Organic Chemistry

- The following two characteristic features enable carbon to form a large number of compounds:
  (i) Carbon has the unique ability to form bonds with other atoms of carbon(self-linking). This property is called catenation.
  These compounds may have long chains of carbon, branched chains of carbon or even carbon atoms arranged in rings. In addition, carbon atoms may be linked by single, double or triple bonds.
  (ii) Since carbon has tetravalency (i.e. valency of four), it is capable of bonding with four other atoms of carbon or atoms of some other mono-valent element.

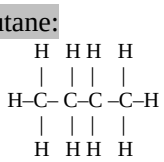
- All the carbon compounds which contain just carbon and hydrogen are called hydrocarbons.
  - The compound of carbon, which are linked by only single bonds between the carbon atoms are called saturated hydrocarbons. The saturated hydrocarbons are called alkanes (C_nH_{2n+2}).
  - Compounds of carbon having double or triple bonds between their carbon atoms are called unsaturated hydrocarbons. The unsaturated hydrocarbons which contain one or more double bonds are called alkenes(C_nH_{2n}). Those unsaturated hydrocarbons containing one or more triple bonds are called alkynes(C_nH_{2n-1}).

Saturated organic compounds	Unsaturated organic compounds
Carbon atoms are joined only by a single covalent bond	Carbon atoms are joined only by a double or triple covalent bond
They are less reactive and undergo substitution reaction	They are more reactive and undergo addition reaction

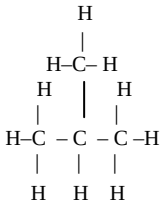
- A homologous series is a group of organic compounds having similar structures and similar chemical properties in which the successive compounds differ by CH_2 group. Ex: alkanes, alkenes, alkynes, haloalkanes, alcohols, aldehydes, ketones and carboxylic acids.
  As the molecular mass increases in any homologous series, a gradual change in their physical properties is seen. the melting points and boiling points increase with increasing molecular mass.
  The chemical properties, which are determined solely by the functional group, remain similar in a homologous series.
  - An atom or a group of atoms which makes a carbon compound reactive and decides its properties is called a functional group.
  - The group formed by the removal of one hydrogen atom from an alkane molecule is called an alkyl group (-R). The general formula of an alkyl group is C_nH_{2n+1}. Ex: Methyl $-CH_3$; Ethyl $-C_2H_5$

Functional group	General formulae	Types of organic compounds	Suffix
Halide – X (F,Cl,Br,I)	R– X	Haloalkanes	ane
Hydroxyl – OH	R– OH	Alcohols	ol
Aldehyde –CHO		Aldehydes	al
Carboxyl –COOH		Carboxylic acid	oic acid
		Ketones	one
	R–O– R′	Ethers	oxy

- The compounds with identical molecular formula but different structural formula are known as isomers, and the phenomenon as isomerism.
  - Chain isomers of Butane:



Butane[*n-butane*]



2-methyl propane[*iso-butane*]

- Chain isomers of Pentane:

$CH_3-CH_2-CH_2-CH_2-CH_3$ Pentane[*n-pentane*]

$CH_3-CH(CH_3)-CH_2-CH_3$ 2-methyl butane[*iso-pentane*]

$CH_3-C(CH_3)_2-CH_3$ 2,2-dimethyl propane[*neo-pentane*]

- Example of position isomerism:

(i) $CH_3-CH_2-C\equiv CH$ (but-1-yne) $CH_3-C\equiv C-CH_3$ (but-2-yne)

(ii) $CH_3-CH_2-C(=O)-CH_2-CH_3$ (pent-3-one) $CH_3-C(=O)-CH_2-CH_2-CH_3$ (pentan-2-one)

The official names or systematic names of organic compounds were given by International Union of Pure and Applied Chemistry in 1958.so they are called IUPAC name or IUPAC nomenclature. Naming a carbon compound can be done by the following method:

(i) The longest continuous chain of 'C' atoms, known as parent chain, is selected. Number of 'C'atoms present in it determine root word of its name.

