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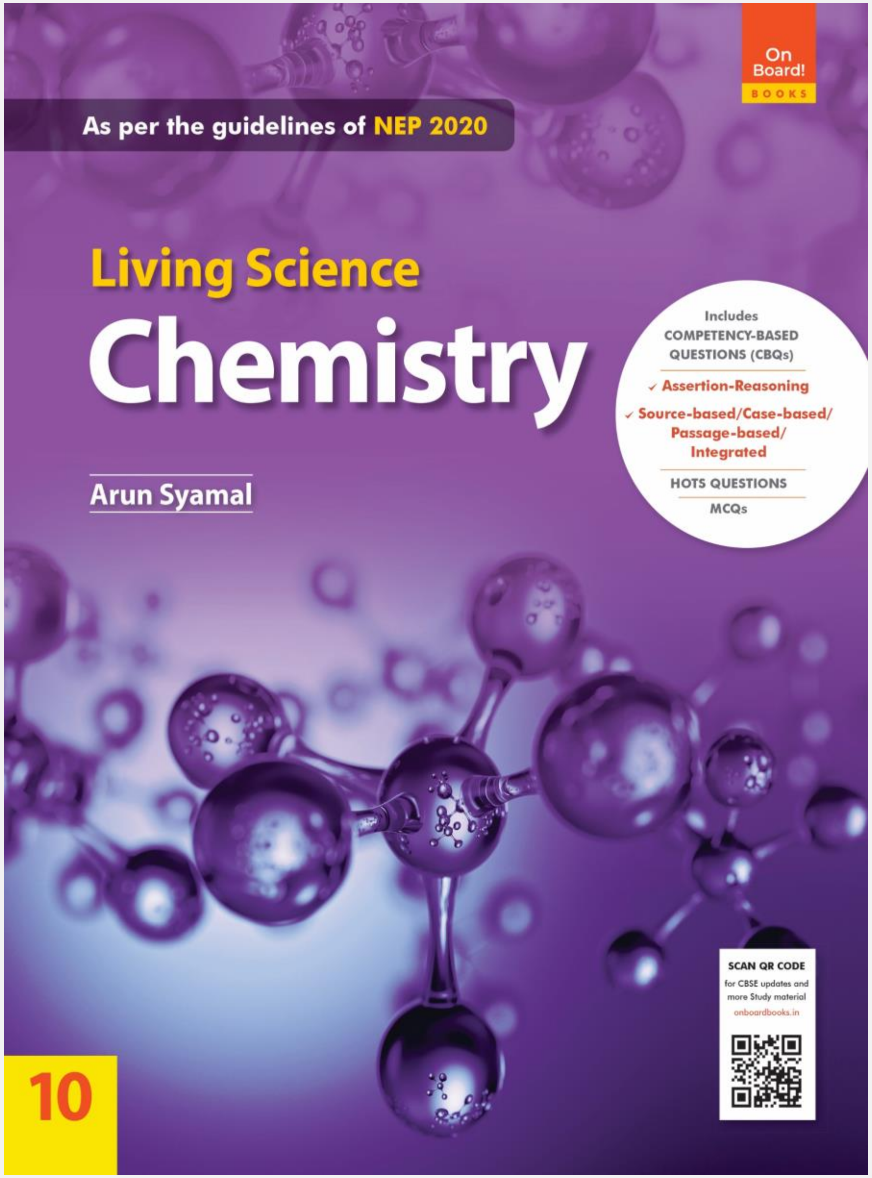
CBSE Living Science CHEMISTRY



CBSE LIVING SCIENCE CHEMISTRY

CLASS 10

Chapter 4

Carbon and its Compounds

Learning Objectives

- Carbon compounds, chemical properties of carbon compounds
- Elementary idea about bonding
- Saturated hydrocarbons
- Nomenclature of carbon compounds
- Alcohols
- Carboxylic acids (no preparation, only properties)
- Soap, cleansing action of soap, detergents

Carbon is a versatile element. The earth's crust contains 0.02% carbon and the atmosphere contains 0.03% carbon as carbon dioxide. In the free elemental state, it occurs in nature as diamond and graphite.

In the combined state, it occurs as carbon dioxide in air, as carbonates (limestone and marble), as hydrocarbons in natural gas and petroleum and as mixture of compounds (coal and petroleum). All living systems are made up of carbon compounds such as carbohydrates, proteins, vitamins, fats, enzymes, etc. The food we eat (grains, pulses, fruits, vegetables, etc.) and the clothes we wear (cotton, wool, nylon, etc.) are all carbon compounds.

BONDING IN CARBON COMPOUNDS - THE COVALENT BOND

The reactivity of elements depends on their tendency to attain noble gas configuration. In ionic compounds, elements either gain or lose electrons from the outermost shell to attain stable noble gas electronic configuration. In case of carbon (atomic no. 6), it has six protons and six electrons and its electronic configuration is 2, 4. Thus, there are four electrons in its outermost shell. It can either lose or gain four electrons to attain a stable noble gas configuration.

Since carbon is a small atom, its valence electrons are strongly held by the nucleus. A huge amount of energy is needed to remove four electrons leaving behind a C^{4+} cation having six protons holding on to only two electrons. No compound with a +4 cation is known in carbon.
The formation of C^{4-} anion is also difficult since the C^{4-} anion would have only six protons holding on to ten electrons. The electron rich C^{4-} anion having four extra electrons would be unstable. Instead of attaining the noble gas electronic configuration through a C^{4+} cation or C^{4-} anion, carbon attains the desired configuration by mutual sharing of electrons with other atoms of carbon or different elements. The shared pair of electrons forming a bond belong to the outermost shells (valence shells) of both the atoms.
A bond formed by the mutual sharing of an electron pair between two atoms is called a covalent bond. The mutual sharing of electrons occurs in such a way that each of the combining atom acquires the stable electronic configuration of the nearest noble gas.

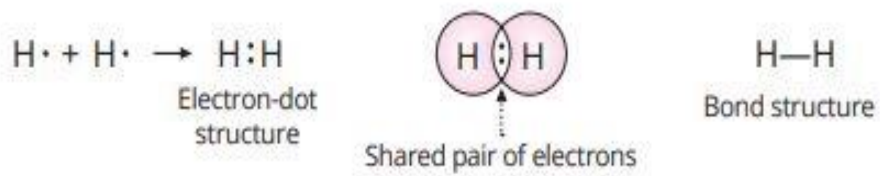
Not only carbon, but many other elements such as nitrogen, phosphorus, oxygen, sulphur, chlorine, etc., form covalent compounds by mutual sharing of electrons. Let us look at some examples of molecules having covalent bonds.

Hydrogen molecule

The electronic configuration of hydrogen atom is 1. Since a hydrogen atom has only one electron in its only orbit (*K* shell), it needs one more electron for acquiring the stable electronic configuration (2, duplet) of the nearest noble gas (helium). When two hydrogen atoms come close to each other, an electron of both the hydrogen atoms is shared between them. In the process of formation of a covalent bond both the hydrogen atoms acquire the stable electronic configuration of noble gas helium.

