Functional groups: Carbon can also form bonds with other elements, such as halogens, oxygen, nitrogen, sulphur etc. These are called hetero atoms. These atoms or group of atoms, replace one or more hydrogen atoms of the hydrocarbon and are responsible the chemical reactivity of the compound, regard1- of the length and nature of carbon chain. Hence these are called functional groups. Thus, functional groups may be defined as an 'atom' or a 'group of atoms' which makes a carbon compound (or organic compound) reactive decide its properties (or functions) regardless of length and nature of carbon chain.

Hetero atom	*Functional Group*	*Formula of Functional Group*
Cl|Br|F|I	Halo (chloro/bromo fluoro/Ido)	—Cl, —Br, —F, —I [substitutes for H- atom]
oxygen	1. Alcohol	—OH
	2. Aldehyde	—CHO
	3. Ketone	—C(=O)—
	4. Carboxylic acid	—C(=O)—OH

Some important functional groups are tabulated below.

Homologous Series: A series of similarly constituted compounds in which the members present have the same functional group and similar chemical properties and any two successive members in a particular series differ in their molecular formula by a —CH2— unit, is called a homologous series. CH_4, C_2H_6, C_3H8, C_4H_{10} are the members of one family.

Characteristics of a Homologous Series:

- All the members of a homologous series can be represented by the same general formula.
- Any two adjacent homologues differ by 1 carbon atom and 2 hydrogen atoms in their molecular formula.
- All the compounds of a homologous series show similar chemical properties.
- With increase in the molecular mass, the gradual change in the physical properties occurs, e.g. the netting and boiling points increase with increasing molecular mass.
- The difference in the molecular masses of any two adjacent homologues or members is 14 u.

Nomenclature of Carbon Compounds: Organic compounds have generally two types of names. These are IUPAC names and common names. The IUPAC have been adopted by the International Union of Pure and Applied Chemistry and are based on certain rules. The common names, also known as trivial names, have no system for naming. In general, the IUPAC names of organic compounds are based on the name of basic carbon chain modified by a prefix (phrase before) or suffix (phrase after) indicating the name (or nature) of the functional group.

Writing IUPAC Name of a Compound: Following steps are used to write the name of an organic compound:

Step I: Count the number of carbon atoms in the given compound and write the root word for it. Root words upto 10 carbon atoms are tabulated below.

Root Words for Carbon Atoms

Number of C-atom(s)	*Root Word*	*Number of C-atom(s)*	*Root Word*
1 (C_1)	Meth	6 (C_6)	Hex
2 (C_2)	Eth	7 (C_7)	Hept
3 (C_3)	Prop	8 (C_8)	Oct
4 (C_4)	But	9 (C_9)	Non
5 (C_5)	Pent	10 (C_{10})	Dec

Step II: If the compound is saturated, add suffix 'ane' to the root word, but if it is unsaturated, add suffix 'ene' and 'yne' for double and triple bonds respectively. e.g. $CH_3CH_2CH_3$ contains three C-atoms, so the root word is 'prop' and it contains only single bonds, thus, suffix used is 'ane'.

Hence, the name of this compound is propane. Similarly, the compound CH_3CHCH_2 is named as propene as here suffix 'ene' is used for double bond.

Step III: If functional group is present in the compound, it is indicated in the name of the compound with either a prefix or a suffix (which are given in the table below).

Prefix and Suffix of Different Functional Groups

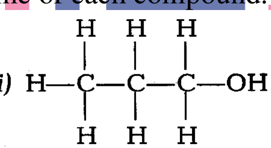
Note • If the functional group is named as a suffix, the final 'e' of alkane (or alkene or alkyne) is substituted by appropriate suffix.

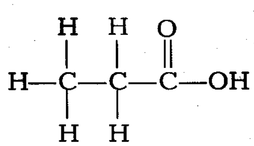
• If the functional group and substituent's are not present at first carbon, then their location is indicated by digits 2,3,4....

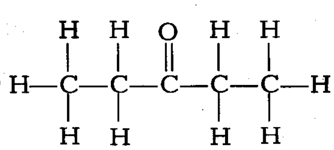
Q: Give the formula and IUPAC names of next two members of homologous series given below.

