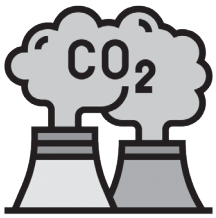
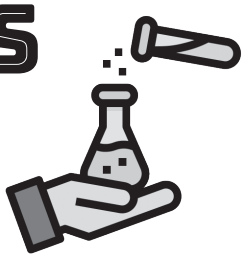
CHAPTER
4



CARBON & ITS COMPOUNDS



KICK

*"You will die but the carbon will not; its career does not end with you. It will return to the soil, and there a plant may take it up again in time, sending it once more on a cycle of plant and animal life."- **Jacob Bronowski***

OFF

Introduction

Organic compounds are those compounds that were isolated directly or indirectly from living or indirectly from living organism such as animals and plants. Examples: urea, sugars, fats, oils, dyes, proteins vitamins etc. The branch of chemistry which deals with the study of these compounds is called **Organic Chemistry.**

The earth crust contains only 0.02% of carbon. Carbon is most essential element as it forms greater number of compounds that are useful in our daily life. **Carbon** is non metal which has atomic number 6. Its atomic mass is 12.011 g. It occurs in native state as well as in combined state. 70% of our body is made up of carbon.

Nature of Bonding in Carbon Compounds

Most of the carbon compounds are poor conductors of electricity. Forces of attraction that are present between these molecules of organic compounds are weak; so these compound does not give rise to any ions.

The reactivity of elements is explained on the basis of their tendency to gain a completely filled valence shell that is, gain of noble gas configuration. Element forming ionic compounds achieve this by either gaining or losing electrons from the outermost shell. In the case of carbon, it has four electrons in its valence shell, so it is needed to gain or lose four electrons to attain noble gas configuration.

(i) It can gain four electrons forming $\mathbf{C^{4-}}$ **anion.** But it will be difficult for the nucleus with six protons to hold on to ten electrons, that is, four extra electrons.

(ii) It can lose four electrons forming $\mathbf{C^{4+}}$ **cation.** But it will require a large amount of energy to remove four electrons leaving behind a carbon cation with six protons in its nucleus holding on to just two electrons.

Hence, it cannot form C^{4+} cation or C^{4-} anion

Carbon overcomes this problem by sharing its outermost electrons with other atoms of carbon or with atoms of other elements to form **covalent bond**.

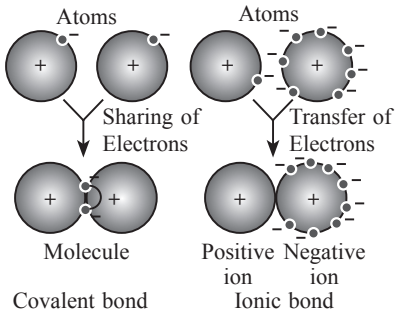


Fig. 1: Formation of covalent and ionic bond

Examples of Molecules Formed by Covalent Bonding:

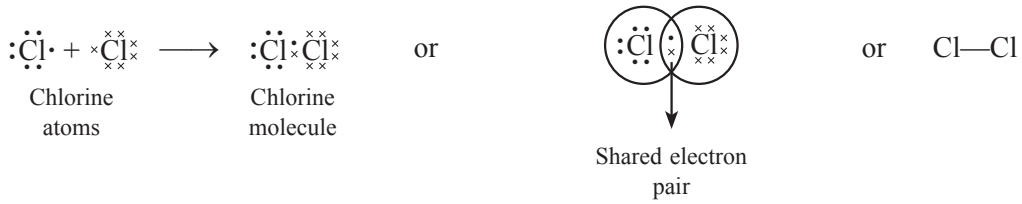
1. **Hydrogen molecules:** H_2 is the simplest molecule that is formed by sharing of electrons. The atomic number of hydrogen is 1 and it has only 1 electron in its outermost (K) shell. Thus it required only 1 more electron to complete the K shell. So, when two hydrogen atoms approach each other, the single electron of both the atoms will form a shared pair.

According to **Lewis notation,** the electrons in the valence shell are indicated by dots and crosses. This method was introduced by **G.N.Lewis** and is known as Lewis structure. The shared pair of electron will form a single bond between the two H atoms and is indicated by a line between the two atoms pictorially, the molecule can be shown by drawing two **overlapping circles** around the symbols of the atoms and indicating the shared pair of electrons in the overlapping part.

Mind it

The octet rule is a chemical rule of thumb that states that atoms of main group elements tend to combine in such a way that each atom has 8 electrons in its valence shell. Except first period elements.

2. **Chlorine molecule :** Cl forms a diatomic molecule each chlorine atom has 7 electrons in its valence shell. When the two Cl atoms come close together, both the atoms shared an electron between them.



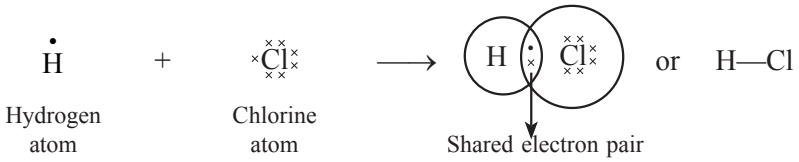
Mind it

Homoatomic Molecule: Molecule that consists of atoms of the same element. examples are - oxygen (O_2), hydrogen (H_2), and nitrogen (N_2)

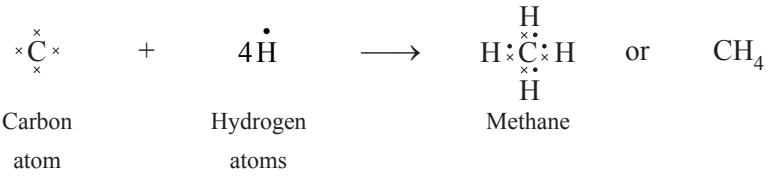
Hetero-atomic Molecule: Molecules formed by different types of atoms are known as Hetero-atomic molecules—for example, CO_2, NO_2, CH_4, HCl etc.

A covalent bond is not only formed between two similar atoms, but it may be formed between dissimilar atoms also.

3. **Hydrogen chloride molecule:** H and Cl form a covalent bond between their atoms. In HCl, H atom has only 1 electron in its valence shell and chlorine atom has 7 electrons in its outermost shell. Hence, by mutual sharing of electron pair between H and a Cl atom. Both the atoms will gain nearest noble gas configuration.



4. **Methane molecule (CH_4):** Methane (CH_4) is a covalent compound that contain covalent bonds. Carbon electronic configuration is 2,4. It has four electrons in its outermost shell and needs 4 more electrons to get the stable noble gas configuration. H atom has one electron and needs one more electron to get stable electronic configuration of nearest noble gas, helium. Thus, one atom of carbon shares its four electrons with four atoms of hydrogen to form four covalent bonds.



Types of Covalent Bonds

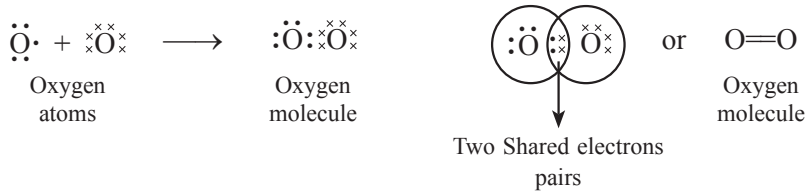
When electron pair is shared between the two atoms it will result into the formation of a covalent bond. This shared pair is also called bonding pair of electron.

1. If two atoms share one electron pair, bond is known as **single covalent bond** and is represented by one dashes (-)
2. If two atoms share two electron pairs, bond is known as **double covalent bond** and is represented by two dashes (=).
3. If two atoms share three electron pairs, bond is known as **triple covalent bond** and is represented by three dashes (≡).

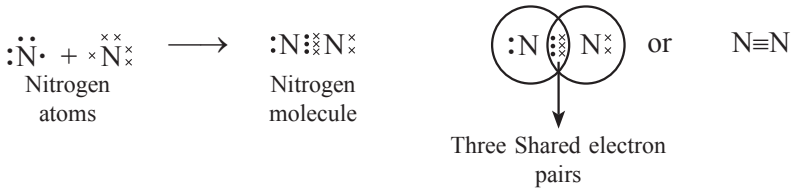
Examples

(i) H_2 molecule formation: H_2 molecule is formed by sharing one pair of electrons to form single bond between its atoms

(ii) Double bond formation (O_2 molecule): Two oxygen atoms combine together to form O_2 molecule by sharing two pairs of electrons. Each oxygen atom has six valence electrons in its valence shell. It needed two electrons to attain nearest noble gas configuration. Hence, both the atoms contribute two electrons each for sharing to form O_2 molecule. In the oxygen molecule, two pairs of electrons are shared and thus there is a double bond between the two oxygen atoms.



(iii) Triple bond formation (N_2 molecule): N atom contains five electrons in its valence shell. N_2 molecule is formed by sharing three pairs of electrons to form triple bond between two nitrogen atoms.



Example

Q. An element X contains 6 electrons in its valence shell, it needs 2 electrons to complete its octet for attaining noble gas configuration. X is an essential element for the survival of all living beings. Identify element X?

Ans. As element X contains 6 electrons in its valence shell, hence its electronic configuration is 2, 6. Therefore, its atomic number is 8. Hence, element X is oxygen. O_2 is used for respiration by the living beings.

Characteristics of Covalent Compounds

(i) Molecules make up the covalent compounds: The covalent compounds are made up of molecules. They do not contain ions. For example - oxygen, nitrogen etc. consist of O_2 and N_2 molecules respectively

(ii) Physical State : Covalent compounds may exist in solid, liquid as well as in gaseous state. For example: diamond is solid, H_2O is liquid and CH_4 is gas.

(iii) Crystal structure - Covalent compounds exhibit both crystalline and non crystalline structure.

(iv) Solubility:

- ☞ Covalent compounds are generally insoluble in water and in polar solvents because they do not form ions in aqueous solution.
- ☞ Covalent compounds are soluble in non-polar organic solvents such as benzene, CCl_4, acetone etc.

(v) Electrical Conductance: As covalent compounds do not contain ions or free electrons for the conduction of electricity, hence, they are poor conductors of electricity. For example: benzene, toluene do not conduct electricity.