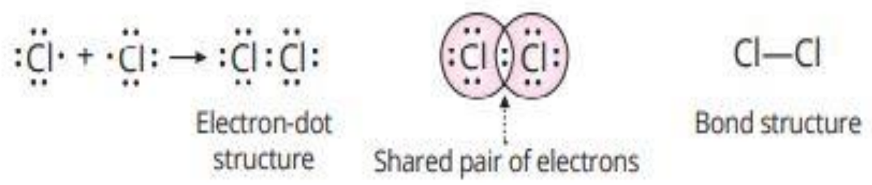
In the formation of H_2 molecule, one pair of electrons is shared by two hydrogen atoms. Covalency of an atom is the number of its electrons forming shared pairs with other atom. Thus, covalency of hydrogen is 1.

In the electron-dot structure, the dots represent the valence electrons. The shared pair of electrons constitutes a single covalent bond between the two atoms. A single covalent bond formed is represented by a line between the two atoms. The pairs of electrons on an atom which are not involved in the bond formation are called lone pairs of electrons.



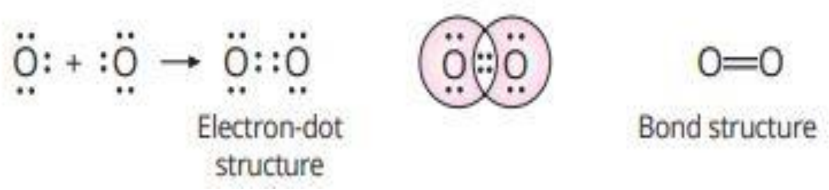
Chlorine molecule

In case of chlorine molecule, each chlorine atom contributes one electron to the shared pair of electrons and complete its octet. As a result, both the chlorine atoms attain the noble gas octet electronic configuration. Since each chlorine atom shares one electron to form the Cl_2 molecule, the covalency of chlorine is 1.



Oxygen molecule

In an oxygen molecule, each oxygen atom contributes two electrons to the shared pairs of electrons and complete its octet. The two lines between two oxygen atoms represent a double bond containing four electrons which are mutually shared by two oxygen atoms. A double bond is stronger than a single bond. Since each oxygen atom shares two electrons to form the O_2 molecule, the covalency of oxygen is 2.

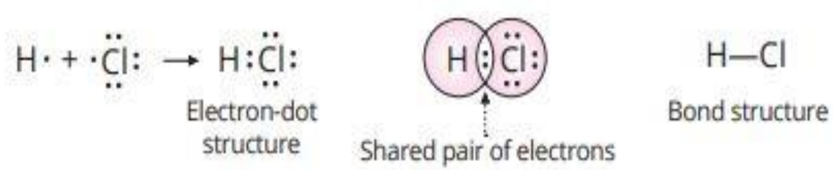


Nitrogen molecule

In nitrogen molecule, each nitrogen atom contributes three electrons to the shared pair of electrons and complete its octet. The three lines between two nitrogen atoms represent a triple bond containing six electrons which are mutually shared by two nitrogen atoms. The triple bond is a very strong bond (stronger than a double bond) and is not easily broken. As a result, the molecular nitrogen is chemically very less reactive. Since each nitrogen atom shares three electrons to form N_2 molecule, the covalency of nitrogen is 3.

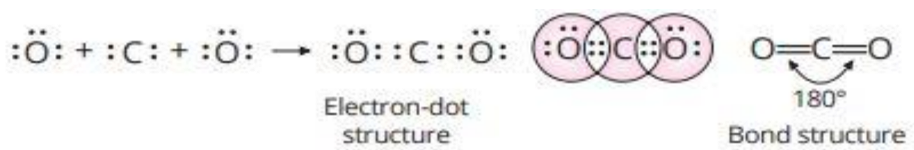
Hydrogen chloride

In a molecule of hydrogen chloride, the hydrogen atom and chlorine atom contribute one electron each to the shared pair of electrons. In the process, the hydrogen atom attains the duplet of electrons and the chlorine atom attains the octet of electrons.



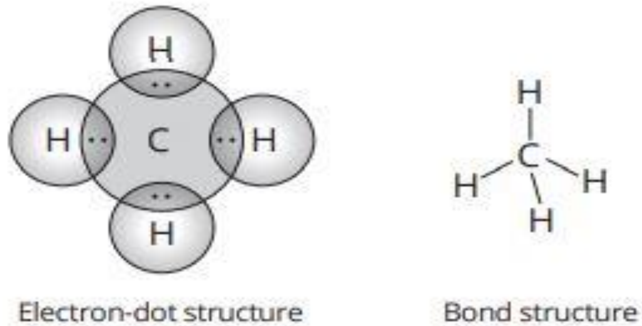
Carbon dioxide

In a carbon dioxide molecule, the oxygen atom and carbon atom contribute two electrons each to the shared pairs of electrons for the formation of each C=O bond. In the process, the oxygen atom and carbon atom attain the octet of electrons. In CO_2 molecule, there are two C=O bonds. Since each oxygen atom shares two of its electrons, the oxygen atom is divalent and since the carbon atom shares four of its electrons, the carbon atom is tetravalent.



Methane

Methane is one of the simplest carbon compounds and its formula is CH_4. The hydrogen atom and carbon atom contribute one electron each to the shared pair of electrons for the formation of each C—H bond. In the process, each hydrogen atom attains duplet of electrons and the carbon atom attains the octet of electrons. In CH_4 molecule, there are four C—H single covalent bonds and four bond pair of electrons.



Properties of Covalent Compounds

Some important properties of covalent compounds are as follows:

1. Covalent compounds possess low melting and boiling points. The intermolecular forces of attraction between the molecules are weak, but the covalent compounds have strong bonds within the molecules.

Compound	Formula	Melting point (K)	Boiling point (K)
Methane	CH_4	90.5	111.0
Ethane	C_2H_6	101.0	184.4
Ethene	C_2H_4	103.6	169.1
Ethyne	C_2H_2	191.2	189.4
Benzene	C_6H_6	278.5	353.1
Chloroform	$CHCl_3$	209.5	334.3
Ethanoic acid	CH_3COOH	289.6	391.1
Methanol	CH_3OH	175.2	337.6
Ethanol	C_2H_5OH	155.7	351.5

2. Covalent compounds are non-conductors of heat and electricity. This is because during the formation of covalent bonds, only electrons are shared between atoms and no charged particles are formed.

3. A covalent bond is a strong bond but is weaker than an ionic bond.

4. Covalent compounds can be gases (for example, HCl, NH_3, CH_4, ethane, etc.), liquids (for example, water, methanol, ethanol, chloroform, benzene, etc.) and solids (for example, dry ice, wax, glucose, polythene, nylon, etc.).
5. Covalent compounds are soluble in non-polar solvents such as chloroform, alcohol, ether, benzene, hexane, etc., and are insoluble in polar solvents like water.