No. of C-atoms	1	2	3	4	5	6
Root word	Meth	Eth	Prop	But	Pent	Hex

(ii) The root word is followed by one appropriate suffix, which represent the nature of bond in carbon-carbon atom.

Nature of bond	Suffix	General name	General formula
Single bond (C-C)	-ane	Alkane	C_nH_{2n+2}
Double bond (C=C)	-ene	Alkene	C_nH_{2n}
Triple bond (C≡C)	-yne	Alkyne	C_nH_{2n-2}

(iii) The branch chains are considered to be substituent, and their positions are indicated by the number of carbon atoms to which they are attached.

(iv) The carbon atoms of the largest chains are numbered in such a way that the alkyl group get the smallest possible number.

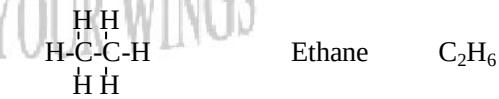
(v) In case, any functional group is also present in the chain, then the carbon atoms are numbered in such a way that the functional group gets the smallest possible number.

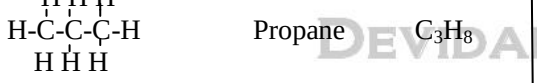
(vi) In nomenclature, 'e' of alkane is replaced by suffix of functional group indicating position.

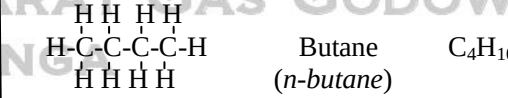
(vii) The position(s) of alkyl group(s) are indicated by writing the position and name of the alkyl group just before the name of parent hydrocarbon.

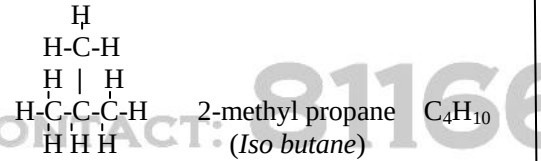
(viii) Di-, tri-, tetra-, are used as prefix for two, three and four groups of the same type.