(vi) Melting and Boiling Point : Covalent compounds have low melting and boiling points due to weak forces of attraction between molecules. Less energy is needed to overcome these forces of attraction.

Example

1. Explain, why covalent compounds are volatile in nature with low melting and boiling point?

Ans. Although, covalent compounds have strong forces of attraction within the molecule but the inter-molecular forces are weak which results in the low melting and boiling point of covalent compounds. Hence, covalent compounds are volatile in nature.

2. Two non-metals X and Y combine with each other by sharing of electron to form compound Z.

(i) What is the nature of compound Z?

(ii) Will it dissolve in water or organic solvents? Give reason for your answer.

Ans. (i) Z is a covalent compound. As the combining atoms form a bond by sharing of electrons.

(ii) Using "like dissolves like" rule, according to which polar molecules dissolve in polar solvents, and non-polar molecules dissolve in non-polar solvents. Compound Z and organic solvents are both covalent (non-polar) in nature, but H_2O is a polar solvent. Hence Z will dissolve in organic solvents.

NCERT Corner

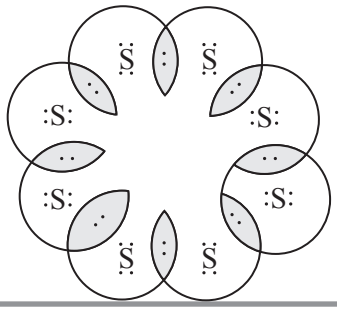
1. What would be the electron dot structure of carbon dioxide which has the formula CO_2?

Ans. Electron dot structure of CO_2 is, Ö::C::Ö

Carbon shares two of its electrons to form a double bond with one oxygen atom and another two electrons to form a double bond with another oxygen atom

2. What would be the electron dot structure of a molecule of Sulphur which is made up of eight atoms of Sulphur? (Hint – The eight atoms of Sulphur are joined together in the form of a ring).

Ans.



Allotropes of Carbon

Allotropy is the property of some chemical elements to exist in two or more different forms and each form has different physical properties but similar chemical properties. These different forms are known as allotropes of the elements. Diamond and graphite are the two common allotropic forms of carbon. Naturally occurring carbon has two stable isotopes $^{12}C_6$ (98.9%) and $^{13}C_6$(1.1%) along with some traces of radioactive isotope $^{14}C_6$ that is used to determine the age of archaeological specimen of organic origin.

Diamond

Structure of Diamond : Diamond is a form of the element carbon with its atoms arranged in a crystal structure and are generally octahedral (eight faced). In the structure of diamond, each carbon atom is bonded to four other carbon atoms to form a three-dimensional rigid structure. This strong bonding is the reason for its hardness and its high density. Because of this regular, symmetrical arrangement, its structure is very difficult to break. We need to break four strong covalent bonds, in order to separate one atom form the structure of diamond.

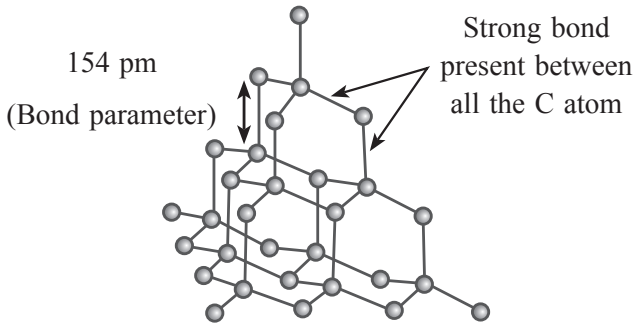


Fig. 2: Structure of diamond

Mind it

Those elements in which atoms are bonded covalently with each other are found in solid state. For example: graphite, diamond, sulphur etc.

Find it

Q. How do diamond can be prepared artificially?

Characteristics of diamond

- It is hardest substance known.
- Its density is 3.5 g/mL.
- Crystals of diamond are octahedral, colourless and transparent
- In the structure of diamond, each carbon atom is covalently bonded to four other carbon atoms to form a three-dimensional rigid structure.
- Diamond is poor conductor of electricity

Uses of Diamond

- It is used in cutting glass and drilling rocks.
- They are used for making jewellery because of their great ability to reflect and refract light.
- Diamond is used for making high precision thermometers, because it has an extraordinary sensitivity to heat rays.
- It is used for making protective windows for space probes.
- They are used by eye-surgeons as a tool to remove cataract from eyes.

Example

Q. Which property of diamond allows it to be used in knives for cutting marble?

Ans. As diamond is the hardest naturally occurring substance known in the world. Hence, because of its hardness it is used in knives to cut marbles.

Graphite

Graphite is a greyish-black substance which is an allotrope of carbon. Graphite is smooth and slippery. It is a very good conductor of electricity.

Structure of Graphite:

It graphite, each carbon is bonded to its three neighboring carbon atoms in the same plane by strong covalent bonds to form layers of hexagonal rings. The various layers of carbon atoms in graphite, are held together by weak Van der Waal's forces. Hence, layers of graphite can easily slide over one another, which makes graphite lubricating, soft and greasy to touch.

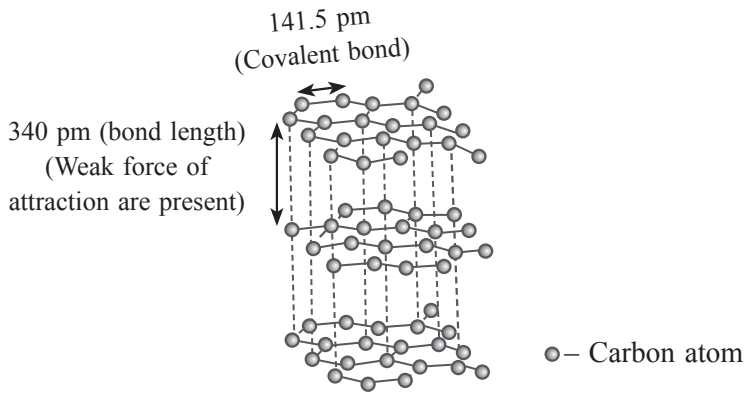


Fig. 3: Structure of graphite

In graphite, carbon atoms are joined together by strong covalent bonds. Hence, graphite also has high melting point because it is difficult to separate carbon atoms from one another.

Characteristics of graphite

- Graphite is soft and slippery to touch.
- Its density is 2.3 g/mL.
- Crystals of graphite are hexagonal coloured and opaque.
- In graphite, each carbon atom is bonded to three carbon atoms by strong covalent bonds..
- Graphite is very good conductor of electricity.

Uses of graphite

- Used as a lubricant for heavy machinery.
- Used for making pencil lead.
- Used in making crucibles for melting substances.
- Used for making graphite electrodes in dry cells.

Fullerenes

Structure: Fullerene is an allotrope of carbon in which 60 carbon atoms are joined together to form a spherical shape like a football. It was discovered in 1985 by Robert Curl, Herald Kroto and Richard Smalley.

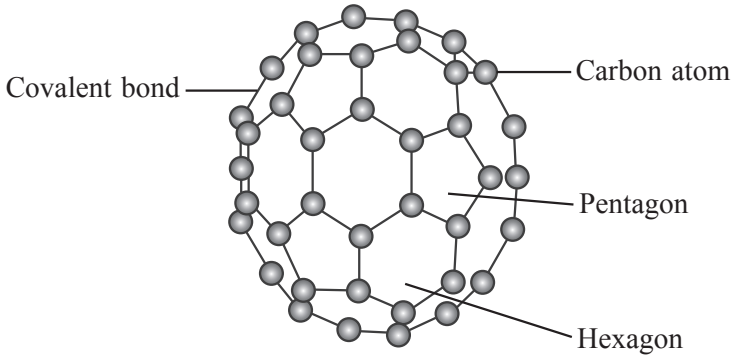


Fig. 4: Structure Of Fullerene

This allotrope of carbon was named buck minster fullerene after the American architect Buckminster Fuller, the inventor of the Geodesic dome, which resembles the molecular structure of C_{60}. One molecule of buckminsterfullerene or fullerene contains 20 hexagons and 12 pentagons of carbon atoms. When it is burnt in oxygen, then only CO_2 is formed.

Uses of Fullerenes:

- ❒ lubricants
- ❒ semiconductors
- ❒ superconductors

Other forms of Carbon : Carbon black, charcoal and coke are the other forms of elemental carbon. These are impure forms of graphite or fullerenes.

- ❒ When hydrocarbons are burnt in a limited supply of air, carbon black is obtained.
- ❒ Coke and charcoal are formed when coal or wood respectively are heated at high temperatures, in the absence of air.

Mind it

Amorphous forms of carbon

Wood → Peat → Lignite (brown coal) → Bituminous coal (common coal) → Anthracite (purest form of coal)

Difference Between Properties of Diamond and Graphite

Characteristics	Diamond	Graphite
Hardness	Hardest natural substance known	Very Soft
Density	3.5 g/mL	2.4 g/mL
Electrical conductivity	Poor conductor of electricity	Good conductor of electricity
Colour	Colourless	Greyish-black
Appearance	Transparent	Opaque
Shape of Crystals	Octahedral	Hexagonal
Occurrence	Rare	Abundant

Uses of Carbon

Forms of carbon	Uses
Graphite	Pencils, Neutron moderator in nuclear reactors, steel manufacture, electrodes in electrolytic extraction of elements.
Diamond	Cutting, gemstone, drilling, grinding, polishing, industry.
Coke	Fuel, steel manufacture.
Activated charcoal	Purification of chemicals, decolourizing agent in sugar industry.
Carbon black	Pigments in ink, rubber industry, plastics and paints
Wood charcoal	Fuel

Carbon Conductivity Nature

All four electrons present in the valence shell of each carbon atom in diamond are used to form covalent bonds. This indicates that there are no free electrons and hence, diamond is an insulator. In graphite, only three of the valence shell electrons of carbon atom are used to form bond to other carbon atoms. Hence, one electron per atom is free to move. Therefore, graphite acts as an electrical conductor.

