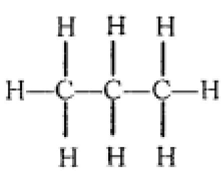
Versatile Nature of Carbon: The existence of such a large number of organic compounds is due to the following nature of carbon,

- Catenation
- Tetravalent nature.

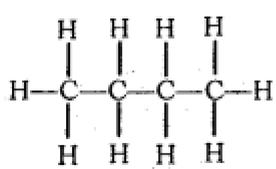
(i) Catenation: The self linking property of an element mainly carbon atom through covalent bonds to form long straight, branched and rings of different sizes are called Catenation.
This property is due to

- The small size of the carbon atom.
- The great strength of the carbon-carbon bond.

Carbon can also form stable multiple bonds (double or triple) with itself and with the atoms of other elements.
Straight Chain

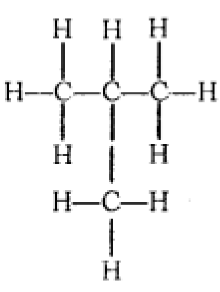


Propane

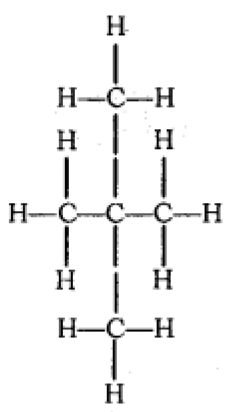


Butane

Branched Chain

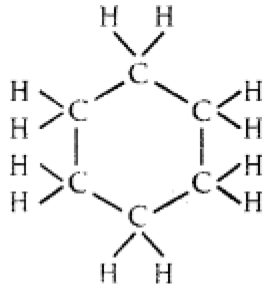


2-Methylpropane

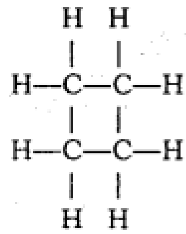


2, 2– Dimethylpropane

Rings

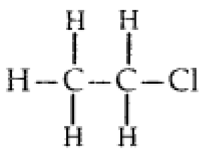


Cyclohexane

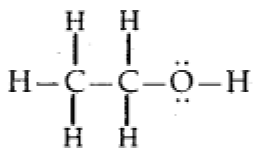


Cyclobutane

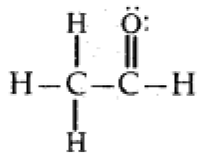
(ii) Tetravalent Nature: Carbon has valency of four. It is capable of bonding with four other atoms of carbon or some other heteroatoms with single covalent bond as well as double or triple bond.



Chloroethane

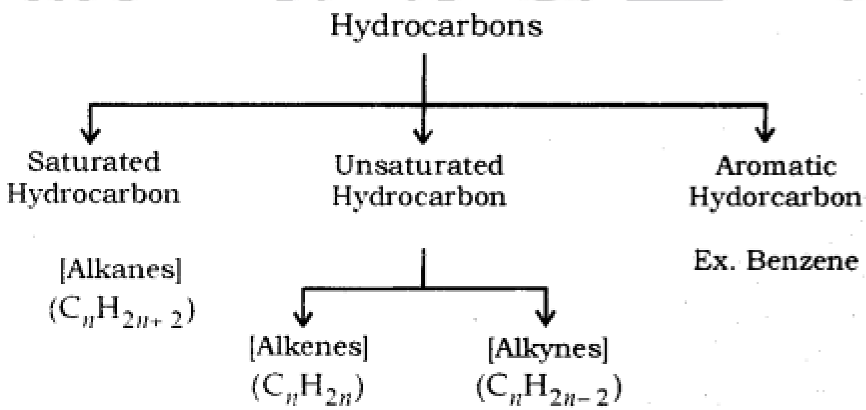


Ethanol

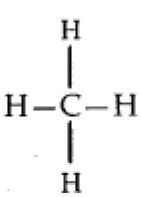


Ethanal

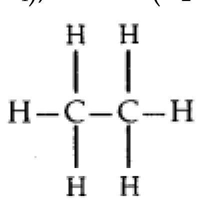
Hydrocarbons: Compounds of carbon and hydrogen are known as hydrocarbons.
For example; Methane (CH_4), Ethane (C_2H_6), Ethene (C_2H_4), Ethyne (C_2H_2) etc.



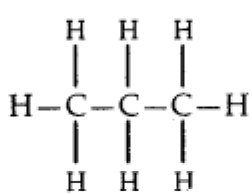
Saturated Hydrocarbon (Alkanes): General formula is C_nH_{2n+2}.
n = number of carbon atoms.
In this, the carbon atoms are connected by only a single bond.
For example; Methane (CH_4), Ethane (C_2H_6) etc.