Methane CH_4

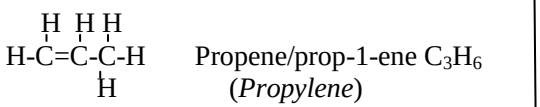

Ethane C_2H_6

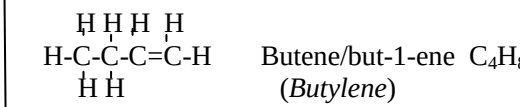

Propane C_3H_8

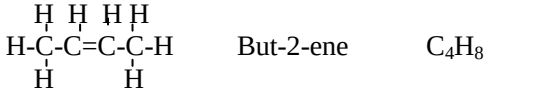

Butane (*n-butane*) C_4H_{10}

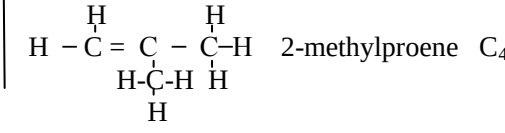

2-methyl propane (*Iso butane*) C_4H_{10}


Ethene (*Ethylene*) C_2H_6


Propene/prop-1-ene (*Propylene*) C_3H_6


Butene/but-1-ene (*Butylene*) C_4H_8


But-2-ene C_4H_8


2-methylproene C_4H_8

Structure	Name	Formula	Structure	Name	Formula
H-C≡C-H	Ethyne (*Acetylene*)	C_2H_2	H H-C-C≡C-H H	Propyne	C_3H_4
H H H-C-C≡C-C-H H H	But-2-yne	C_4H_6	H H-C-O-H H	Methanol/Methan-1-ol	CH_3OH
H H H-C-C-O-H H H	Ethanol	C_2H_5OH	H H H H-C-C-C-O-H H H H	Propanol/Propan-1-ol	C_3H_7OH
H H H H-C–C – C-H H O-H H	Propan-2-ol	C_3H_7OH	H H H H-C – C – C-H OH OH OH	propan-1,2,3-triol (Glycerol)	$C_3H_5(OH)_3$
H H-C=O	Methanal/Methan-1-al (*Formaldehyde*)	CH_2O	H H H-C-C=O H	Propanal/Propan-1-al (*Acetaldehyde*)	C_2H_4O
H O H H-C-C-C-H H H	Propan-2-one (*Acetone*)	C_3H_6O	O H-C-O-H	Methanoic-1-oic acid (*Formic acid*)	CH_2O_2
H O H-C-C-O-H H	Ethanoic acid (*Acetic acid*)	$C_2H_4O_2$	H H O H H-C-C-O-C-C-H H H H	Ethyl ethanoate (*Ethyl acetate*)	$C_4H_8O_2$
H H-C-Cl H	Chloromethane	CH_3Cl	H Br H H-C-C-C-Br H H H	1,2-dibromopropane	$C_3H_6Cl_2$
Cl H-C-Cl Cl	Trichloromethane (*Chloroform*)	$CHCl_3$	Cl Cl-C-Cl Cl	tetrachloromethane (*Carbon tetrachloride*)	CCl_4

Compound	Ethene	Ethyne	Ethanol	Methanal	Ethanal	Propanone	Methanoic acid	Ethanoic acid	Ethyl ethanoate
Common name	Ethylene	Acetylene	Ethyl alcohol	Formaldehyde	Acetaldehyde	Acetone	Formic acid	Acetic acid	Ethyl acetate or, ester

ALKANE

General formula: C_nH_{2n+2} Members of series: Methane (CH_4) , Ethane (C_2H_6)....

- Saturated hydrocarbon (Since all the four valencies of carbon are fully satisfied by a single bond.)
- Also known as Paraffins (little affinity)
- They undergo substitution reaction.

Lab preparation:

- Methane can be obtained by heating a mixture of sodium ethanoate (sodium acetate) and soda lime (a mixture of sodium hydroxide and calcium oxide)

$$CH_3COONa + NaOH \xrightarrow{CaO;\ 300°C} Na_2CO_3 + CH_4\uparrow$$

sodium ethanoate (sodium acetate)

- Ethane can be obtained by heating a mixture of sodium propanoate (sodium propionate) and soda lime.

$$C_2H_5COONa + NaOH \xrightarrow{CaO;\ 300°C} Na_2CO_3 + C_2H_6\uparrow$$

sodium propanoate (sodium propionate)

- **Other method of preparation:** Iodomethane (methyl iodide) or bromoethane (ethyl bromide0 is reduced by nascent hydrogen at ordinary room temperature to give methane or ethane.

$$CH_3I + 2[H] \rightarrow CH_4 + HI$$
$$C_2H_5Br + 2[H] \rightarrow C_2H_6 + HBr$$

Nacent hydrogen is produced by the action of Zn powder and dil HCl.

- **Substitution reaction:** Methane or ethane reacts with chlorine, bromine or iodine in diffused sunlight (or heated upto 600K) to give corresponding substituted products.

$$CH_4 + Cl_2 \xrightarrow{\text{Sunlight}} CH_3Cl + HCl \quad ; \quad CH_3Cl + Cl_2 \xrightarrow{\text{Sunlight}} CH_2Cl_2 + HCl$$
$$CH_2Cl + Cl_2 \xrightarrow{\text{Sunlight}} CHCl_3 + HCl \quad ; \quad CHCl_3 + Cl_2 \xrightarrow{\text{Sunlight}} CCl_4 + HCl$$

By supplying more chlorine, it is possible to replace all the hydrogen atoms of methane by chlorine, in successive steps. In this way we can obtain four compounds: Chloromethane(CH_3Cl), Dichloromethane (CH_2Cl_2); Trichlromethane or Chloroform ($CHCl_3$); and Tetrachloromethane (CCl_4).

Similarly one mole of ethane reacts with one mole chlorine to give chloroethane.