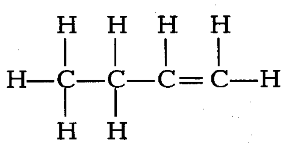
1. CH_3OH
2. C_2H_6
3. HCOOH

Q: Identify and name the functional groups present in the following compounds. Also write the IUPAC name of each compound.

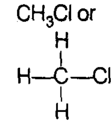
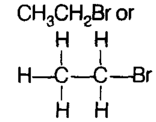
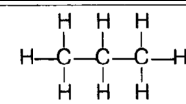
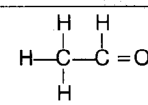
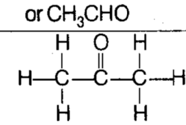
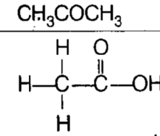
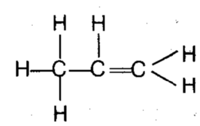
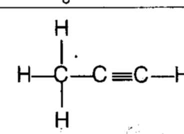
(i) 

(ii) 

(iii) 

(iv) 

Prefix and Suffix of Different Functional Groups

Functional Group	*Prefix/Suffix*	*Example*	*IUPAC Name*
Halogen	Prefix-chloro, bromo etc.	CH_3Cl or 	Chloromethane
		CH_3CH_2Br or 	Bromoethane
Alcohol	Suffix-ol	 $CH_3—CH_2—CH_2OH$	Propane $\xrightarrow[-e]{+ol}$ Propanol
Aldehyde	Suffix-al	 or CH_3CHO	Ethane $\xrightarrow[-e]{+al}$ Ethanal
Ketone	Suffix-one	 or CH_3COCH_3	Propane $\xrightarrow[-e]{+one}$ Propanone
Carboxylic acid	Suffix-oic acid	 or CH_3COOH	Ethane $\xrightarrow{+oic}$ Acid noic acid
Double bond (alkenes)	Suffix-ene	 or $CH_3—CH=CH_2$	Propene
Triple bond (alkynes)	Suffix -yne	 or $CH_3—C\equiv CH$	Propyne

Chemical Properties of Carbon Compounds: Some of the important chemical properties of carbon pounds are as follows:

1. **Combustion:** The carbon compounds (including its allotropic forms burn in oxygen to give carbon dioxide and water vapors. Heat and light are also released during this process. This reaction is called as combustion.

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$$C + O_2 \longrightarrow CO_2 + Heat + Light$$
$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + Heat + Light$$
$$CH_3CH_2OH + 6O_2 \longrightarrow 4CO_2 + 6H_2O + Heat + Light$$

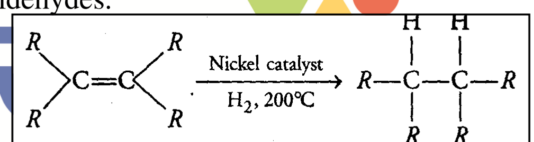
Further, once carbon and its compounds ignite, they keep burning without the requirement of additional energy. That's why these compounds are used as fuels. Saturated hydrocarbons give a clean blue flame due to their complete combustion whereas, unsaturated hydrocarbons have a yellow flame with lots of black smoke as they do not undergo complete combustion.

The burning of unsaturated hydrocarbons always results in the deposition of soot [a black substance]. However, in the limited supply of air, even saturated hydrocarbons undergo incomplete combustion and give a sooty flame. The gas stoves used at home has inlets for air so at a sufficiently oxygen-rich mixture is burnt to give a clean blue flame. However, sometimes the bottoms of cooking vessels gets blackened because the air holes present at the bottom of the vessels gets blocked and fuel [or LPG] do not get oxygen and therefore, it does not burn properly and undergoes complete combustion producing sooty flames which blackened the vessels bottom.

$$\underset{\text{Ethanol}}{CH_3CH_2OH} + [O] \xrightarrow[\text{or acidified } K_2Cr_2O_7 + \text{Heat}]{\text{Alkaline } KMnO_4 + \text{Heat}} \underset{\substack{\text{Acetic acid} \\ \text{(Ethanoic acid)}}}{CH_3\overset{O}{\overset{||}{C}}—OH}$$