VERSATILE NATURE OF CARBON

Carbon is a versatile element and it exhibits many unique properties. Some important factors which are responsible for the versatile nature of carbon are discussed below:

Catenation

Due to the strong and stable nature of carbon–carbon bond, carbon exhibits the unique property to form bonds with other carbon atoms giving rise to large straight chain compounds, branched chain compounds and rings of carbon atoms. This property is known as **catenation**.

Due to catenation, carbon forms a large number of compounds. It has the unique property to make bond with another carbon atom forming single bond (C—C), double bond (C=C) or triple bond (C≡C). Although, some other elements such as silicon and sulphur also exhibit the property of catenation, the extent of catenation is much less in these elements in comparison to carbon. Silicon forms compounds with hydrogen which contain chains of up to seven or eight silicon atoms but these compounds are very reactive.

Tetravalent Nature of Carbon and Formation of Multiple Covalent Bonds
With Other Elements

Carbon has the tendency to attain octet through the formation of multiple covalent bonds with nitrogen, oxygen, sulphur, etc., giving rise to the formation of compounds with specific properties.

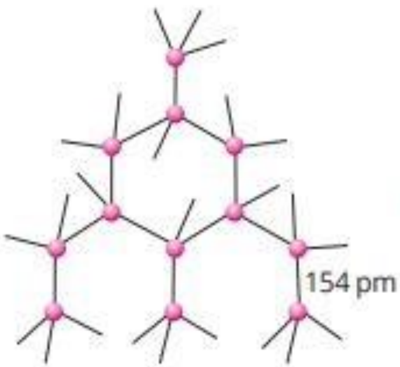
Carbon forms multiple covalent bonds of the type C=N, C=O, etc. The formation of multiple covalent bonds by carbon is attributed to its small size and strong nature of these multiple covalent bonds. Due to the small size of carbon, the nucleus of carbon can hold on to the shared pairs of electrons strongly.

The tetravalent nature of carbon and catenation are together responsible for the formation of a large number of carbon compounds.

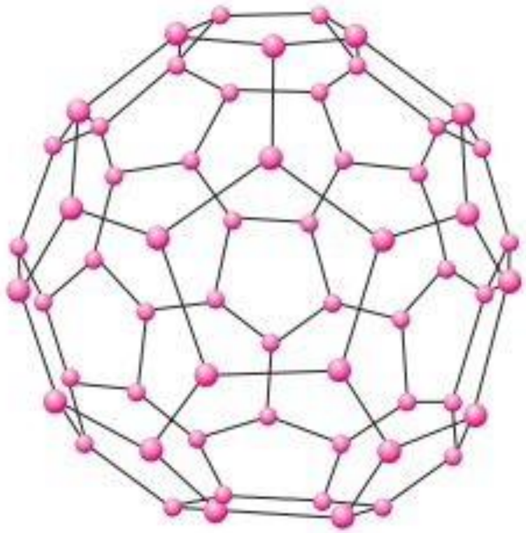
ALLOTROPES OF CARBON

Allotropy is the property by virtue of which an element exists in more than one form and each form has different physical properties but identical chemical properties. These different forms are called allotropes. Carbon exhibits allotropy.

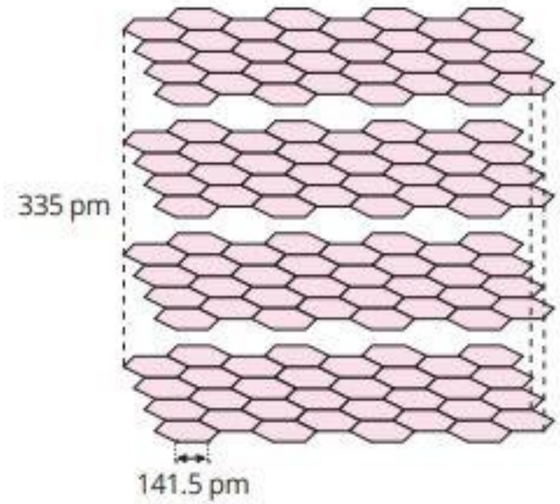
The allotropes of carbon are diamond, graphite and fullerene. In these allotropes, the sequence of bonding of carbon atoms is different.



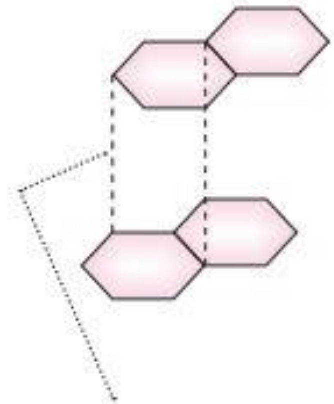
Structure of diamond



Structure of $[C_{60}]$ fullerene



Structure of graphite



Weak intermolecular force between the planar layers in graphite

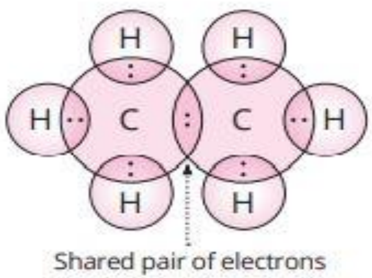
ORGANIC COMPOUNDS

The compounds of carbon except its carbides, oxides, carbonates and hydrogen carbonate salts, are known as organic compounds. The organic compounds were initially considered to be derived from animal and vegetable sources. It was observed that while inorganic compounds such as sodium chloride can be prepared directly from their elements, the organic compounds such as urea, ethyl alcohol, sugar, etc., could not be prepared from their elements.

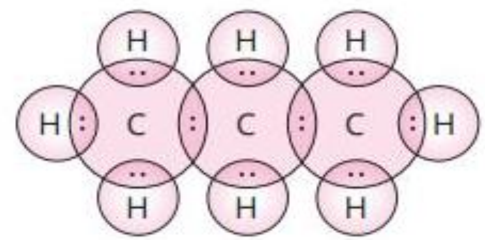
Types of organic compounds

A. Saturated and unsaturated carbon compounds

i. Saturated carbon compounds: The carbon compounds which have only single covalent bonds between the carbon atoms are called saturated carbon compounds. For example, methane (CH_4), ethane (C_2H_6), propane (C_3H_8), etc.

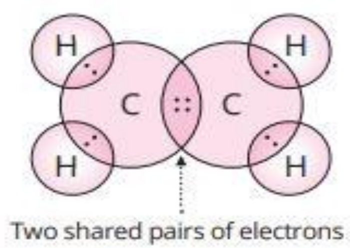


Electron-dot structure of ethane

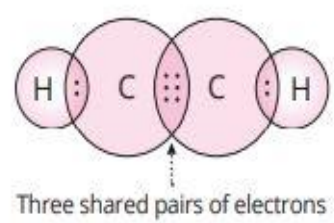


Electron-dot structure of propane

ii. Unsaturated carbon compounds: The carbon compounds containing one or more double bonds between carbon atoms are called unsaturated carbon compounds. The examples of unsaturated carbon compounds are ethene (C_2H_4), propene (C_3H_6), ethyne (C_2H_2), etc.