Versatile Nature of Carbon

Carbon forms a large number of compounds due to the following reason:

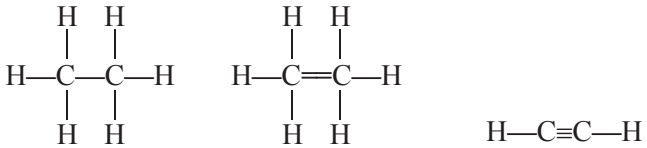
(i) Catenation: Catenation is the property of self linking of carbon atoms by covalent bonds to form long straight or branched chains and rings of different sizes. Because of its small size, electronic configuration and unique strength of C-C bonds, carbon shows maximum catenation property in the periodic table.

Mind it

- ❒ Because of catenation property, any number of carbon atoms can be linked up together covalent bonds.
- ❒ Besides carbon, sulphur is the second element which shows maximum catenation property.

(ii) Tetravalency of carbon: Since, carbon has a valency of four, it is capable of bonding with four other atoms of carbon or atoms of some other mono-valent element. For example: CH_4 is formed when four electrons of carbon are shared with four hydrogen atoms.

(iii) Tendency to form multiple bond: Carbon has a strong tendency to form multiple bond (double & triple bonds) by sharing more than one pair of electrons, because of its small size. Hence, it can form a variety of compound. For example -

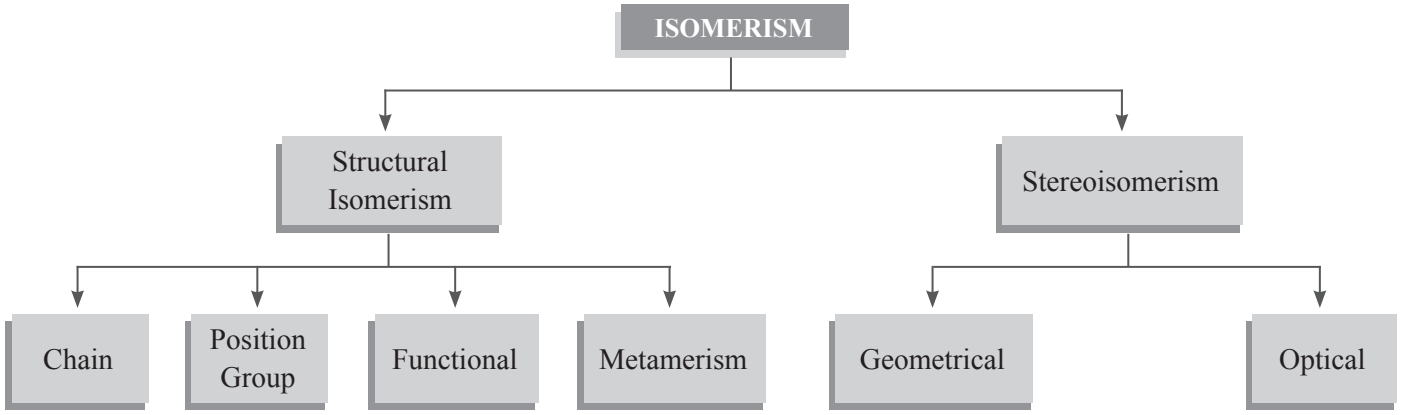


Mind it

As the number of carbon atoms increases in the compound, the number of isomers of that compounds also increases.

Isomerism

Isomers are the compounds having same molecular formula but different physical or chemical properties. This phenomenon is known as isomerism.



Structural Isomerism

Compounds having same molecular formula but different structural arrangement of atoms in their molecules are known as structural isomers and this phenomenon is known as **structural isomerism**.

Four types of structural isomerism are as follows:

1. **Chain isomerism :** In chain isomerism, the isomers differ from each other due to the presence of different carbon chain skeletons.

   For example:

   (i) C_4H_8

   $CH_3—CH_2—CH=CH_2$
   But-1-ene

   $CH_3—C(CH_3)=CH_2$
   2 - Methylpropene

   (ii) C_5H_{12}

   $CH_3—CH_2—CH_2—CH_2—CH_3$
   n-Pentane

   $CH_3—CH(CH_3)—CH_2—CH_3$
   2- Methylbutane
   (Isopentane)

   $CH_3—CH(CH_3)—CH_3$
   2, 2-Dimethylpropane
   (neo-pentane)

2. **Position isomerism:** In position isomerism, structure of isomers differ due to difference in the position of the multiple bond or functional group.

   For example:

   (i) C_4H_8

   $CH_2—CH_2—CH=CH_2$
   But-1-ene

   $CH_3—CH=CH—CH_3$
   But-2-ene

   (ii) C_3H_8O

   $CH_3—CH_2—CH_2—OH$
   Propan-1-ol

   $CH_3—C(OH)—CH_3$
   Propan-2-ol

3. **Functional group isomerism :** In functional group isomerism, structure of isomers differ due to the presence of different functional groups.

   For example:

   (i) **C_3H_8O**

   $CH_3—CH_2—CH_2—OH$ Propan-1-ol

   $CH_3—CH_2—O—CH_3$ Methoxy ethane

   (ii) **C_4H_6**

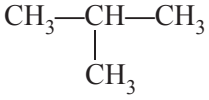
   $CH_3—CH_2C{\equiv}CH$ But-1-yne

   $CH_2{=}CH—CH{=}CH_2$ 1,3-Butadiene

Example

Q. What should be the least number of carbon atoms that is required to form a branched organic compound?

Ans. The least number of carbon atoms required to form a branched compound should be 4; 3 carbon atoms in the parent chain and 1 carbon atom in the branched chain. The compound is isobutane.



2-methylpropane (isobutane)

4. **Metamerism**

   In metamerism isomerism, compounds have the same molecular formula but different alkyl groups present on both sides of functional groups.

   For example:

   $CH_3CH_2OCH_2CH_3$ (diethyl ether)

   $CH_3OCH_2CH_2CH_3$ (methyl n-propyl ether)

Stereo isomerism

Stereo isomerism is shown by compounds which have same molecular formula but different spatial arrangment.

Types of stereo-isomerism:

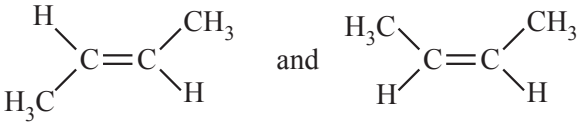
1. **Geometrical isomerism:** Geometrical isomerism is shown by compounds having same structural formula but have a different spatial arrangement of the groups around a doubly bonded carbon atoms.

   Types of geometrical isomerism are as follows:

   (i) Cis: In cis-geometrical isomerism, atoms are groups are present at the same side of the double bond.

   (ii) Trans: In trans-geometrical isomerism, atoms or groups are present at the opposite side of the double bond.

   Example of geometric isomerism is but-2-ene.



(Trans-but-2-ene) and (Cis-but-2-ene)

   In first case, the CH_3 groups are present on opposite sides of the double bond, it is known as trans isomer and in the second case, the CH_3 groups are present on the same side of the double bond, it is known as cis isomer.

2. **Optical isomerism:** Optical isomerism arises from different arrangement of atoms or groups in three-dimensional space which results in two isomerism that are mirror images of each other.

Theory of Vital Force

As, organic compounds require the presence of a mysterious force (i.e., vital force) that exists only in living organisms, hence they cannot be synthesized in the laboratory.

Wohler's Synthesis

Friedrich Wohler in year 1828, synthesized urea (a well known organic compound) by heating ammonium cyanate in the laboratory

$$\underset{\text{Ammonium sulphate}}{(NH_4)_2\,SO_4} + \underset{\text{Potassium cyanate}}{2\,KCNO} \longrightarrow \underset{\text{Ammonium cyanate}}{NH_4CNO} + \underset{\text{Potassium sulphate}}{K_2SO_4}$$

$$\underset{\text{Ammonium cyanate}}{NH_4CNO} \xrightarrow[\text{Rearrangent}]{\text{Heat}} \underset{\text{Urea}}{NH_2{-}\overset{\overset{O}{\|}}{C}{-}NH_2}$$

Note: Urea was the first organic compounds synthesized in the laboratory.

Hydrocarbons

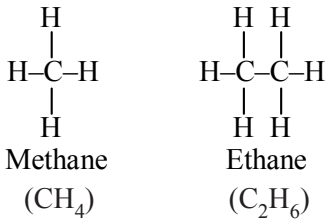
Hydrocarbons are the compounds which contain carbon and hydrogen only. For example: CH_4(methane), C_2H_4 (ethene), C_2H_2 (ethyne), etc.

Types of Hydrocarbons

Saturated hydrocarbons

Alkanes: Saturated hydrocarbons are the hydrocarbons which contain only single bonds. For example: CH_4 (methane), C_2H_6 (ethane) etc.

General formula for alkanes is C_nH_{2n+2}



Methane (CH_4) Ethane (C_2H_6)

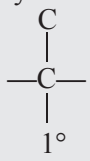
Mind it

Alkanes are also known as paraffins. In latin, 'parum' means less and 'affin' means reactive.

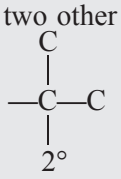
Test Prep

Types of carbon atoms in alkanes

- **Primary carbon (1°) atom** is attached to only one other carbon atom.

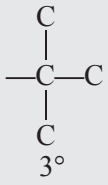
i.e., 

- **Secondary carbon (2°) atom** is attached to two other carbon atoms.

i.e., 

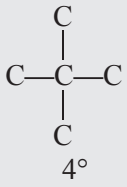
❒ **Tertiary carbon (3°) atom** is attached to three other carbon atoms.

i.e.,



❒ **Quaternary carbon (4°))atom** is attached to four other carbon atoms.

i.e.,

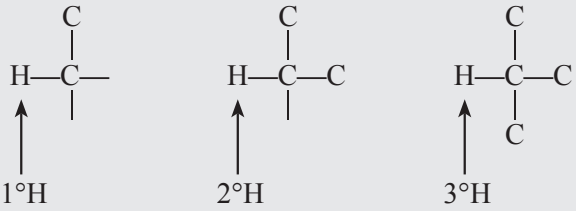


In the similar way, hydrogen atoms can also be classified as:

❒ **Primary hydrogens (1°)** are attached to carbon which is bonded to one other C atom.

❒ **Secondary hydrogens (2°)** are attached to carbon which is bonded to two other carbon atoms.

❒ **Tertiary hydrogens (3°)** are attached to carbon which is bonded to three other carbon atoms.