2. **Oxidation:** It is the reaction involving the addition of oxygen and removal of hydrogen. Alcohols can be oxidised by heating them either in presence of oxidising agents like alkaline KMno4 (potassium permanganate) or acidified K2Cr07 (potassium dichromate). Substances that are capable of adding oxygen to other substances are called oxidising agents. Alcohols are converted into carboxylic acid only under complete oxidation. In partial oxidation, alcohols are converted into aldehydes.

$$\text{In general, Alcohol} \xrightarrow{[O]} \text{Aldehyde} \xrightarrow{[O]} \text{Acid}$$



3. **Addition Reactions:** The reactions in which a reagent completely adds to a reactant without the removal of small molecules are called additions. E.g. addition of hydrogen (hydrogenation) in the presence of catalysts like palladium or nickel, to unsaturated hydrocarbons yields saturated hydrocarbons.

The reaction shown is commonly used in the hydrogenation of vegetable oils [that are unsaturated compounds] using a nickel catalyst. **Note**

- A catalyst is that substance which alters the rate of a reaction without being consumed in the reaction.
- Saturated fatty acids which are generally present in animal fats are harmful for health.
- Oils containing unsaturated fatty acids should be chosen for cooking.
- Unsaturated compounds discharge the pink colour of alkaline KMnO4. This is known as test of unsaturation.

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

4. **Substitution Reactions:** The reactions in which a reagent replaces an atom or a group of atoms from the reactant (substrate) are called substitution reactions. These are generally shown by saturated compounds. Most of the saturated hydrocarbons are fairly inert and unreactive in the presence of most reagents. However, these reactions take place readily in the presence of sunlight e.g. In the presence of sunlight, chlorine is added to hydrocarbons at a rapid rate. In this reaction, Cl replaces H-atom one by one.

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Fuels and flames fuels: Those carbon compounds which have energy stored in them and burn with heat and light are called fuels. The released energy (heat or light) is utilised for various purposes like for cooking food, running machines in factories etc. In fuels, the carbon can be in free state as present in coal, coke and charcoal or in combined state as present in petrol, LPG (Liquefied petroleum gas whose main constituent is butane), CNG (Compressed natural gas, main constituent of which is methane), kerosene, petroleum, natural gas etc. Those fuels which were formed by the decomposition of the remains of the pre-historic plants and animals (fossils) buried under the earth long ago are called fossil fuels. E.g. coal, petroleum and natural gas.

Coal: It is a complex mixture of compounds of carbon, hydrogen and oxygen and some free carbon along with traces of nitrogen and sulphur. It is formed by the decomposition of plants, ferns and trees which got buried under the earth millions of years ago.

Petroleum: It is dark viscous foul smelling oil and is also known as rock oil or black gold. It is formed by the decomposition of the remains of extremely small plants and animals buried under the sea millions of years ago.

Note: Since, coal and petroleum have nitrogen and sulphur in small amounts therefore their combustion results in the formation of oxides of sulphur and nitrogen that are major pollutants in the environment that's why, they play an important role in causing pollution (air pollution).

Flame: A flame is the region where combustion (or burning) of gaseous substances takes place. Depending upon the amount of oxygen available and burning of fuels, flames are of the following two types:

1.Blue or non - luminous Flame: When the oxygen supply is sufficient, the fuels burn completely producing a blue flame and no light is produced. E.g. burning of LPG in gas stove.

2.Yellow or Luminous Flame: In the insufficient supply of air, the fuels burn incompletely and produce yellow flame because of the presence of unburnt carbon particles, e.g. burning of wax vapours.

Note: Some solid and liquid fuels like coal and charcoal do not vaporize on heating. Such fuels burn without producing a flame. They just glow red and gives out heat.

Some important carbon compounds

1.**Ethanol**: Its common name is ethyl alcohol and formula is C_2H_5OH or CH_3CH_2OH.

Preparation: Alcohol (ethanol) is obtained by the fermentation of molasses which are obtained from sugarcane juice.