Methane (n = 1)



Ethane (n = 1)

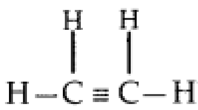


Propane (n = 3)

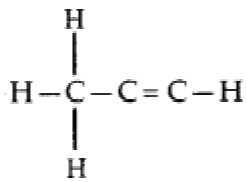
Unsaturated Hydrocarbons

Alkenes: General formula is C_nH_{2n}, where n = number of carbon atoms.

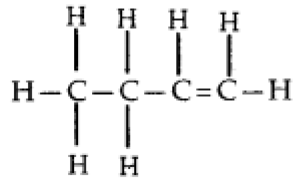
In this, the two carbon atoms are connected by double bond.



Ethene
(Ethylene)



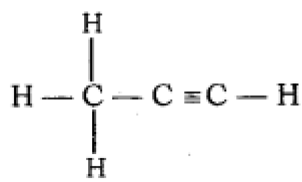
Propane



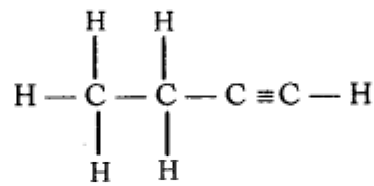
Butene

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.

Ethyne
(Acetylene)

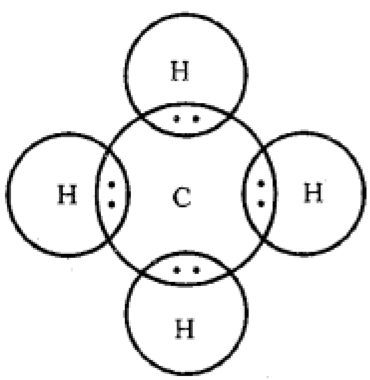


Propyne

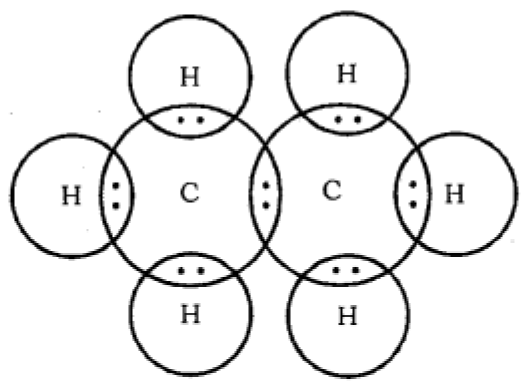


Butyne

Electron Dot Structure of Hydrocarbons



Methane

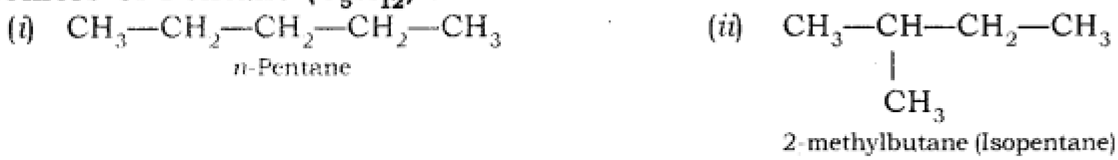


Ethane

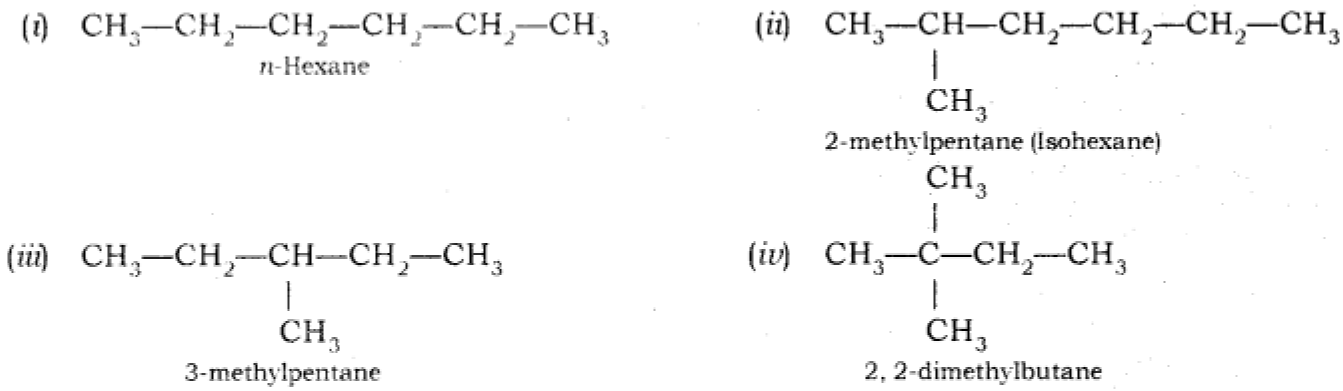
Isomerism: Compounds having the same molecular formula but different structural formula and properties are known as Isomers and this phenomenon is known as Isomerism.