In alkanes, reactivity order of hydrogens:

Tertiary (3°) > secondary (2°) > primary (1°)

Unsaturated hydrocarbons

Unsaturated hydrocarbons are those hydrocarbons in which valency of carbon is satisfied by double or triple bonds. For example: C_2H_4, C_2H_2 etc.

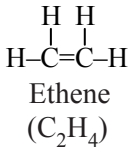
Mind it

Unsaturated hydrocarbons (containing double or triple bonds) are more reactive than saturated hydrocarbons (containing single bond).

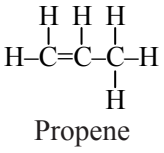
Alkenes: Alkenes are unsaturated hydrocarbons containing carbon - carbon double (=) bond. Alkenes contain two hydrogen atoms less than the corresponding alkanes.

General formula for alkenes is C_nH_{2n}

For example:



Ethene
(C_2H_4)



Propene
(C_3H_6)

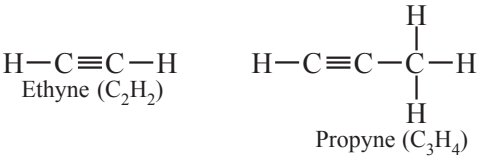
Mind it

General formula for alkenes i.e., C_nH_{2n} is only applicable if alkene contains one carbon-carbon double bond. Formula will change, if the number of double bond increases.

Alkynes: Alkynes are also unsaturated hydrocarbons containing carbon - carbon triple bond. Alkynes contain four hydrogen atoms less than the corresponding alkanes.

General formula for alkynes is C_nH_{2n-2}

For example: C_2H_2 (Ethyne)
C_3H_4 (Propyne) etc.



Ethyne (C_2H_2) Propyne (C_3H_4)

Mind it

Ethylene gas is used for artificial ripening of fruits and vegetables.

Example

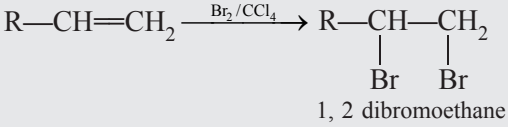
Q. Which among the following are alkenes?
CH_4, C_2H_6, C_2H_4, C_3H_6 and C_3H_8

Ans. C_nH_{2n} is the general formula for alkenes, where 'n' is the number of carbon atoms.
Hence, C_2H_4 and C_3H_6 are alkenes (put n = 2, 3)

Test Prep

Test to distinguish between Saturated and Unsaturated Compounds

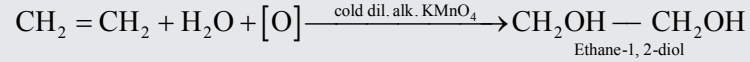
1. **Bromine water test**
   Bromine water is an orange solution due to presence of bromine in it. Unsaturated compounds (i.e., alkenes/alkynes) decolourises bromine water while saturated compounds (i.e., alkanes) do not decolourise it.



1, 2 dibromoethane

   Reddish brown orange colour of Br_2 in CCl_4 is discharged in the above reaction.

2. **Alkaline potassium permagnate test**
   The alkaline potassium permanganate test is used to identify the presence of unsaturation compounds like alkene and alkyne in the qualitative organic analysis.
   Cold dilute aqueous solution of $KMnO_4$, is known as **Baeyer's reagent.**
   Baeyer's reagent oxidizes alkenes to corresponding diols.



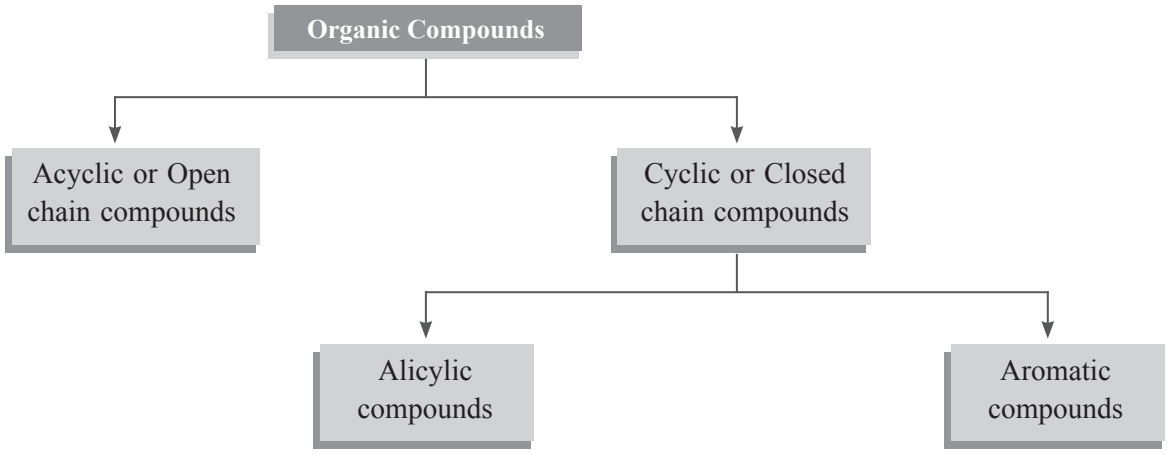
Ethane-1, 2-diol

   As alkenes/alkynes decolourise $KMnO_4$, therefore above reaction is used to test unsaturation.

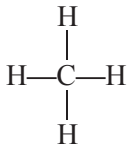
Classifications of Organic Compounds

As, carbon shows catenation property, hence there are very large number of organic compounds present.

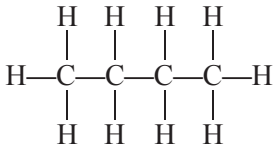
These organic compounds can be classified as:



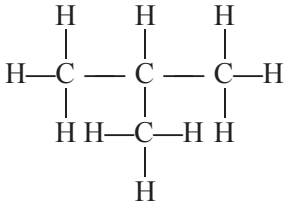
(i) Open chain compounds: Open chain compounds consists of an open chain of carbon atoms which may be either straight chain or branched chain in nature. Based upon the naturev of bonding in the carbon atoms, open chain compounds may be saturated or unsaturated. These compounds are also known as aliphatic compounds. For example.



Methane



Butane



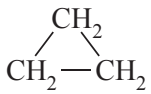
2-Methylpropane

Butane is a straight chain alkane and 2- Methylpropane is branched chain alkane.

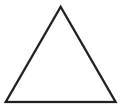
(ii) Closed chain or Cyclic compounds : The organic compounds may also have can have cyclic or ring structures. At least three atoms are required to form a ring. Cyclic compounds are further classified into:

(a) Alicyclic compounds: Alicyclic compounds are those compounds which shows similar properties to that of aliphatic compounds. Alicyclic compounds contain carbon atoms joined in the form of a ring.

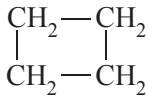
For example:



or



Cyclopropane



or

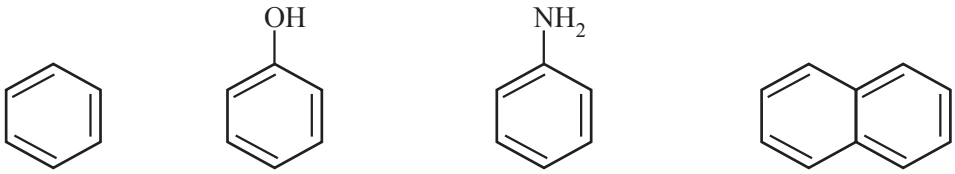
Cyclobutane

Mind it

At least three carbon atoms should be present for a hydrocarbon to exist as closed chain.

(b) Aromatic compounds: Aromatic compounds contain one or more fused or isolated benzene rings.

For example:



Benzene Phenol Aniline Naphthalene

Functional Group

Functional group may be defined as an atom or group of atoms that is responsible for the characteristic reactions of a particular compound. Functional group determines the properties of a compound. An organic compound generally consists of two parts -

(i) Hydrocarbon radical (ii) Functional group

—COOH

Hydrocarbon radical **Functional group**

- ❒ Functional group is the most reactive part of the molecule.
- ❒ The chemical properties of an organic compound is determined by functional group.
- ❒ The physical properties of the organic compound is determined by hydrocarbon radical.

Main Functional Groups

(i) Halogen group: Halides are the organic compounds which contain - X(F, Cl, Br or I) group.
For e.g. Chloromethane (CH_3Cl), Bromomethane (CH_3Br) etc.

(ii) Alcohol group (—OH) : Alcohols are the organic compounds which contain - OH group.
For e.g. Methanol (CH_3OH), Ethanol (CH_3CH_2OH) etc.

(iii) Aldehyde group (—CHO) : Aldehydes are the organic compounds which contain CHO group.
For e.g. Methanal (HCHO), Ethanal (CH_3CHO) etc.

(iv) Ketone group (—CO—) : Ketones are the organic compounds which contain —CO— group.
For e.g. propan-2-one (CH_3COCH_3), butan-2-one ($CH_3COCH_2CH_3$) etc.

(v) Carboxyl group (—COOH) : Carboxylic acids are the organic acids which contain carboxyl group.
For e.g. Ethanoic acid (CH_3COOH)
Propanoic acid (CH_3CH_2COOH)

(vi) Ester group: Esters are the organic compound which contain RCOOR' group (where R might be a hydrogen atom, an alkyl group, or an aryl group, and R′ might be an alkyl group or an aryl group).
For e.g., Methylethanoate (CH_3COOCH_3).
Ethylethanoate ($CH_3COOCH_2CH_3$)

Mind it

The chemical properties of hydrocarbon is largely decided by the functional group attached to it.

Homologous Series

Homologous series is a series of compounds in which the compounds show similar chemical properties. In homologous series, two consecutive members differ in their molecular formula by - $\mathbf{CH_2}$ unit.

Characteristics of Homologous Series

(i) Two consecutive members of homologous series differ in their formula by a $-CH_2$ unit and differ in molecular mass by 14u.

(ii) All the members of homologous series can be represented by the same general formula.

For eg. General formula for alkenes series is C_nH_{2n}.

(iii) Different member in a homologous series contains same functional group.

For eg. All the members of aldehyde family have – CHO group.

(iv) All the members of a homologous series show almost identical chemical properties. Their physical properties show a regular gradation as the molecular mass increases.

(v) The members of a particular series can be prepared almost by the identical methods.

Homologues

The different members of a homologous series are called as homologues.