Physical Properties: It is a liquid at room temperature. Its melting point 156 K and boiling point is 351 K. It is soluble in water in all proportions.

Chemical Properties:

a) Reaction with Sodium: Ethyl alcohol reacts win sodium metal leading to the evolution of hydrogen gas alongwith the formation of sodium ethoxide. Hydrogen gas burns with a pop sound.

$$\underset{\text{Sodium}}{2Na} + \underset{\text{Ethanol}}{2CH_3CH_2OH} \longrightarrow \underset{\text{Sodium ethoxide}}{2CH_3CH_2O^-Na^+} + \underset{\text{Hydrogen gas}}{H_2\uparrow}$$

b) Dehydration: Removal of water molecules from a compound is known as dehydration reaction. When ethanol is heated at 443 K with excess conc. H_2SO_4, the water molecules get removed from it and ethene is obtained. Thus in this reaction H_2SO_4 act as dehydrating agent.

$$\underset{\text{Ethanol}}{CH_3-CH_2OH} \xrightarrow[H_2SO_4,\ 170°C]{\text{Hot conc.}} \underset{\text{Ethene}}{CH_2{=}CH_2} + \underset{\text{Water}}{H_2O}$$

Uses:

a) It is used as an active ingredient in all alcoholic drinks.

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b) It is useful in medicines like tincture of iodine, cough syrups and many other tonics.
c) Alcohol is used as an additive in petrol, since it is a cleaner fuel and gives rise to only CO_2 and H_2O when burnt in sufficient air.

Effect of Ethanol on Living Beings: When large quantities of alcohol/ethanol are consumed, it tends to slow metabolic processes and depress the central nervous system which in turn results in lack of coordination, drowsiness, mental confusion, lowering of the normal inhibitors and finally stupour. The individual may be relaxed but does not realise that his sense of judgement and muscular coordination have been seriously impaired. Therefore, in order to stop the misuse of ethanol, it is made unfit for drinking by adding poisonous substances like methanol, copper sulphate, pyridine etc. and coloured substance like dyes. Such alcohol is called denatured alcohol. In liver, methanol is oxidised to methanal which reacts readily with the components of cells and causes coagulation of protoplasm. It also affects optic nerves, causing blindness.

2. Ethanoic Acid or Acetic Acid: commonly known as acetic acid. Its formula is CH_3COOH. 5-8% solution of ethanoic acid in water is known as vinegar.

Physical Properties: Its melting point is 290 K. During winters it often freezes and forms ice like flakes, so it is also called glacial acetic acid. Glacial acetic acid is a trivial name for water free (anhydrous) acetic acid. It is a weaker acid than HCI but stronger than alcohol.

Chemical Reactions:

a) Acidity: Weak acidity of acetic acid as compared to HC1 is because of its low ionisation but is more acidic than alcohol is because of the more stability of ion formed after the removal of a proton (H^+). It evolves hydrogen gas when reacts with sodium metal.

$$\underset{\text{Acetic acid}}{2CH_3COOH} + \underset{\text{Sodium metal}}{2Na} \longrightarrow \underset{\text{Sodium acetate}}{2CH_3CO\bar{O}Na^+} + H_2\uparrow$$

b) Reaction with a base: It reacts with a base such as sodium hydroxide to give a salt (sodium ethanoate or sodium acetate) and water.

$$\underset{\text{Acetic acid}}{CH_3COOH} + \underset{\text{Sodium hydroxide}}{NaOH} \longrightarrow \underset{\text{Sodium acetate}}{CH_3CO\bar{O}Na^+} + H_2O$$

c) Esterification: When ethanol (an alcohol) reacts with acetic acid (a carboxylic acid) in the presence of an acid as catalyst a fruity (sweet) smelling liquid called ester is obtained. This reaction is called esterification. Here, H_2SO_4 act as dehydrating agent, i.e. it removes water formed, otherwise ester formed will get converted into acid. The ester gets converted back into alcohol and sodium salt of acid when treated with alkali like sodium hydroxide. This reaction is called saponification, as it is used for the preparation of soap.