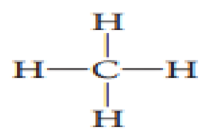
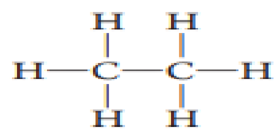
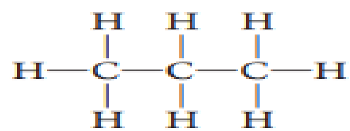
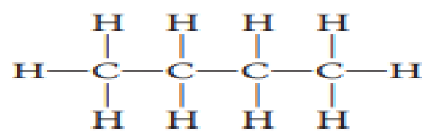
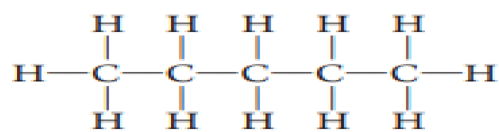
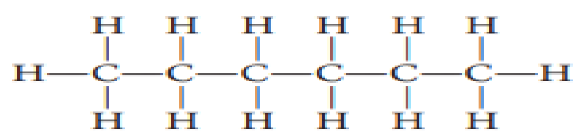
Electron-dot structure of ethene



Electron-dot structure of ethyne

B. Chains, branches and rings

i. Straight chain compounds: In these compounds, the carbon atoms join to give a straight chain. For example, methane, ethane, propane,etc. The names and structures of first six straight chain carbon compounds are given in table below.

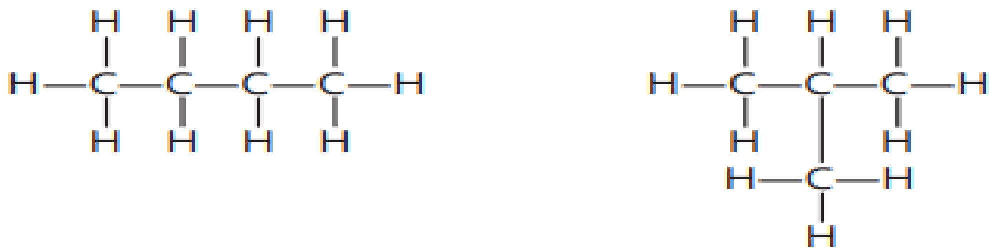
No. of carbon atoms in the chain	Name	Molecular formula	Structure
1	Methane	CH_4	
2	Ethane	C_2H_6	
3	Propane	C_3H_8	
4	Butane	C_4H_{10}	
5	Pentane	C_5H_{12}	
6	Hexane	C_6H_{14}	

ii. Branched chain compounds: The carbon compounds in which at least one carbon atom of the chain is linked to three or four other carbon atoms are called branched chain compounds. Let us look at an example of butane.

Butane has four carbon atoms. The carbon skeleton with four carbon atoms can be arranged in two different ways as follows:

Two possible carbon skeletons having four carbon atoms

Satisfying the remaining valencies of each carbon atom with hydrogen atoms, we have the following two structures having the same molecular formula (C_4H_{10}).

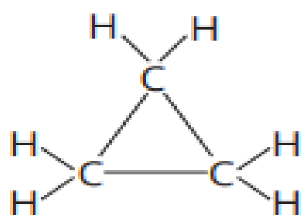


Structural formula of two molecules having the same molecular formula (C_4H_{10})

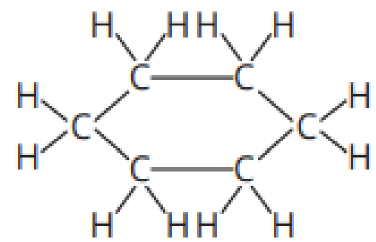
The above two structures have the same molecular formula (C_4H_{10}). The compounds having the same molecular formula but different structures are called structural isomers.

iii. Cyclic compounds: The compounds of carbon in which carbon atoms are arranged in a ring are called cyclic compounds. The cyclic carbon compounds are of the following two types.

a. **Saturated cyclic compounds:** Examples, cyclopropane (C_3H_6), cyclopentane (C_5H_{10}), cyclohexane (C_6H_{12}), etc.

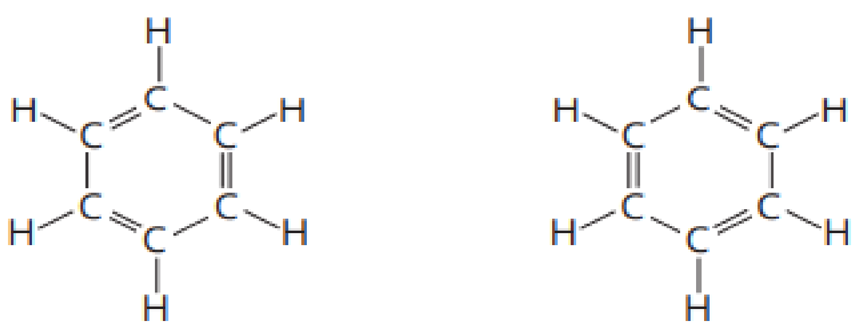


Structural formula of cyclopropane



Structural formula of cyclohexane

b. **Unsaturated cyclic compounds:** Examples, benzene (C_6H_6), naphthalene ($C_{10}H_8$), etc.



Structural formula of benzene

Hydrocarbons

The organic compounds containing only carbon and hydrogen are called hydrocarbons. Methane (CH_4), ethane (C_2H_6), ethene (C_2H_4), ethyne (C_2H_2) are few examples of hydrocarbons.

The hydrocarbons are the simplest organic compounds and they are regarded as parent organic compounds. All other organic compounds are considered to be derived from hydrocarbons by the replacement of one or more hydrogen atoms of hydrocarbons by other atoms or groups of atoms. The major sources of hydrocarbons are the fossil fuels such as coal, petroleum and natural gas.

Types of Hydrocarbons

Hydrocarbons can be classified as:

i. Saturated hydrocarbons: The hydrocarbons containing single carbon–carbon covalent bonds are called saturated hydrocarbons. In the IUPAC system, the saturated hydrocarbons are known as alkanes. The simplest alkane is methane and the other members of the series are ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{12}), hexane (C_6H_{14}), etc. The general formula of alkanes is C_nH_{2n+2} where n is the number of carbon atoms.

ii. Unsaturated hydrocarbons: The hydrocarbons containing one or more multiple bonds between carbon atoms are called unsaturated hydrocarbons.

The unsaturated hydrocarbons containing one or more double bonds are called alkenes. For example, ethene, propene, etc. The unsaturated hydrocarbons containing one or more triple bonds are called alkynes. For example, ethyne, propyne, etc. The general formula of alkenes is C_nH_{2n} and those of alkynes is C_nH_{2n-2} where n = 2, 3, 4 …

Homologous Series

A group of organic compounds having similar structures, same functional group, similar chemical properties and a regular gradation in physical properties, in which the successive compounds differ by a CH_2 group or 14 mass units is called homologous series. The molecular mass of the successive members of a homologous series differ by 14 u. The individual members of homologous series are called homologues.

Characteristics of a Homologous Series

❖ All the members of a homologous series are represented by the same general formula.

❖ Each successive homologue of a homologous series differs in the molecular formula by a —CH_2— unit.

❖ The relative molecular mass of two immediate members differs by 14 mass units (CH_2 = 12 + 2 = 14).