One more example of substitution reaction is

$$C_2H_6 + Cl_2 \xrightarrow{\text{Sunlight}} C_2H_5Cl + HCl$$
$$C_2H_6 + Br_2 \xrightarrow{\text{Sunlight}} C_2H_5Br + HBr$$

- **Reaction with oxygen:** Methane or ethane burn in air with a bluish non-sooty flame to form carbon dioxide and water vapour.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$
$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

- **Oxidation:** On controlled oxidation or catalytic oxidation, alkane give alcohols or aldehydes or carboxylic acids, depending upon the reaction conditions.

$$2CH_4 + O_2 \xrightarrow[120atm]{\text{475K Cu tube}} 2CH_3OH \quad ; \quad 2C_2H_6 + O_2 \xrightarrow[120atm]{\text{475K Cu tube}} 2C_2H_5OH$$
$$2CH_4 + O_2 \xrightarrow{\text{Mollybdenum oxide (MoO)}} HCHO + H_2O \quad ; \quad C_2H_6 + O_2 \xrightarrow{MoO} 2CH_3CHO + H_2O$$
$$2CH_4 + 3O_2 \xrightarrow{\text{Mn compound}} 2HCOOH + 2H_2O \quad ; \quad C_2H_5OH + O_2 \xrightarrow{\text{Pt , 300°c}} CH_3COOH + H_2O$$

ALKENE

General formula: C_nH_{2n} Members of series: Ethene (C_2H_4) , Propene (C_3H_6)....

- Unsaturated aliphatic hydrocarbon containing a double bond.
- Also known as Olefins (Oil forming)
- They undergo Addition reaction.

- **Preparation of Ethene (ethylene):**
  - By dehydration of ethyl alcohol

$$2C_2H_5OH \xrightarrow[\text{Conc } H_2SO_4]{170°C} C_2H_4 + H_2O$$

Obtained ethene gas is passed through NaOH solution to remove impurities (CO_2 and SO_2).

For industrial purpose ethene can be obtained by passing ethanol vapours through a tube containing alumina (Al_2O_3) at 300°C

$$2C_2H_5OH \xrightarrow[Al_2O_3]{300°C} C_2H_4 + H_2O$$

  - By dehydrohalogenation:

$$C_2H_5Cl + KOH \text{ (alcoholic hot and concentrated)} \rightarrow C_2H_4 + KCl + H_2O$$
$$C_2H_5Br + KOH \text{ (alc. hot \& conc)} \rightarrow C_2H_4 + KBr + H_2O$$
$$C_2H_5I + KOH \text{ (alc. hot \& conc)} \rightarrow C_2H_4 + KI + H_2O$$

- **Addition reactions:**
  - Hydrogenation:

$$\underset{(CH_2=CH_2)}{C_2H_4} + H_2 \xrightarrow[200°C]{\text{Ni catalyst}} \underset{(CH_3-CH_3)}{C_2H_6}$$

This reaction can take place at ordinary temperature in presence of platinum or palladium catalyst.

- Halogenation: $CH_2=CH_2 + Cl_2 \rightarrow CH_2(Cl)-CH_2(Cl)$ 1,2-dichloroethane(*ethylene chloride*)
  (C_2H_4) ($C_2H_4Cl_2$)

  $C_2H_4 + Br_2 \rightarrow CH_2Br-CH_2Br$ 1,2-dibromoethane(*ethylene bromide*)

  ! Bromine solution in CCl_4 has an orange colour, when added dropwise to ethene, the orange colour of bromine disappears due to formation of the colourless ethylene bromide.

- Hydration: $C_2H_4 + H_2O \xrightarrow{H^+} C_2H_5OH$
  ($CH_2=CH_2$)
  A water molecule gets added to alkene in the presence of acids (e.g. sulphuric acid) to form alcohol.

- Addition of HCl: $C_2H_4 + HCl \rightarrow C_2H_5Cl$
  ($CH_2=CH_2$) (CH_3-CH_2Cl)

- Oxydation: Ethene is oxidised with alkaline $KMnO_4$ at room temperature.

  $CH_2=CH_2 + H-O-H + 2[O] \xrightarrow{\text{Alkaline } KMnO_4} CH_2(OH)-CH_2(OH)$ Ethan-1,2-diol

  The purple colour of $KMnO_4$ decolourises.

ALKYNE

General formula: C_nH_{2n-2} Members of series: Ethyne (C_2H_2) , Propyne (C_3H_4)...