For e.g.,

(i) Homologous series of alkanes

General formula for alkanes: C_nH_{2n+2}.

Table- 1: Homologous series of alkanes

n	Chemical Formula	IUPAC Name
1	CH_4	Methane
2	C_2H_6	Ethane
3	C_3H_8	Propane

(ii) Homologous series of alkenes

General formula for alkenes: C_nH_{2n}.

Table- 2: Homologous series of alkenes

n	Chemical Formula	Common Name	IUPAC Name
2	C_2H_4	Ethylene	Ethene
3	C_3H_6	Propylene	Propene
4	C_4H_8	α-Butylenes	But-1-ene

Mind it

Alkenes are also called olefins. In greek-ole means oil and fiant means production. As, lower members of alkenes form oily product with chlorine, hence these are also known as olefins.

(iii) Homologous series of alkynes

General formula for alkynes: C_nH_{2n-2}

Table- 3: Homologous series of alkynes

n	Chemical Formula	Common Name	IUPAC Name
2	C_2H_2	Acetylene	Ethyne
3	C_3H_4	Methyl acetylene	Propyne
4	C_4H_6	Ethyl acetylene	But-1-yne

Example

Q. Write the chemical formula of ethene and also write its three succeeding members with their names.

Ans. The chemical formula of ethene is C_2H_4. The three succeeding members of ethene in this homologous series are:

Propene (C_3H_6), Butene (C_4H_8), Pentene (C_5H_{10})

Nomenclature of Organic Compounds

Nomenclature means assigning names to organic compounds. Two main systems of nomenclature of organic compounds are as follow:

- Trivial system
- IUPAC system (International Union of Pure and Applied Chemistry)

Basic Rules for Nomenclature of Compounds in IUPAC System:

In simple aliphatic compounds, the normal saturated hydrocarbons are considered as the parent compounds and the other compounds are considered as their derivatives which are obtained by the replacement of one or more hydrogen atoms with various functional groups.

Each systematic name consists of the following parts :

(i) Word root : Word root is the basic unit which denotes linear or continuous number of carbon atoms.

(ii) Suffix: There are two types of suffixes:

(a) Primary suffix: The nature of linkage in the carbon atoms is indicated by primary suffix.

(b) Secondary suffix : The presence of a particular functional group in the carbon chain is indicated by the secondary suffix. Secondary suffixes are added after the primary suffix.

Nomenclature of Straight Chain Hydrocarbons

The name of straight chain hydrocarbon may be divided into two parts

(i) Word root (ii) Primary suffix

(i) Word root

Table- 4: Word roots for straight chain hydrocarbons

Namer of carbons	Word Root	Number of carbons	Word Root
C_1	Meth-	C_6	Hex –
C_2	Eth –	C_7	Hept –
C_3	Prop –	C_8	Oct –
C_4	But –	C_9	Non –
C_5	Pent -	C_{10}	Dec -

(ii) Primary suffix

Table- 5: Primary suffix for straight chain hydrocarbons

Compounds	Type	Primary Suffix	General Name
>C—C<	Saturated	- ane	Alkane
>C=C<	Unsaturated	- ene	Alkene
(—C≡C—)	Unsaturated	- yne	Alkyne

For example:

Molecular Formulae	Word Root	Primary Suffix	IUPAC Name
CH_4	Meth –	- ane	Methane
C_2H_6 (CH_3—CH_3)	Eth –	- ane	Ethane
C_3H_8 (CH_3—CH_2—CH_3)	Prop –	- ane	Propane
C_4H_{10} (CH_3—CH_2—CH_2—CH_3)	But –	- ane	Butane
C_2H_4 (CH_2=CH_2)	Eth –	- ene	Ethene
C_3H_6 (CH_3—CH=CH_2)	Prop –	- ene	Propene
C_3H_4 (CH_3—C≡CH)	Prop –	- yne	Propyne

Nomenclature of Branched Chain Hydrocarbon

In a branched chain compound small chains of carbon atoms are attached at one or more carbon atoms of the parent chain. The small carbon chains (branches) are called alkyl groups. An alkyl group is obtained from an alkane by removal of a hydrogen. The general formula for an alkyl group is - C_nH_{2n+1}. It is represented by R.

For Example.

(a) CH_4 (Methane) $\xrightarrow{-H}$ $-CH_3$ (Methyl)

(b) H_3C—CH_3 (Ethane) $\xrightarrow{-H}$ H_3C—CH_2—v (Ethyl)

(c) H_3C—CH_2—CH_3 (Propane)

–H → H—C(H)(H)—C(H)(H)—C(H)(H)— n-propyl or (1-Propyl)

–H → H—C(H)(—)—C(H)(H)—C(H)(H)—H isopropyl or (2-Propyl)

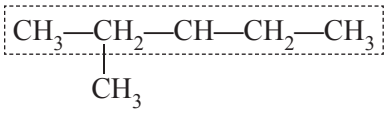
General IUPAC Rules for Nomenclature of Branched Chain Hydrocarbon

Rule 1 : Longest chain rule : First of all, the longest carbon chain in the molecule is identified. If any multiple bond is present, then the chain selected must contain the multiple bond.

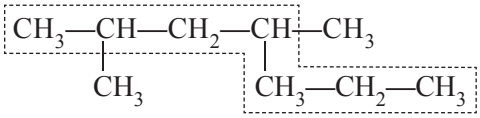
(i) The number of carbon atoms present in the selected carbon chain determines the **word root.**

(ii) Primary suffix is determined by the presence of saturation or unsaturation.

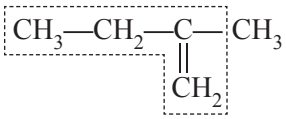
(iii) Prefixes indicate the alkyl substituents present in the hydrocarbons.

1. 

Prefix : Methyl, word root : pent, Primary. suffix : ane

2. 

Prefixes : Methyl, Word root : Hept, Primary. Suffix : ane

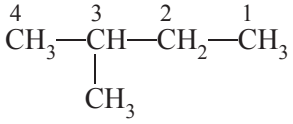
3. 

Prefix : Methyl, Word root: But, Primary suffix : ene

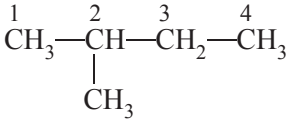
Rule 2: Lowest number Rule : The selected longest carbon chain is numbered in terms of arabic numerals and the position of the alkyl groups attached to carbon chain is denoted by the number of the carbon atom to which alkyl group is attached.

(i) The numbering is done in such a way that the branched carbon atoms/substituents carbon atom get the lowest possible numbers.

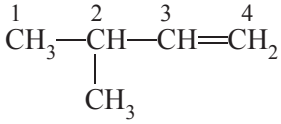
(ii) If the chain contains some multiple bond, then the carbon atoms which are involved in the multiple bond should get lowest possible numbers.

1. 

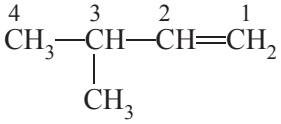
3-Methyl butane
(Wrong)



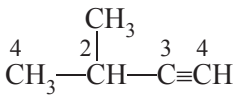
2-Methyl butane
(Correct)

2. 

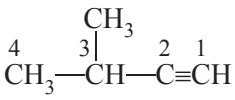
2-Methylbut-3-ene
(Wrong)



3-Methylbut-1-ene
(Correct)

3. 

2-Methylbut-3-yne
(Wrong)



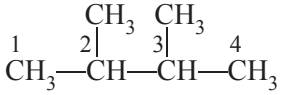
3-Methylbut-1-yne
(Correct)

In general, the sequence which is followed for writing the name of the compound is: **(Position of substituents) - (prefixes) (word root) (primary - suffix)**

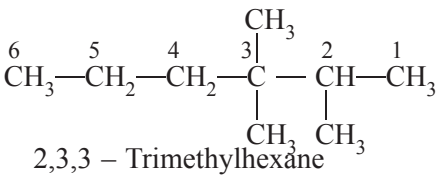
Rule : 3 Using prefixes di, tri etc. : If more than one similar alkyl groups are present in the compound then, their positions are denoted separately and prefixes like di, tri, tetra etc., is attached to the name of the substituents. The positions of the attached substituents are separated by commas.

For example:

eg.

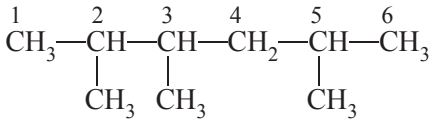


2, 3 – Dimethylbutane



2,3,3 – Trimethylhexane

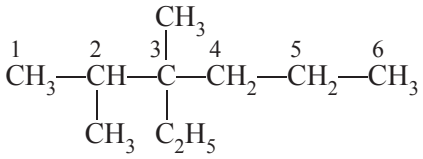
eg.



2, 3, 5-Trimethylhexane

Rule 4: Arrangement of prefixes alphabetical : In a compound, if different alkyl substituents are present then their names are written in the alphabetical order. For such compounds, numerical prefixes, like di, tri, tetra etc. are not considered for the alphabetical order.

eg.

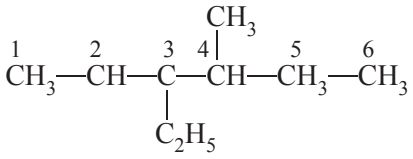


3 – Ethyl – 2, 3 - dimethylhexane

Rule 5: Numbering of different alkyl substituents at the equivalent positions :

If the compound contains two alkly substituents at the equivalent position then numbering of the parent chain is done is such a way that the alkyl group which comes first in the alphabetical order gets the lowest number.

eg.

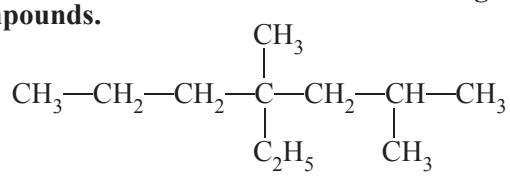


3 – Ethyl – 4 – methylhexane

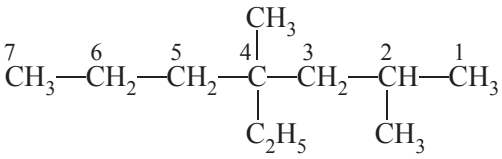
Example

Q. Write the IUPAC Name of the given compounds.

(i)

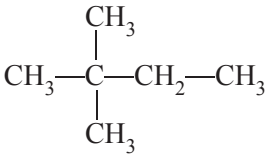


Ans.