❖ All the members of a homologous series have the same functional group and similar chemical properties.

Functional Group

A functional group is an atom or group of atoms which determines the characteristic functions or chemical properties of a particular organic compound. A functional group contains one or more atoms of elements other than carbon such as oxygen, nitrogen, sulphur and halogens. These atoms are known as heteroatoms and they can replace one or more hydrogen atoms in a hydrocarbon chain. These heteroatoms are responsible for the specific properties of organic compounds regardless of nature and length of the carbon chain. These heteroatoms or group of heteroatoms are known as functional groups.

A functional group distinguishes one class of compounds from the others. The chemical properties of the compounds having the same functional group are similar.

Since the functional group is solely responsible for chemical properties, the chemical properties are similar in the homologues.

Some important functional groups are listed in the given table.

Heteroatom/ Multiple bond	Name of functional group	Formula of functional group	Formula of compound containing functional group	Name of the compound containing functional group
Oxygen	1. Hydroxyl (or alcoholic)	$-OH$	C_2H_5OH	Ethanol
	2. Aldehyde	$-CHO$	$HCHO$	Methanal
	3. Ketone	$-\overset{O}{\overset{\|}{C}}-$	CH_3COCH_3	Propanone
	4. Carboxylic acid	$-\overset{O}{\overset{\|}{C}}-OH$	CH_3COOH	Ethanoic acid
	5. Ester	$-\overset{O}{\overset{\|}{C}}-OR$	CH_3COOCH_3	Methyl ethanoate
Halogen (Chlorine/ Bromine)	Halo (chloro/bromo)	$-Cl$	CH_3Cl	Chloromethane
		$-Br$	CH_3Br	Bromomethane
Nitrogen	1. Amino	$-NH_2$	CH_3NH_2	Methanamine
	2. Nitro	$-NO_2$	CH_3NO_2	Nitromethane
	3. Cyano	$-CN$	CH_3CN	Ethanenitrile
Double bond	Double bond	$>C=C<$	$H_2C=CH_2$	Ethene
Triple bond	Triple bond	$-C\equiv C-$	$HC\equiv CH$	Ethyne

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Nomenclature of Organic Compounds

The naming of organic compounds can be done by following the rules given below:

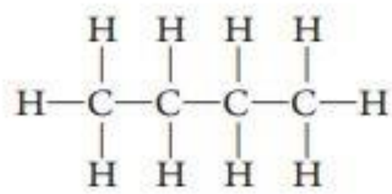
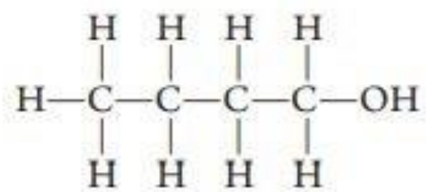
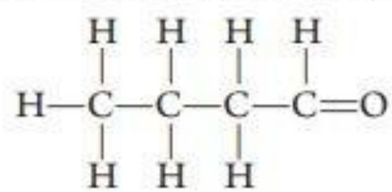
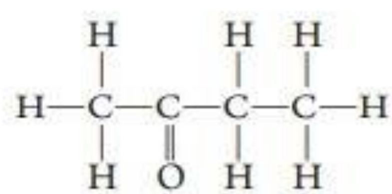
Rule 1: Identify the longest carbon chain: While identifying the longest carbon chain in the compound, include in the chain any double or triple bond present between carbon atoms. The name of the compound is based on the number of carbon atoms in the longest chain. It has a prefix depending upon the number of carbon atoms in the longest chain and has a suffix depending on the structure of the compound, i.e. whether the compound has single, double or triple bonds between carbon atoms.

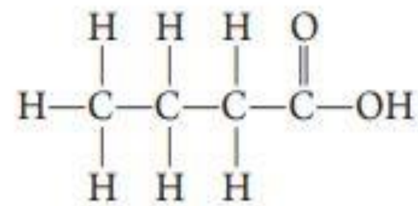
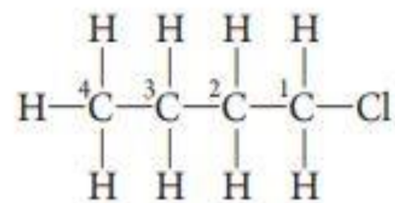
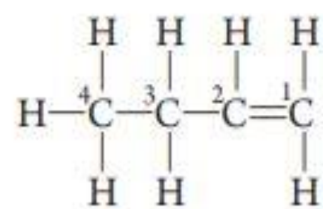
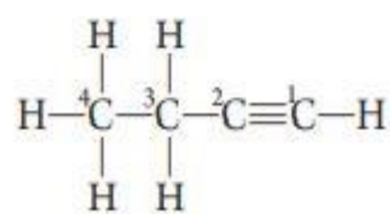
Rule 2: Lowest number for functional group rule: The carbon atoms are numbered in such a way that the functional group gets the smallest possible number.

Rule 3: When the name of the functional group is given as a suffix and if it starts with a vowel, the name of the carbon chain is modified by deleting the final ‘e’ and then adding the suffix.

Rule 4: When the carbon chain is unsaturated containing double or triple bond, the name of the carbon chain is modified by deleting the final ‘ane’ and adding ‘ene’ or ‘yne’.

Nomenclature of organic compounds

Class of compounds	**Prefix/Suffix**	**Formula of organic compound**	**Name of organic compound**
Single bond (alkanes)	Suffix–ane		Butane
Alcohol	Suffix–ol		Butanol
Aldehyde	Suffix–al		Butanal
Ketone	Suffix–one		Butanone

Class of compounds	Prefix/Suffix	Formula of organic compound	Name of organic compound
Carboxylic acid	Suffix–oic acid		Butanoic acid
Halogen	Prefix–chloro or bromo		1-Chlorobutane
Double bond (alkenes)	Suffix–ene		But-1-ene
Triple bond (alkynes)	Suffix–yne		But-1-yne

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CHEMICAL PROPERTIES OF CARBON COMPOUNDS

The chemical properties of carbon and its compounds are described below.