- Unsaturated aliphatic hydrocarbon containing a triple bond.
- They undergo Addition reaction.

Preparation of Ethyne (acetylene):

- Lab method :
  Calcium carbide reacts with water to produce colourless gas with ether like odour (acetylene gas)
  $CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2\uparrow$

- By boiling 1,2-dibromoethane (ethylene dibromide) with alcoholic potassium hydroxide, ethyne is formed.
  $CH_2Br-CH_2Br + 2KOH \xrightarrow[\text{boiling}]{200°C} CH\equiv CH + 2KBr + 2H_2O$
  (alcoholic)

Addition reactions:

- Hydrogenation: $CH\equiv CH + H_2 \xrightarrow[200°C]{\text{Ni catalyst}} CH_2=CH_2 \xrightarrow[+ H_2]{\text{Ni ,200°C}} CH_3-CH_3$

- Halogenation: $CH\equiv CH + Cl_2 \longrightarrow CHCl=CHCl \xrightarrow{Cl_2} CHCl_2-CHCl_2$
  1,2-dichloroethene (acetylene dichloride)

  $C_2H_2 + Br_2 \rightarrow C_2H_2Br_2 \xrightarrow{Br_2} C_2H_2Br_4$
  1,2,3,4-tetrabromoethane (acetylene tetrabromide)

  ! When bromine solution in CCl_4, is added dropwise to ethyne, its brown colour disappears due to formation of the colourless addition product (acetylene dibromide or acetylene tetrabromide).

Chemical tests to distinguish between Alkane, Alkenes and Alkynes

Test	Alkanes	Alkenes	Alkynes
On dding a few drops of bromine solution in carbon tetrachloride(CCl_4) solution to the hydrocarbon.	No change	Redish brown colour of bromine solution gets decolourised	Redish brown colour of bromine solution gets decolourised
On adding a few drops of alkaline potassium permanganet (purple colour) to hydrocarbon	No change	The purple colour fades	The purple colour fades (Baeyer's test)
On adding a few drops of ammonical cuprous chloride to the hydrocarbon.	No change	No change	Red precipitate of copper acetylene is formed
On adding ammonical silver nitrate to the hydrocarbon.	No change	No change	White precipitate of silver acetylide is formed

ALCOHOL

Ethanol (or Ethyl alcohol): Ethanol is an inflammable volatile liquid. The melting point of ethanol is 78°C (351 K). Ethanol is a good solvent and due to presence of hydroxyl group it is also soluble in water in all proportions.

Ethanol is obtained from fermentation of sugar. $C_6H_{12}O_6 \xrightarrow{\text{enzymes, } 37°C} 2C_2H_5OH + 2CO_2$

- **Preparation of Ethanol (or Ethyl alcohol):**
  - Lab method: Alcohol can be prepared by the hydrolysis of alkyl halides on reaction with a hot dilute alkali.

    $CH_3Br + KOH(aq) \xrightarrow{\text{boil}} 2CH_3OH + KBr$ $\quad C_2H_5Cl + KOH(aq) \xrightarrow{\text{boil}} 2C_2H_5OH + KCl$

    $C_2H_5Br + NaOH(aq) \xrightarrow{\text{boil}} 2C_2H_5OH + NaBr$ $\quad C_2H_5I + NaOH(aq) \xrightarrow{\text{boil}} 2C_2H_5OH + NaI$

  - Industrial method (large scale method): When conc. Sulphuric acid is added to ethene at a temperature of 80°C and pressure of 30atm, ethyl hydrogen sulphate is produced. Ethyl hydrogen sulphate, on hydrolysis with boiling water, gives ethanol.