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[-H_2O]{\text{Acid}} \underset{\text{Ester}}{CH_3-\overset{\overset{}{}}{\underset{\underset{O}{\|}}{C}}-O-CH_2CH_3}$$

$$\underset{\text{Ethyl acetate}}{CH_3COOCH_2CH_3} \xrightarrow{NaOH} \underset{\text{Ethyl alcohol}}{CH_3CH_2OH} + \underset{\text{Sodium acetate}}{CH_3CO\bar{O}Na^+}$$

d) Reaction with carbonates and hydrogen carbonates: In the reaction of acetic acid with carbonates or hydrogen carbonates, carbon dioxide gas is obtained. It is an example of acid-base reaction.

$$CH_3COOH + NaHCO_3 \longrightarrow \underset{\text{Sodium acetate}}{CH_3CO\bar{O}Na^+} + H_2O + CO_2\uparrow$$

$$2CH_3COOH + Na_2CO_3 \longrightarrow \underset{\text{Sodium acetate}}{2CH_3CO\bar{O}Na^+} + H_2O + CO_2\uparrow$$

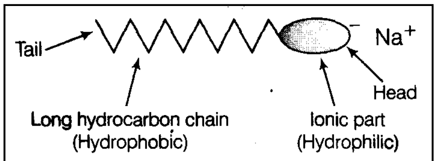
Uses:
a) It is used for making vinegar.
b) It is widely used as a preservative in pickles.
c) It is used for the synthesis of other compounds like esters.

Soaps and Detergents: Soaps are sodium or potassium salts of long chain carboxylic acids and have general formula RCOONa. where, R = $C_{15}H_{31}$, $C_{17}H_{35}$ etc. Detergents are usually ammonium or sulphonate salts of long chain carboxylic acids. They are also called as soapless soap.

$$\underset{\text{(Ester)}}{\text{Fat or Oil}} + \underset{\text{(Sodium hydroxide)}}{\text{Alkali}} \xrightarrow{\text{Heat}} \underset{\text{(Sodium salt of fatty acid)}}{\text{Soap}} + \underset{\text{(An alcohol)}}{\text{Glycerol}}$$

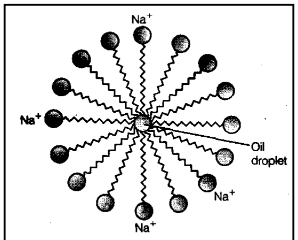
Manufacture of Soaps and Detergents: Soaps are made from animal fats or vegetable oils by heating it with sodium hydroxide. This process of preparation of soap is called saponification.

Structure of a Soap Molecule: A soap molecule is made up of two parts: a long hydrocarbon part (or non-ionic part) and a short ionic part containing —$COONa^+$ group. The long hydrocarbon part is hydrophobic and therefore insoluble in water but soluble in oil. The ionic portion of the soap molecule is hydrophilic so, soluble in water and insoluble in oil.



Structure of a soap molecule

Cleansing Action of Soaps (Micelle Formation): Soap molecules have different properties at their two ends. It's one end is hydrophilic (soluble in water) and another is hydrophobic (soluble in fats or oils). At the surface of water, the hydrophobic end or tail of soap will be insoluble in water and the soap will align along the surface of water with the ionic end in water and the hydrocarbon 'tail' protruding out of water.



Formation of micelles

Inside water, these molecules show a unique orientation that keeps the hydrocarbon portion out of the water. This is done by forming clusters of molecules in which the hydrophobic tails are in the interior of the cluster and on the surface of cluster, ionic ends are present.

This formation of cluster of molecules is called **micelle**. To wash away the loosened dirt particles in the form of micelles from the surface of the cloth, it is either scrubbed mechanically or beaten or agitated in washing machine.

In the form of a micelle, soap is able to clean, since the oily dirt is being collected in the centre of micelle. Micelles stay as colloids in the solution and does not come closer to precipitate due to ion-ion repulsion. Hence, the dirt suspended in the micelles is also easily rinsed away.

Note: Soap solution appears cloudy because the ion aggregate to form spherical clusters which forms micelles are large enough to scatter light.

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