1. Combustion

Complete oxidation of carbon compounds with excess of oxygen or air is called combustion. All allotropic forms of carbon burn in oxygen to form either only carbon dioxide or carbon monoxide and carbon dioxide with the release of heat and light.

$$\underset{\text{Diamond}}{C} + O_2 \rightarrow CO_2 + \text{Heat} + \text{Light}$$

$$\underset{\text{Graphite}}{3C} + 2O_2 \rightarrow CO_2 + 2CO + \text{Heat} + \text{Light}$$

$$\underset{\text{Methane}}{CH_4} + 2O_2 \rightarrow CO_2 + 2H_2O + \text{Heat} + \text{Light}$$

$$\underset{\text{Ethene}}{C_2H_4} + 3O_2 \rightarrow 2CO_2 + 2H_2O + \text{Heat} + \text{Light}$$

$$\underset{\text{Ethyne}}{2C_2H_2} + 5O_2 \rightarrow 4CO_2 + 2H_2O + \text{Heat} + \text{Light}$$

2. Oxidation

Addition of oxygen to a substance is called oxidation. The organic compounds such as alcohols and aldehydes undergo oxidation in the presence of an oxidising agent such as alkaline potassium permanganate solution or acidified potassium dichromate solution to produce acids and other compounds.

$$\underset{\text{Ethanol}}{CH_3{-}CH_2{-}OH} \xrightarrow[\text{or acidified } K_2Cr_2O_7 \text{ + heat}]{\text{alkaline } KMnO_4 \text{ + heat}} \underset{\text{Ethanoic acid}}{CH_3COOH}$$

3. Addition Reaction

The unsaturated hydrocarbons such as ethene, propene, etc., undergo addition reaction with hydrogen in the presence of nickel or palladium catalyst at 150–250 °C to form saturated hydrocarbons. This reaction is known as hydrogenation reaction. It is commonly used in the hydrogenation of vegetable oils to produce vegetable *ghee*.

$$\underset{\text{Ethene}}{H_2C{=}CH_2} + H_2 \xrightarrow{\text{Ni, 150–250 °C}} \underset{\text{Ethane}}{H_3C{-}CH_3}$$

$$\underset{\text{(Liquid)}}{\text{Vegetable oil}} + H_2 \xrightarrow{\text{Ni, 200 °C}} \underset{\text{(Solid)}}{\text{Vanaspati ghee}}$$

3. Substitution Reaction

In a substitution reaction, one type of atom is substituted by another type of atom or a group of atoms. The reaction is also called halogenation reaction. Methane on halogenation forms four products such as CH_3Cl, CH_2Cl_2, $CHCl_3$ and CCl_4.

$$\underset{\text{Methane}}{CH_4} + Cl_2 \xrightarrow{\text{sunlight}} \underset{\text{Chloromethane}}{CH_3Cl} + HCl$$

$$CH_3Cl + Cl_2 \xrightarrow{\text{sunlight}} \underset{\text{Dichloromethane}}{CH_2Cl_2} + HCl$$

$$CH_2Cl_2 + Cl_2 \xrightarrow{\text{sunlight}} \underset{\text{Chloroform}}{CHCl_3} + HCl$$

$$CHCl_3 + Cl_2 \xrightarrow{\text{sunlight}} \underset{\text{Carbon tetrachloride}}{CCl_4} + HCl$$

SOME IMPORTANT CARBON COMPOUNDS

Carbon compounds are very useful to us. Here, we shall study the properties of two commercially important compounds such as ethanol and ethanoic acid.

Ethanol

Ethanol is the most important member of the homologous series of alcohols. It is the second member of alcohol series. It is also known as grain alcohol or spirit of wine. Its molecular formula is C_2H_5OH.

Properties of Ethanol

Physical Properties

1. Ethanol is a colourless, inflammable liquid having a characteristic odour and burning taste.
2. Ethanol melts at 156 K and boils at 351.1 K.
3. It is soluble in water in all proportions.
4. It is lighter than water.

Chemical Properties

1. **Reaction with Sodium:** Ethanol reacts with sodium to form sodium ethoxide with the evolution of hydrogen. The reaction is used as a test for ethanol.

$$\underset{\text{Ethanol}}{2C_2H_5OH} + \underset{\substack{\text{Sodium}\\\text{metal}}}{2Na} \rightarrow \underset{\text{Sodium ethoxide}}{2C_2H_5ONa} + H_2$$

2. **Dehydration:** Ethanol undergoes dehydration when heated with conc. H_2SO_4 at 170 °C to form ethene.

$$\underset{\text{Ethanol}}{C_2H_5OH} \xrightarrow{\text{conc. } H_2SO_4,\ 170\ ^\circ C} \underset{\text{Ethene}}{CH_2{=}CH_2} + H_2O$$

In this reaction conc. H_2SO_4 acts as a dehydrating agent which removes water from ethanol.

Ethanoic Acid (Acetic Acid)

Ethanoic acid is the second member of the homologous series of carboxylic acids. It is present in vinegar which contains 5–8% of ethanoic acid. It is present in fruits, plant extracts and biological fluids in the form of esters and metal salts. Its molecular formula is CH_3COOH.

Properties of Ethanoic Acid

Physical Properties

1. Ethanoic acid is a colourless, pungent-smelling and corrosive liquid.
2. Ethanoic acid melts at 290 K and boils at 391 K.
3. Ethanoic acid solidifies on cooling to an ice like crystalline solid (which looks like a glacier) and hence its name is glacial acetic acid.
4. Ethanoic acid is soluble in water, alcohol and ether in all proportions.

Chemical Properties

1. **Reaction with Alkalis:** Ethanoic acid reacts with alkalis to form a salt and water.

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Sodium hydroxide}}{NaOH} \rightarrow \underset{\text{Sodium ethanoate}}{CH_3COONa} + H_2O$$

2. **Reaction with Carbonates and Hydrogencarbonates:** Ethanoic acid reacts with metal carbonates and metal hydrogencarbonates to form salt, water and to give carbon dioxide with an effervescence.

$$\underset{\text{Ethanoic acid}}{2CH_3COOH} + \underset{\text{Sodium carbonate}}{Na_2CO_3} \rightarrow \underset{\text{Sodium ethanoate (sodium acetate)}}{2CH_3COONa} + H_2O + CO_2$$

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Sodium hydrogencarbonate}}{NaHCO_3} \rightarrow \underset{\text{Sodium ethanoate}}{CH_3COONa} + H_2O + CO_2$$

3. Reaction with Alcohols: Ethanoic acid reacts with alcohols in the presence of a catalyst such as concentrated sulphuric acid or dry hydrogen chloride gas to form sweet-smelling substances called esters. This reaction is called esterification reaction.

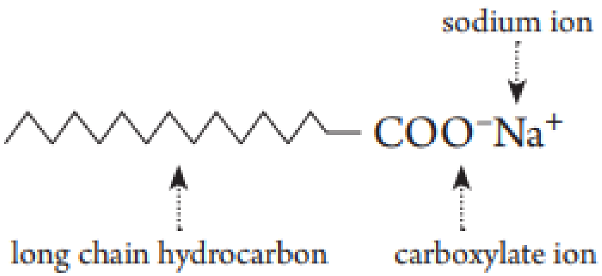
$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Ethanol}}{C_2H_5OH} \xrightarrow[\text{heat}]{\text{conc. } H_2SO_4} \underset{\text{Ethyl ethanoate (ester)}}{CH_3COOC_2H_5} + H_2O$$

Esters are used in making perfumes, cosmetics and as flavouring agents. Esters react with alkalis such as sodium hydroxide to form alcohol and sodium salt of carboxylic acid. This reaction is known as saponification as it is used in the manufacture of soap. Saponification is the reverse of esterification.

$$\underset{\text{Ethyl ethanoate}}{CH_3COOC_2H_5} \xrightarrow{NaOH} \underset{\text{Ethanol}}{C_2H_5OH} + \underset{\text{Sodium ethanoate}}{CH_3COONa}$$