Structural Isomerism: Compounds having the same molecular formula but different structures are called Structural isomers. Example: Isomers of butane (C_4H_{10})

Isomers of Pentane (C_5H_{12}) :



Isomers of Hexane (C_6H_{14}) :



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 Alkanes, Alkenes and Alkynes

Alkanes : Methane (CH_4)
Ethane ($CH_3—CH_3$)
Propane ($CH_3—CH_2—CH_3$)
Alkenes : Ethene ($CH_2 = CH_2$)
Propene ($CH_3—CH = CH_2$)
Alkynes : 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 shows similar chemical properties.

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

Functional Group	Formula of Functional Group
1. Halo- Chloro- Bromo-	$—Cl$ $—Br$
2. Alcohol	$—OH$
3. Aldehyde	$—CHO$ or $—\overset{\overset{\large O}{\parallel}}{C}—H$
4. Ketone	$—CO—$ or $—\overset{\overset{\large O}{\parallel}}{C}—$
5. Carboxylic acid	$—COOH$ or $—CO_2H$ or $—\overset{\overset{\large O}{\parallel}}{C}—O—H$

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 is as follows:

1. 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

2. Identify the functional group

S. No.	**Functional 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

3. Name the Compounds By Following Order

Prefix + Word Root + Suffix

Examples :

A. Double bond (=)

1. $CH_3—CH_2—CH = CH_2$ $[C_4H_8]$
   But + ene = Butene
2. $CH_3—CH = CH_2$ $[C_3H_6]$
   Prop + ene = Propene
3. $CH_2 = CH_2$ $[C_2H_4]$
   Eth + ene = Ethene

B. Triple bond (≡) :

1. $CH \equiv CH$ $[C_2H_2]$
   Eth + yne = Ethyne
2. $CH_3—C \equiv CH$ $[C_3H_4]$
   Prop + yne = Propyne
3. $CH_3—CH_2—C \equiv CH$ $[C_4H_6]$
   But + yne = Butyne
4. $CH_3—CH_2—CH_2—C \equiv CH$ $[C_5H_{10}]$
   Pent + yne = Pentyne

C. Chlorine (—Chloro) :

(i) $CH_3—CH_2—Cl$ $[C_2H_5Cl]$
Chloro + ethane = Chloroethane

(ii) $CH_3—CH_2—CH_2—Cl$ $[C_3H_7Cl]$
Chloro + propane = Chloropropane

D. Bromine (—Bromo) :

(i) $CH_3–Br$ $[CH_3Br]$
Bromo + methane = Bromomethane

(ii) $CH_3—CH_2—CH_2—CH_2—Br$ $[C_4H_9Br]$
Bromo + butane = Bromobutane

E. Alcohol (—OH) :

(i) $CH_3—CH_2—OH$ $[C_2H_5OH]$
Ethan – e + ol = Ethanol

(ii) $CH_3—CH_2—CH_2—CH_2—OH$ $[C_3H_7OH]$
Propan – e + ol = Propanol

F. Aldehyde (—CHO) :

(i) CH_3CHO
Ethan – e + al = Ethanal

(ii) $CH_3—CH_2—CH_2—CHO$
Butan – e + al = Butanal

G. Ketone $\left(\begin{array}{c} O \\ \| \\ —C— \end{array}\right)$ **:**

(i) CH_3COCH_3
Propan – e + one = Propanone

(ii) $CH_3—CH_2COCH_3$
Butan – e + one = Butanone

H. Carboxylic Acid (—COOH) :

(i) $HCOOH$
Methan – e + oic acid = Methanoic acid

(ii) CH_3COOH
Ethan – e + oic acid = Ethanoic acid

(iii) CH_3CH_2COOH
Propan – e + oic acid = Propanoic acid

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 and petroleum 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.

$$\underset{\text{Ethanol}}{CH_3CH_2\text{—}OH} \xrightarrow[\text{or Acidified } K_2Cr_2O_7 \text{ + Heat}]{\text{Alkaline } KMnO_4 \text{ + Heat}} \underset{\text{Ethanoic acid}}{CH_3COOH}$$

Oxidizing Agent: Some substances are capable of adding oxygen to others, are known as Oxidising Agent.
Example: Alkaline $KMnO_4$ (or $KMnO_4$—KOH)
Acidified $K_2Cr_2O_7$ (or $K_2Cr_2O_7$—H_2SO_4)
$KMnO_4$ – Potassium permanganate
$K_2Cr_2O_7$ – Potassium dichromate

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.

$$\underset{\text{Ethene}}{CH_2 = CH_2} + H_2 \xrightarrow{\text{Ni catalyst}} \underset{\text{Ethane}}{CH_3\text{—}CH_3}$$

Catalyst: Substances that cause a reaction to occur or proceeds to different rate without consuming in it are called a catalyst. For example; Ni, Pt, Pd, etc.