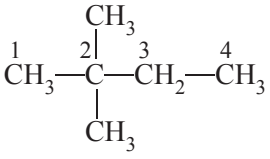


Word root : Hept
Primary suffix : ane
Substituents : two methyl & one ethyl groups
IUPAC name : 4- Ethyl - 2,4 - dimethylheptane

(ii)

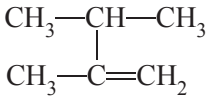


Ans.

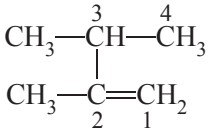


Word root : But
Primary Suffix : ane
Substituents : two methyl groups
IUPAC name : 2,2- Dimethylbutane

(iii)

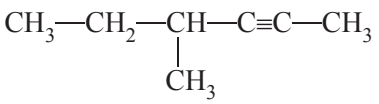


Ans.

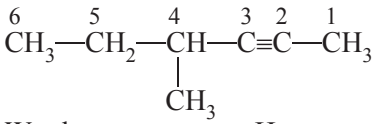


Word root : But
Primary Suffix : ene
Substituents : two methyl groups
IUPAC name : 2, 3 – Dimethylbut - 1 - ene

(iv)



Ans.



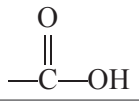
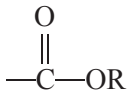
Word root : Hex
Primary Suffix : yne
Substituents : one methyl groups
IUPAC name : 4-Methylhex-2-yne

Nomenclature of Organic Compounds having Functional Group

Secondary suffix is used to indicate the presence of functional group (other than C═C and C≡C). Secondary suffixes are added after the primary suffix. If a suffix begins with 'a', 'e', 'i', 'o', 'u', then, the terminal 'e' of the primary suffix is removed. Some groups such as —F, —Cl, —Br and —I are considered as substituents and are denoted by the prefixes.

Some groups such as —CHO,  , —COOH, and —OH are considered as functional groups and are denoted by suffixes.

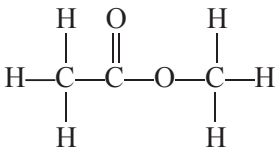
Table- 6: Some functional groups and classes of organic compounds

Class of compounds	Functional Group	IUPAC group Prefix	IUPAC group Suffix	IUPAC Name
Aldehyde	—CHO	Formyl or oxo	- al	Alkanal
Ketone		oxo	- one	Alkanone
Carboxylic acid		Carboxy	- oic acid	Alkanoic acid
Ester		Alkoxycarbonyl	Alkyl (r;) – oate	Alkyl alkanoate
Alcohol	—OH	Hydroxy	- ol	Alkanol
Alkenes	C═C	-	- ene	Alkyne
Alkynes	C≡C	-	- yne	Alkene
Halides	—X (X = F, Cl, Br, I)	Halo	-	Haloalkane

Example

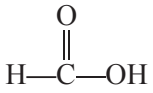
1. Draw the structural formula of methyl ethanoate.

Ans.



The molecular formula is $C_3H_6O_2$.

2. Find the number of double bonds between carbon and oxygen in methanoic acid. Write its general formula.



(Methanoic acid)

Ans. Methanoic acid contains 1 C=O bond and 1 C-O bond.

The general molecular formula of a carboxylic acid is $C_nH_{2n}O_2$

General Rules for Nomenclature of Organic Compounds having Functional Group

Rule 1 : The longest chain of carbon atoms containing the functional group is numbered in such a way that the functional group is attached at the carbon atom possessing lowest possible number in the chain.

Rule 2 : Primary suffix is decided by the presence of carbon - carbon multiple bond.

Rule 3 : The secondary suffix is decided by the functional group.

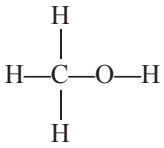
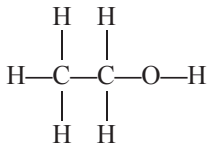
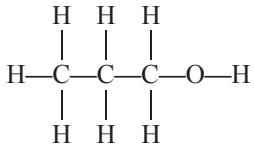
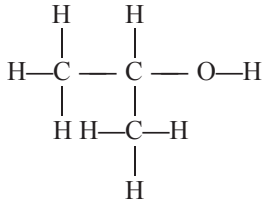
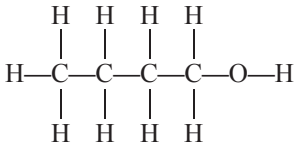
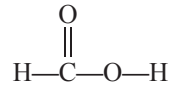
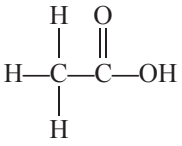
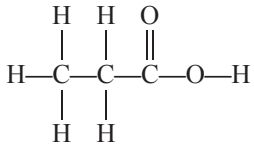
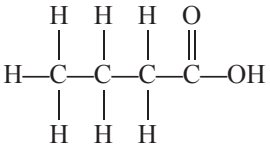
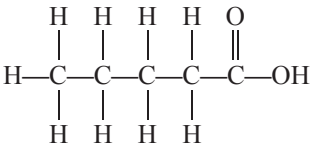
Rule 4 : The name of the compound is written as -

Prefixes - word root - primary suffix - secondary suffix

Mind it

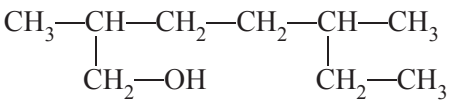
Word root is decided by the number of carbon atoms in the parent chain decides the word root.

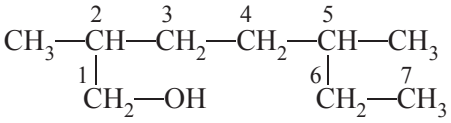
Table- 7: Common and IUPAC names of some organic compounds

Compound	IUPAC Name	Common name	Strucutre
$CH_3—OH$	Methanol	Methyl alcohol or Wood spirit	
$CH_3—CH_2—OH$	Ethanol	Ethyl alcohol	
$CH_3—CH_2—CH_2—OH$	1-Propanol	n-Propyl alcohol	
$CH_3—CH(CH_3)—OH$	2-Propanol	Isopropyl alcohol	
$CH_3—CH_2—CH_2—CH_2—OH$	1-Butanol	n-Butyl alcohol	
HCOOH	Methanoic acid	Formic acid	
$CH_3—COOH$	Ethanoic acid	Acetic acid	
$CH_3—CH_2—COOH$	Propanoic acid	Propionic acid	
$CH_3—CH_2—CH_2—COOH$	Butanoic acid	Butyric acid	
$CH_3—CH_2—CH_2—CH_2—COOH$	Petanoic acid	Valeric acid	

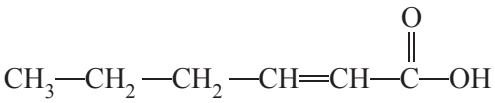
Example

Q. Write the IUPAC name of the following compounds.

(i) 

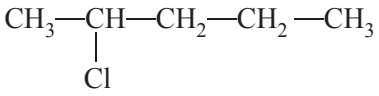
Ans. 

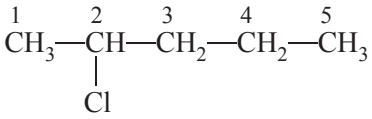
Longest carbon chain contains 7 carbon
Word root : Hept
primary suffix : ane
Substituents: 2 methyl groups
Functional group : OH
Secondary suffix : ol
IUPAC Name : 2, 5-Dimethylheptan-1-ol

(ii) 

Ans. 

Word root : Hex
Primary suffix : ene
Secondary suffix : -oic acid
Position of double bond : IInd
IUPAC name : Hex-2-en-1-oic acid

(iii) 

Ans. 

Word root : Pent
Primary suffix : ane
Prefix : chloro
IUPAC name : 2 - Chloropentane

Test Prep

Nomenclature of Organic Compounds having Polyfunctional Groups

Polyfunctional compounds are the organic compounds that contain two or more functional groups.

Rule 1 : One of the functional groups is considered as the principal functional groups in a polyfunctional compounds while rest of the other functional groups are considered as substituents.

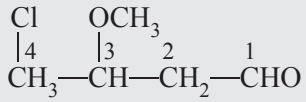
Functional groups are listed in the priority table according to their priorities in decreasing order, The functional group having highest priority is considered as the principle functional group

Rule 2 : In a polyfunctional compound, the selected principal chain must be numbered in such a way that the principal functional group gets the lowest possible number then followed by double bond (=), triple (≡) bond and substituents.

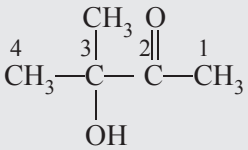
Priority order: Principle functional group > double bond (=) > triple bond (≡) > substituents.

Rule 3 : If the compound contains two functional groups of same priority at equivalent positions from either end of the parent chain, then the lowest number must be given to the group whose prefix comes first in the alphabetical order.

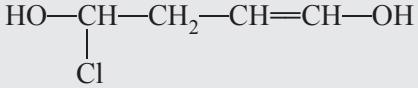
For Example



4-Chloro-3-methoxybutan-1-al



3-Hydroxy-3-methylbutan-2-one

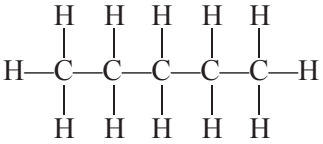


4-Chlorobut-1-ene-1, 4-diol (not 1-Chlorobut-3-ene-1, 4-diol)

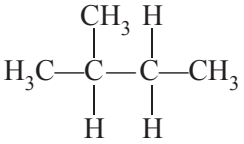
NCERT Corner

1. How many structural isomers can you draw for pentane?

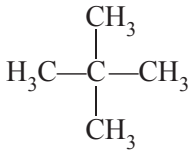
Ans. Structural isomer of pentane are:



n-pentane



2-methylbutane



2, 2-dimethylpropane

2. What are the two properties of carbon which lead to the huge number of carbon compounds we see around us?

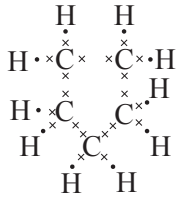
Ans. Two properties of carbon which lead to the huge number of carbon compounds we see around us are

(i) Catenation: Carbon has unique ability to form bonds with other atoms of carbon.