SOAPS

Soaps are the sodium or potassium salts of long chain carboxylic acids (fatty acids) which have cleansing properties in water. A fatty acid is represented by the general formula RCOOH. Hence, soaps are described by the formula $RCOO^-Na^+$ or $RCOO^-K^+$. A soap molecule consists of an anion $RCOO^-$ (where R is a long hydrocarbon chain) and a cation Na^+ or K^+. A soap molecule is represented as:

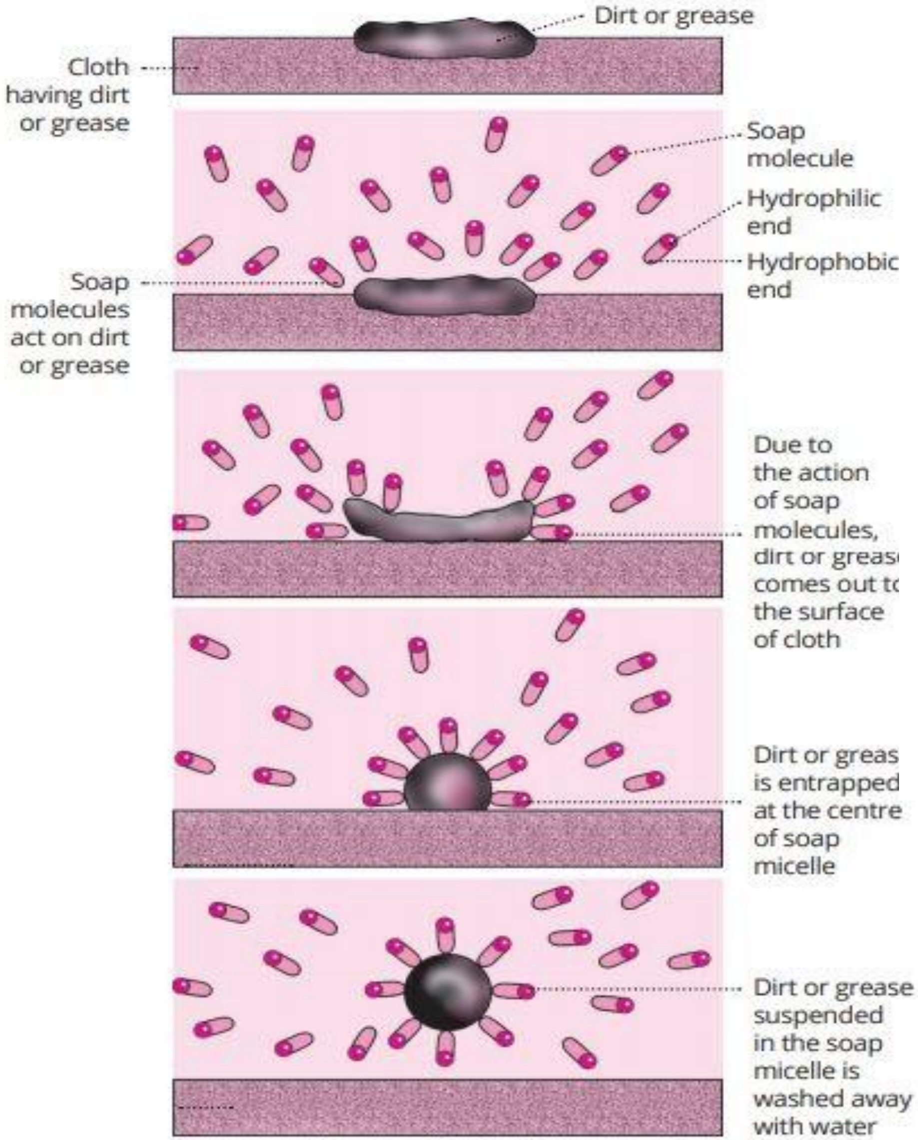


A soap molecule

Cleansing Action of Soap

Soaps are the cleansing agents which are capable of reacting with water and remove the dirt particles from clothes. The ionic-end of soap interacts with water while the carbon chain interacts with oil. The soap molecules, thus form structures called micelles where one end of the molecules is towards the oil droplet while the ionic-end faces outside. This forms an emulsion in water. The soap micelle thus helps in pulling out the dirt in water.

Cleansing Action of Soap



The cleansing action of soap or micelles on dirt and grease

A spherical micelle formed by soap in water

SUMMARY

1. Carbon is a versatile element and carbon compounds play important roles in life processes and by meeting our daily needs.
2. **Catenation**: The property to form compounds with long chains and rings of identical atoms is called **catenation.** A large variety of compounds is formed by carbon due to catenation and tetracovalency of carbon.
3. **Bonding in carbon compounds**: Carbon attains tetracovalency by forming single and multiple covalent bonds. Covalent bonds are formed by the mutual sharing of electrons between two atoms so that both the atoms can achieve a completely filled outermost shell.
4. Methane is tetrahedral, ethene is planar and ethyne is linear. In methane, the ∠H—C—H bond angles are 109 °28′. In ethane, the ∠H—C—H and ∠C—C—H bond angles are 120 °. In ethyne, the ∠H—C—C bond angle is 180 °.
5. **Hydrocarbons**: The organic compounds containing only carbon and hydrogen are called **hydrocarbons**. Hydrocarbons are classified into **a.** saturated hydrocarbons and **b.** unsaturated hydrocarbons. The carbon chains are in the form of straight chains, branched chains or rings.
6. **Alkanes**: The saturated hydrocarbons are called **alkanes**. Alkanes have the general formula C_nH_{2n+2}, where n is the number of carbon atoms.
7. **Alkenes**: Unsaturated hydrocarbons containing a double bond between the carbon atoms are called **alkenes**. Alkenes have the general formula C_nH_{2n} where $n = 2, 3, 4, \ldots$ etc.
8. **Alkynes**: Unsaturated hydrocarbons containing a triple bond between the carbon atoms are called **alkynes**. Alkynes have the general formula C_nH_{2n-2} where $n = 2, 3, 4, \ldots$ etc.
9. Cyclic hydrocarbons are either saturated or unsaturated. The saturated cyclic hydrocarbons are called **cycloalkanes** having the general formula C_nH_{2n}. The unsaturated cyclic compounds of carbon are called **aromatic compounds**.
10. **Homologous series**: A group of organic compounds having similar structures, same functional group and similar chemical properties but different physical properties, in which the successive compounds differ by a CH_2 group, is called **homologous series**.
11. **Functional group**: A functional group is an atom or a group of atoms, which determines the characteristic properties of an organic compound. For example, the —OH group is called **hydroxyl group** and the —COOH group is called **carboxyl group**.

12. **Alcohols**: An organic compound which is obtained by replacing one hydrogen atom in an alkane by a hydroxyl group (—OH), is called **alcohol**. The functional group in alcohols is —OH. Alcohols have the general formula $C_nH_{2n+1}OH$, where *n* is the number of carbon atoms. Ethanol finds use in our daily life.