Process of converting vegetable oil into solid fat (vegetable ghee) is called Hydrogenation of Oil.
Vegetable oil + $H_2 \rightarrow$ Vegetable ghee

Vegetable fats are saturated fats 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

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

- Reaction with concentrated H2SO4 (Dehydration Reaction)

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

Dehydrating agent: Substances which removes water from ethanol (alcohols) is known as Dehydrating agent. For example; Cone. H_2SO_4.
Uses: As solvent, as antiseptic (tincture iodine), as anti-freeze in automobiles.

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.

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

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.

$$\begin{array}{ccccccc} CH_3COOC_2H_5 & + & NaOH & \xrightarrow{H_2SO_4} & C_2H_5OH & + & CH_3COONa \\ \text{Ethyl ethanoate} & & \text{Sodium hydroxide} & & \text{Ethanol} & & \text{Sodium ethanoate (soap)} \end{array}$$

(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.

$$\begin{array}{ccccccccc} 2CH_3COOH & + & Na_2CO_3 & \longrightarrow & 2CH_3COONa & + & H_2O & + & CO_2 \\ \text{Ethanoic acid} & & \text{Sodium carbonate} & & \text{Sodium ethanoate} & & & & \end{array}$$

$$\begin{array}{ccccccccc} CH_3COOH & + & NaHCO_3 & \longrightarrow & CH_3COONa & + & H_2O & + & CO_2 \\ \text{Ethanoic acid} & & \text{Sodium bicarbonate} & & \text{Sodium ethanoate} & & & & \end{array}$$

- Used as vinegar.
- Used as raw material for the preparation of acetyl chloride and esters.

Soap: Sodium or potassium salts of long chain fatty acids is called Soap.
General formula: $RCOO^-Na^+$

Detergent: Ammonium and sulphonate salts of long chain fatty acids are called Detergent.
Example: $CH_3-(CH_2)_{11}-C_6H_4-SO_3Na$.

Hard and Soft Water: Water that does not produce lather with soap readily is called Hard water and which produces lather with soap is called Soft Water.
Hardness of water is due to the presence of bicarbonates, chlorides and sulphate salt of calcium and magnesium.

Difference between soaps and detergents

Soaps	**Detergents**
(i) These are sodium or potassium salts of long chain fatty acids.	(i) These are ammonium and sulphonate salts of long chain fatty acids.
(ii) Ionic part of the soap is $-COO^-Na^+$	(ii) Ionic part of detergent is $-OSO^{3-}Na^+$.
(iii) Their efficiency decreases in hard water	(iii) Their efficiency is unaffected in hard water.
(iv) Soaps are biodegradable.	(iv) Detergents are non-biodegradable.

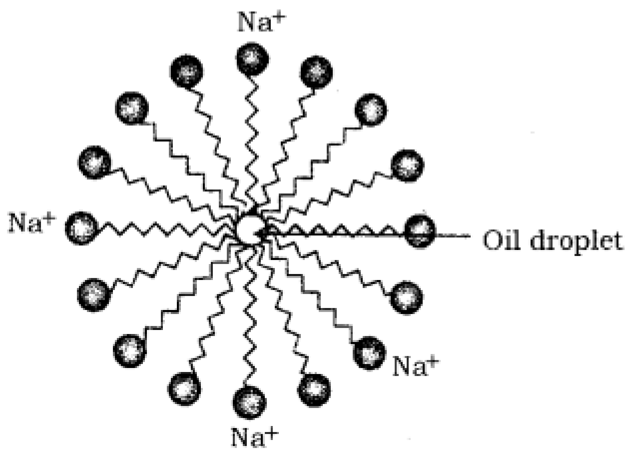
Advantage of Detergents: The main advantage of detergent over soaps is that soaps cannot be used in hard water for washing because hard water reacts with soap to form curdy white precipitate called Scum.

$$\underset{\substack{\text{Sodium stearate}\\ \text{(soap)}}}{2C_{17}H_{35}COONa} + \underset{\substack{\text{Calcium}\\ \text{chloride}}}{CaCl_2} \longrightarrow \underset{\substack{\text{Calcium streate}\\ \text{(scum)}}}{(C_{17}H_{35}COO)_2Ca} + 2NaCl$$

Thus, in hard water, soap does not give lather while detergent does.

Cleansing Action of Soaps and Detergents: Both soaps and detergents cantains two parts. A long hydrocarbon part which is hydrophobic (water repelling) in nature and a short ionic part which is hydrophillic (water attracting) in nature.

The hydrocarbon part of the soap molecule links itself to the oily (dirt) drop and ionic end orients itself towards water and forms a spherical structure called micelles. The soap micelles helps in dissolving the dirt in water and wash our clothes.



Micelle formation