    $C_2H_4 + H_2SO_4 \xrightarrow[80°C]{30\text{ atm}} C_2H_5HSO_4$

    $C_2H_5HSO_4 + H_2O \rightarrow C_2H_5OH + H_2SO_4$

    Ethyl hydrogen sulphate (Boiling)

! Alternatively, ethanol is produced when ethene is heated with water at 300°C and 60atm pressure in presence of phosphoric acid catalyst.

$$C_2H_4 + H_2O \xrightarrow[300°C,\ 60\text{ atm}]{H_3PO_4} C_2H_5OH$$

- **Combustion:** Ethanol burns readily in air to form carbon dioxide and water vapour, and releasing a lot of heat and light.

$$C_2H_5OH + 3O_2 \xrightarrow{\text{Combustion}} 2CO_2 + 3H_2O$$

- **Reaction with sodium**: Alcohols react with sodium leading to the evolution of hydrogen.

$$2CH_3OH + 2Na \rightarrow 2CH_3ONa + H_2\uparrow$$

(sodium methoxide)

$$2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2\uparrow$$

(sodium ethoxide)

This effervescence of hydrogen serve as a test for alcohol.

- **Dehydration with conc. Sulphuric acid:** Heating ethanol at 443 K with excess concentrated sulphuric acid results in the dehydration of ethanol to give ethene.

$$CH_3CH_2OH \xrightarrow{\text{Conc. } H_2SO_4 \text{ ; } 170°C} CH_2 = CH_2 + H_2O$$

  - The conc. sulphuric acid can be regarded as a dehydrating agent who removes water from ethanol.

- **Oxidation:** Alcohols get converted to carboxylic acids on oxidation:

$$CH_3OH \xrightarrow[K_2Cr_2O_7]{[O]} HCHO + H_2O \xrightarrow[K_2Cr_2O_7]{[O]} HCOOH$$

$$C_2H_5OH \xrightarrow[K_2Cr_2O_7]{[O]} CH_3CHO + H_2O \xrightarrow[K_2Cr_2O_7]{[O]} CH_3COOH$$

  - Alkaline potassium permanganate or acidified potassium dichromate are oxidising alcohols to acids, that is, adding oxygen to the starting material. Hence they are known as oxidising agents.

- **Uses:**
  - It is used in thermometers.
  - It is used as antifreeze for automobile radiators.
  - In addition, because it is a good solvent, it is also used in medicines such as tincture iodine, cough syrups, and many tonics.
  - Some countries now use alcohol as an additive in petrol since it is a cleaner fuel

Carboxylic Acids

Ethanoic acid (or Acetic acid): Ethanoic acid is commonly called acetic acid and belongs to a group of acids called carboxylic acids. 5-8% solution of acetic acid in water is called vinegar and is used widely as a preservative in pickles. The anhydrous acid on cooling forms crystalline mass resembling ice; at its melting point 290 K (or 17°C) and for this reason, it is called glacial acetic acid.

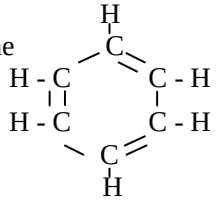
- **Reaction with a base:** Like mineral acids, ethanoic acid reacts with a base such as sodium hydroxide to give a salt (sodium ethanoate or commonly called sodium acetate) and water:

$$CH_3COOH + NaOH \longrightarrow \underset{\text{(Sodium ethanoate)}}{CH_3COONa} + H_2O$$

- **Esterification reaction:** Ethanoic acid reacts with absolute ethanol in the presence of a few drops of concentrated sulphuric acid (as catalyst) to give an ester –

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Ethanol}}{HOC_2H_5} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\text{Ethyl ethanoate (Ethyl acetate / ester)}}{CH_3COOC_2H_5} + H_2O$$

  - Esters are sweet-smelling substances. These are used in making perfumes and as flavouring agents.

- Methane is a green house gas.
- Ethene is used for ripening many raw fruits and Polythene is made up by polymerisation of ethene.
- Iso butane is used in cooking gas LPG (Liquid petroleum Gas).
- Acetylene is used for oxy-acetylene welding at very high temperature.
- Ethanol is an important industrial solvent. To prevent the misuse of ethanol produced for industrial use, it is made unfit for drinking by adding poisonous substances like methanol and pyridine to it. Dyes like copper sulphate are also added in small amount to colour the alcohol blue so that it can be identified easily. This is called denatured alcohol.
- Spurious alcohol contains large proportions of methanol in a mixture of alcohol.
- Benzene 

Cyclopropane