The common name of an alcohol: Name of the alkyl group + alcohol $\longrightarrow$ Name of alcohol

The IUPAC name of an alcohol: Name of alkane – e + ol $\longrightarrow$ Name of alcohol

13. **Properties of methanol**

- **Combustion**: $2CH_3OH + 3O_2 \longrightarrow 2CO_2 + 4H_2O$
- **Reaction with sodium**: $2CH_3OH + 2Na \longrightarrow 2CH_3ONa + H_2$
- **Oxidation**: $CH_3OH \xrightarrow[K_2Cr_2O_7/H_2SO_4]{[O]} HCHO \xrightarrow[K_2Cr_2O_7/H_2SO_4]{[O]} HCOOH$
- **Esterification**: $CH_3OH + CH_3COOH \xrightarrow[\text{warm}]{\text{conc. } H_2SO_4} CH_3COOCH_3 + H_2O$

14. **Properties of ethanol**

- **Combustion**: $C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$
- **Reaction with sodium**: $2C_2H_5OH + 2Na \longrightarrow 2C_2H_5ONa + H_2$
- **Esterification**: $C_2H_5OH + CH_3COOH \xrightarrow[\text{warm}]{\text{conc. } H_2SO_4} CH_3COOC_2H_5 + H_2O$
- **Dehydration**: $C_2H_5OH \xrightarrow[-H_2O]{\text{conc. } H_2SO_4,\ 170°C} CH_2{=}CH_2$
- **Oxidation**: $C_2H_5OH \xrightarrow[K_2Cr_2O_7/H_2SO_4]{[O]} CH_3CHO \xrightarrow[K_2Cr_2O_7/H_2SO_4]{[O]} CH_3COOH$

15. **Carboxylic acid**: An organic compound containing —COOH group in its molecule is called **carboxylic acid**. The functional group in carboxylic acid is —COOH.
The IUPAC name of a carboxylic acid: Name of alkane – e + oic acid $\longrightarrow$ Name of carboxylic acid. In naming carboxylic acids, the carbon atoms of the carboxyl group is given the number 1.

16. **Properties of ethanoic acid**:

- Ethanoic acid is a colourless, pungent smelling and corrosive liquid which boils at 118 °C. It is soluble in water, alcohol and ether in all proportions. Ethanoic acid finds use in our daily life.
- **Reaction with alkalis**: $CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$
- **Reaction with carbonates and hydrogencarbonates**:

$$2CH_3COOH + Na_2CO_3 \longrightarrow 2CH_3COONa + H_2O + CO_2$$

$$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + H_2O + CO_2$$

- **Reaction with active metals**: $2CH_3COOH + 2Na \longrightarrow 2CH_3COONa + H_2$
- **Esterification**: Ethanoic acid reacts with ethanol in the presence of conc. H_2SO_4 to form a sweet-smelling ester ethyl ethanoate.
- **Decarboxylation**: Sodium ethanoate on heating with sodalime undergoes decarboxylation to form methane.

17. **Soaps**: Soaps are the sodium or potassium salts of long chain fatty acids, which have cleansing properties in water. Soaps do not perform well in hard water.

18. **Cleansing action of soap**: The cleansing action of soap is due to the formation of micelles which entrap the oily dirt.

19. **Synthetic detergents**: Synthetic detergents are cleansing agents which clean clothes without forming any insoluble scum. They are better cleansing agents than soaps. The examples of synthetic detergents are sodium *p*-dodecylbenzenesulphonate and sodium dodecylsulphate.

MIND MAP

CARBON AND ITS COMPOUNDS

PROPERTIES OF CARBON

- forms inorganic and organic compounds
- catenation
- tetravalent nature
- can form multiple covalent bonds with other elements

CRYSTALLINE ALLOTROPES OF CARBON

- diamond
- graphite
- fullerenes

TYPES OF ORGANIC COMPOUNDS

Saturated hydrocarbons

- alkanes
- C_nH_{2n+2}

Unsaturated hydrocarbons

- alkenes, C_nH_{2n}
- alkynes, C_nH_{2n-2}

Chains, branches and rings

- straight chain, H_3C-CH_3
- branched chain, $H_3C-CH(CH_3)-CH_3$
- cyclic
  - saturated, cyclohexane, 
  - unsaturated, benzene, 

MIND MAP

FUNCTIONAL GROUPS

Heteroatom/ Multiple bond	Name of functional group	Formula of functional group	Formula of compound containing functional group	Name of the compound containing functional group
Oxygen	**1.** Hydroxyl (or alcoholic)	—OH	C_2H_5OH	Ethanol
	2. Aldehyde	—CHO	HCHO	Methanal
	3. Ketone	$-\overset{O}{\overset{\|\|}{C}}-$	CH_3COCH_3	Propanone
	4. Carboxylic acid	$-\overset{O}{\overset{\|\|}{C}}-OH$	CH_3COOH	Ethanoic acid
	5. Ester	$-\overset{O}{\overset{\|\|}{C}}-OR$	CH_3COOCH_3	Methyl ethanoate
Halogen (Chlorine/ Bromine)	Halo (chloro/bromo)	—Cl	CH_3Cl	Chloromethane
		—Br	CH_3Br	Bromomethane
Nitrogen	**1.** Amino	$-NH_2$	CH_3NH_2	Methanamine
	2. Nitro	$-NO_2$	CH_3NO_2	Nitromethane
	3. Cyano	—CN	CH_3CN	Ethanenitrile
Double bond	Double bond	$>C=C<$	$H_2C=CH_2$	Ethene
Triple bond	Triple bond	$-C\equiv C-$	$HC\equiv CH$	Ethyne

STRUCTURAL ISOMERS

- compounds with similar molecular formula but different structures

MIND MAP

CHEMICAL PROPERTIES OF CARBON

- **Combustion reaction**
  - $CH_3CH_2OH + O_2 \rightarrow CO_2 + H_2O + \text{heat} + \text{light}$
- **Oxidation**
  - $2CH_4 + O_2 \xrightarrow[\text{100 atm}]{\text{Cu, 250 °C}} 2CH_3OH$
- **Addition reaction**
  - $H_2C{=}CH_2 + H_2 \xrightarrow{\text{Ni, 150–250 °C}} H_3C{-}CH_3$
- **Substitution reaction**
  - $CH_4 + Cl_2 \xrightarrow{\text{sunlight}} CH_3Cl + HCl$

SOME IMPORTANT CARBON COMPOUNDS

- **Ethanol**
  - **Reaction with Na**
    - $2Na + 2C_2H_5OH \rightarrow 2C_2H_5ONa + H_2$
  - **Dehydration reaction**
    - $C_2H_5OH \xrightarrow[\text{170 °C}]{\text{Conc. } H_2SO_4} CH_2{=}CH_2 + H_2O$
- **Ethanoic acid**
  - **Esterification reaction**
    - $CH_3COOH + C_2H_5OH \xrightarrow[\text{heat}]{\text{Conc. } H_2SO_4} CH_3COOC_2H_5 + H_2O$
  - **Saponification reaction**
    - $CH_3COOC_2H_5 \xrightarrow{\text{NaOH}} C_2H_5OH + CH_3COONa$
  - **Reaction with alkalis**
    - $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$
  - **Reaction with carbonates**
    - $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$