(ii) Tetravalency of carbon: Carbon has a valency of four, hence it is capable of bonding with four other atoms of carbon or atoms of some other monovalent element. Carbon easily forms covalent bond with oxygen, chlorine, nitrogen, sulphur, hydrogen etc.

3. What will be the formula and electron dot structure of cyclopentane?

Ans. Formula : C_5H_{10}



4. Draw the structures for the following compounds.

(i) Ethanoic acid

(ii) Bromopentane*

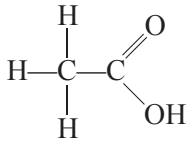
(iii) Butanone

(iv) Hexanal

***Are structural isomers possible for bromopentane?**

Ans. Structure of ethanoic acid:

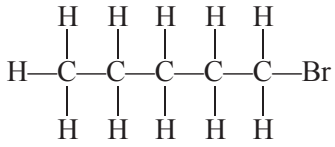
(i)



Ethanoic acid

Structure of Bromopentane:

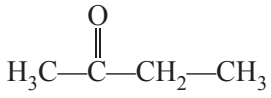
(ii)



Bromopentane

Structure of Butanone:

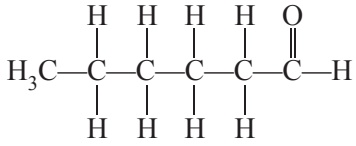
(iii)



Butanone

Structure of Hexanal:

(iv)

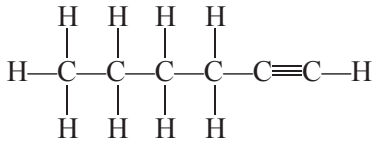


Hexanal

Yes, structural isomer for bromopentane is possible.

Three structural isomers of bromopentane are 1-bromopentane, 2-bromopentane and 3- bromopentane

5. How would you name the following compounds?

- $CH_3—CH_2—Br$
- 
- 

Ans. 1. Bromoethane

2. Methanal or Formaldehyde

3. 1-Hexyne

Carbon Compounds-Chemical Properties

Combustion

All allotropic forms of carbon, burns in the presence of oxygen to form CO_2 with release of heat and light energy. As, diamond, graphite and fullerene are the purest form of carbon, hence they burn completely to form CO_2.

$$C + O_2 \longrightarrow CO_2 + \text{Heat} + \text{light}$$

Most carbon compounds also release a large amount of heat and light on burning.

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l) + \text{heat} + \text{light}$$

$$CH_3CH_2OH(l) + 3O_2 \longrightarrow 2CO_2(g) + 3H_2O(l) + \text{heat}$$

Mind it

Acetylene on combustion with oxygen gives a flame of over 3600 K. Because of this high temperature of flame, oxyacetylene gas is used in welding and cutting. 20% (approx) of acetylene is supplied by the industrial gases industry.

Combustion of Hydrocarbons : Limited air supply results in incomplete combustion. Hence, if hydrocarbons are burnt in limited supply of oxygen then if gives sooty flame due to incomplete combustion whereas, complete combustion takes place in the presence of excess oxygen and non-luminous bluish flame with high temperature is produced.

Substances Burn With Sooty or Non-Sooty Flame

Coal or charcoal when burns in an 'angithi', sometimes just glows red and gives out heat without a flame. This is because a flame is only produced when gaseous substances burn. When wood or charcoal is ignited, the volatile substances present vapourise and burn with a flame in the beginning.

A luminous flame is seen when the atoms of the gaseous substances are heated and start to glow. The colour of the flame is characteristic of that element. For e.g., a bluish green colour is observed when a copper wire is heated in the flame of a gas stove.

Saturated hydrocarbons generally burn with a clean blue non-sooty flame. This is due to the presence of low percentage of carbon in these compounds which gets oxidised completely by the oxygen present in the air.

Whereas, **unsaturated hydrocarbons** burn to give yellow sooty flame. This is due to the presence of high percentage of carbon in these compounds as compared to saturated compounds. Hence, all the carbon does not get oxidised completely in the presence of oxygen of the air. Due to incomplete combustion, it produces sooty flame due to the presence of unburnt carbon particles.

Some amount of nitrogen and sulphur are present in the fuels like coal and petroleum. These fuels are burnt to oxides of nitrogen and sulphur, which are released in the atmosphere. These are the major pollutants in the environment.

Mind it

Coal and Petroleum Formation

Coal and petroleum are the fossil fuels. These have been formed from biomass which has been subjected to various biological and geological processes inside the earth. Coal is the remains of trees, ferns and other plants that lived millions of years ago. These remains were crushed into the earth during earthquakes, volcanoes etc. These remains were pressed down by layers of earth and rock. Because of high temperature, high pressure and in the absence of air inside the earth, they slowly decayed into coal. This process of conversion of plants and animals buried deep inside the earth under high temperature and pressure to coal is known as **carbonisation.** It is a very slow process and might have taken thousands of years.

Petroleum is obtained from the bacterial degradation of the remains of plants and animals which got buried under the sea millions of years ago. When these organisms died, their bodies sank to the sea bed and got covered by sand and clay. These remains got converted into hydrocarbons by heat, pressure and catalytic action. Over a period of millions of years. The formed hydrocarbons then rose though porous rocks and got trapped between two layers of impervious rock forming an oil trap.

Find it

Q. The gas/kerosene stoves used at home have inlets for air. What is the purpose of these inlets? What will happen, if these inlets are not provided?

Oxidation

In oxidation process, oxygen is added to a substance.

Oxidising Agent : Those substances which are capable of adding oxygen to others are known as oxidising agents. For example: alkaline potassium permanganate ($KMnO_4$) and acidified potassium dichromate etc.

(i) $CH{\equiv}CH + 4(O) \xrightarrow{\text{Alkaline } KMnO_4}$ $\begin{matrix}COOH\\|\\COOH\end{matrix}$

Oxalic acid

(ii) $CH_3CH_2OH \xrightarrow[\text{or Acidified } K_2Cr_2O_7 + \text{Heat}]{\text{Alkaline } KMnO_4 + \text{Heat}} CH_3COOH$

Example

Q. (i) Alcohols are converted into carboxylic acid only under …….

(ii) In partial oxidation; alcohols are converted into ……..

Ans. (i) complete oxidation (Alcohols are converted into carboxylic acid in the presence of strong oxidizing agents like acidified potassium dichromate)

(ii) aldehyde

Addition Reactions

In addition reactions, unsaturated compounds react with a molecule such as H_2, Cl_2, Br_2 etc. to give saturated hydrocarbons compounds.

(i) Addition of H_2 (hydrogen):

$$\underset{\text{Ethene or Ethylene}}{CH_2{=}CH_2} + \underset{\text{Hydrogen}}{H_2} \xrightarrow[573K]{\text{Nickel catalyst}} \underset{\text{Ethane}}{CH_3{-}CH_3}$$

This reaction is known as **hydrogenation**.

This hydrogenation reaction is commonly used in the hydrogenation of vegetable oils using a nickel catalyst. Vegetable oils (like mustard oil, ground nut oil) etc., have long unsaturated carbon chains which on reaction with H_2 in the presence of nickel as catalyst, get converted into vanaspati ghee which is solid at room temperature like butter or ghee.

$$\underset{\text{(Unsaturated hydrocarbons)}}{\text{Vegetable oil}} + H_2 \xrightarrow[\text{Catalyst}]{\text{Ni}} \underset{\text{(Saturated hydrocarbons)}}{\text{Vanaspati ghee}}$$

(ii) Addition of halogen to alkenes:

$$\underset{\text{Ethene}}{CH_2{=}CH_2} + \underset{\text{Bromine}}{Br_2} \xrightarrow{CCl_4} \underset{\text{1, 2-Dibromoethane}}{CH_2(Br)-CH_2(Br)}$$

$$\underset{\text{Ethene}}{CH_2{=}CH_2} + \underset{\text{Chlorine}}{Cl_2} \xrightarrow{CCl_4} \underset{\text{1, 2-Dicloroethane}}{CH_2(Cl)-CH_2(Cl)}$$

Mind it

As, vegetable oils contain unsaturated compounds which are very reactive and can undergo oxidation easily when exposed to air and may turn rancid, hence, hydrogenation of vegetable oil is necessary.

Example

Q. Explain, why vegetable oils are considered healthy as compared to vegetable ghee?

Ans. Vegetable oils generally have long contain unsaturated fatty acids which are good for the health, while vegetable ghee have saturated fatty acids which are harmful to our health. Hence, vegetable oils are considered healthy as compared to vegetable ghee.

Substitution Reactions

In substitution reactions, an atom or group of atoms of a compound is replaced or get substituted by another atom or group of atoms.

Saturated hydrocarbons do not react with most reagents, because they are less reactive in nature.

Saturated hydrocarbons react with halogens in the presence of sunlight and undergo substitution reaction. As, this reaction takes place in the presence of sunlight, hence it is a photochemical reaction. This photochemical reaction is very fast.

$$CH_4(g) + Cl_2(g) \xrightarrow{\text{Sunlight}} \underset{\text{Chloromethane}}{CH_3Cl(g)} + HCl(g)$$

$$CH_3Cl(g) + Cl_2(g) \xrightarrow{\text{Sunlight}} \underset{\text{Dichloromethane}}{CH_2Cl_2(g)} + HCl(g)$$

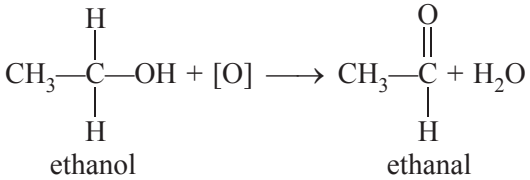
Find it

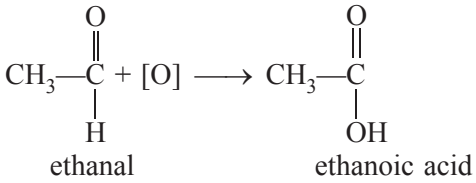
Q. Compound P contains three carbon atoms, which burns with non-sooty flame. Predict what is P? Write its electron dot structure.

NCERT Corner

1. Why is the conversion of ethanol to ethanoic acid an oxidation reaction?

Ans.





As, removal of hydrogen atom and addition of oxygen is involved in the conversion of ethanol to ethanoic acid, hence it is an oxidation reaction. Firstly, ethanal is formed from ethanol by the removal of H_2 molecule. As loss of Hydrogen is oxidation reaction, hence, this reaction is an oxidation reaction. In the similar way, Oxygen atom is added to form ethanoic acid from ethanal. As, gain of Oxygen is known as oxidation reaction. Hence, the reaction is an oxidation reaction.

2. A mixture of oxygen and ethyne is burnt for welding. Can you tell why a mixture of ethyne and air is not used?

Ans. A mixture of oxygen and ethyne is burnt for welding and not a of mixture of ethyne and air because the production of heat is very important for welding metals. When a mixture of oxygen and ethyne are burnt, it burns completely and gives a flame with higher temperature but when the mixture of air and ethyne are burnt gives a sooty flame which means that there are unburnt carbon particles, which results in lesser heat.

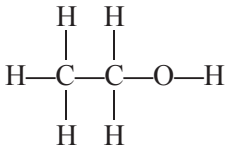
Find it

Q. Why is the reaction between methane and chlorine considered a substitution reaction?

Some Important Carbon Compounds

Ethanol

- It is also known as ethyl alcohol or methyl carbinol.
- It is the second member of the homologous alcoholic series.
- Structural formula of alcohol is:



Properties of Ethanol

(a) Physical properties of ethanol:

- It is colourless liquid
- It has a pleasant smell.
- It boils at 351 K (78°C).
- It is miscible with water in all proportions
- It does not contain ions, hence it is a non-conductor of electricity

Chemical properties of ethanol

(i) Combustion : In the presence of air, ethanol burns with a blue flame to give CO_2 and H_2O.

$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$

(Ethanol)

(ii) Oxidation

(a) Oxidation of alcohol by mild oxidizing agent CrO_3 (Chromic anhydride).

$$\underset{\text{(Ethanol)}}{CH_3CH_2OH} \xrightarrow[\text{In glacial acetic acid}]{CrO_3} \underset{\text{(Ethanal)}}{CH_3CHO}$$

(b) Oxidation of alcohol by strong oxidizing agent ($K_2Cr_2O_7 + H_2SO_4$ or alkaline $KMnO_4$).

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[\text{or } K_2Cr_2O_7+H_2SO_4]{\text{Alkaline } KMnO_4} \underset{\text{Ethanoic acid}}{CH_3COOH}$$

(iii) Reaction with sodium: Ethanol reacts with sodium leading to the evolution of hydrogen gas.

$$2Na + 2CH_3CH_2OH \longrightarrow \underset{\text{(sodium ethoxide)}}{2CH_3CH_2ONa} + H_2$$

(iv) Reaction with carboxylic acids : Alcohols react with carboxylic acid to give an ester, this process is known as esterification reaction.

$$\underset{\text{Carboxylic acid}}{R{-}\overset{\overset{O}{\|}}{C}{-}OH} + \underset{\text{Alcohol}}{HO{-}R'} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\substack{\text{Alkyl Alkanoate}\\ \text{(sweet smelling ester)}}}{R{-}\overset{\overset{O}{\|}}{C}{-}OR'} + H_2O$$

Ethanol reacts with ethanoic acid in the presence of conc. H_2SO_4 to produce ethyl ethanoate (ester) and water.

$$\underset{\substack{\text{Ethanoic acid}\\ \text{or Acetic acid}}}{CH_3COOH} + \underset{\text{Ethanol}}{C_2H_5OH} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\substack{\text{Ethyl Ethanoate}\\ \text{(ester)}}}{CH_3COOC_2H_5} + H_2O$$

Mind it

Sugarcane plants are the most efficient converter of sunlight energy into chemical energy. In the presence of yeast (which contains the enzyme invertase and zymase), molasses (thick dark coloured syrup left after the crystallisation of sugar from sugarcane) give alcohol by fermentation process.

(v) Dehydration : Heating ethanol at 443 K with excess concentrated sulphuric acid results in the dehydration of ethanol to give ethene.

$$\underset{\text{Ethanol}}{CH_3{-}CH_2OH} \xrightarrow[443\text{ K}]{\text{Conc. } H_2SO_4} \underset{\text{ethene (or ethylene)}}{CH_2 = CH_2} + H_2O$$

Note: The concentrated sulphuric acid can be regarded as a dehydrating agent which removes water from ethanol.

Mind it

Some Important Terms

(i) Rectified spirit : Ethanol containing 5 % H_2O is known as rectified spirit.

(ii) Absolute alcohol : 100 % pure ethanol is known as absolute alcohol. Absolute alochol is obtained by heating the rectified spirit under reflux over quicklime (CaO) for nearly about 5-6 hours and then its is allowed to stand for 12 hours. On distillation, absolute alcohol (C_2H_5OH = 100%) is obtained.

(iii) Denatured alcohol : To prevent the misuse of ethanol produced for industrial use, it is made unfit for drinking by poisonous substances, like methanol to it. It is known as denatured alcohol.

(iv) Power alcohol : Power alcohol, is used for generating power. It consists of a mixture of absolute alcohol and petrol roughly in the ratio 20 : 80. As alcohol itself, does not mix with petrol, completely hence, a third solvent like benzene, ether etc. is added as a co-solvent.

Uses of Ethanol

(i) It is used in the manufacture of paints, medicines, dyes, perfumes, soaps and synthetic rubber.

(ii) Ethanol is the active ingredient of beverages like wine, beer, whisky and other liquors.
Wine = 10 - 20% Ethanol
Beer = 3 - 6% Ethanol
Whisky = 50% Ethanol

(iii) It is used as an antiseptic to sterilize wounds and syringes.

(iv) It is used as antifreeze in the radiators of vehicles in cold countries.

(v) It is used in medicines such as tincture of iodine, cough syrups etc.

Find it

Q. Why alcohol supplied for industrial purpose is mixed with copper sulphate?

Harmful effects of drinking alcohol

(i) It causes addiction and mixes with blood.

(ii) It damages liver if taken regularly in large amount.

(iii) If ethanol is mixed with methanol and consumed, it can cause serious poisoning and can cause blindness.

(iv) It's higher consumption leads to loss of body control & consciousness. It may even cause death.

Find it

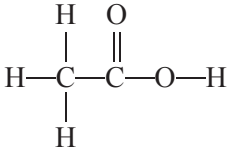
Q. What will be observed on adding a 5% alkaline $KMnO_4$ solution drop by drop to some warm ethanol taken in a test tube? Which compound will be formed during the above chemical reaction?

Ethanoic acid

Ethanoic acid is also known as acetic acid (5-8)% solution of acetic acid in water is known as **vinegar**. Vinegar is used for the preservation of food-sausage, pickles etc

(a) Molecular formula of ethanoic acid: CH_3COOH

(b) Structural formula of ethanoic acid:



Mind it

Ethanoic acid (CH_3COOH) has a melting point of 290 K and therefore it often freezes during winter in cold climates. Hence, it is named as **glacial acetic acid**.

Reactions of Ethanoic Acid

1. **Reaction with Na_2CO_3 and $NaHCO_3$:** It reacts with Na_2CO_3 and $NaHCO_3$ with the evolution of CO_2 gas.

$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2 \uparrow$

$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2 \uparrow$

2. **Reaction with a base:** Acetic acid or ethanoic acid is a monobasic acid –COOH group in ethanoic acid contains a replaceable hydrogen atom. Hence, ethanoic acid neutralizes alkalies.

   It reacts with a solution of NaOH to give sodium ethanoate and water.

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

   Formed sodium ethanoate (CH_3COONa) is an ionic compound which gets dissolved in polar solvents like water, but does not get dissolved in non polar solvents like alcohol, propanone etc.

   Due to hydrolysis, the aqueous solution of sodium ethanoate (CH_3COONa) is alkaline in nature.

   $$\underset{\text{Weak acid}}{CH_3COOH} + \underset{\text{Strong base}}{NaOH} \xleftrightharpoons{H_2O} CH_3COONa$$

Example

Q. Which functional group can be detected by using sodium hydrogen carbonate test?

Ans. Carboxylic acid (—COOH) functional group can be detected by using $NaHCO_3$ (sodium hydrogen carbonate) test. A carboxylic acid reacts with $NaHCO_3$ to liberate CO_2 gas. The involved reaction is:

$R—COOH + NaHCO_3 \rightarrow R—COONa + CO_2 + H_2O$

3. **Reaction with sodium:** It reacts with metals like Na, Zn and Mg to liberate H_2 gas.

   $2CH_3COOH + 2Na \rightarrow 2CH_3COONa + H_2 \uparrow$

   $2CH_3COOH + Zn \rightarrow (CH_3COO)_2Zn + H_2 \uparrow$

4. **Esterification reaction :** Ethanoic acid reacts with ethanol in the presence of an acid catalyst to give an ester.

   $$\underset{\text{(Ethanoic acid)}}{CH_3COOH} + \underset{\text{(Ethanol)}}{CH_3CH_2OH} \xrightarrow{\text{Acid}} CH_3—\underset{\underset{\underset{\text{(Ester)}}{O}}{\|}}{C}—O—CH_2—CH_3$$

   This process of Ester formation is known as **esterification.**

   Esters : Esters are pleasant fruity smelling compounds. Carboxylic acids react with alcohols to form esters. These are used in making perfumes, ice creams, cold drinks, and in flavouring agents.

Mind it

The smell of bananas is due to the presence of an aromatic ester in them.

5. **Hydrolysis of esters in acidic medium :** Acidic hydrolysis of esters give carboxylic acid and alcohol.

   $$\underset{\text{Ethyl ethanoate}}{CH_3COOC_2H_5} + \underset{\text{Water}}{H_2O} \xrightarrow{H^+} \underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Ethanol}}{C_2H_5OH}$$

   Saponification reaction: Esters on treating with NaOH solution get converted back to alcohol and sodium salt of carboxylic acid. This reaction is known as saponification reaction.

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

   Saponification is also used in the for preparation of soap.

6. Decarboxylation

CH_3COONa when heated with CaO (quick lime) produces methane.

$$\underset{\text{Sodium ethanoate}}{CH_3COONa} + NaOH \xrightarrow{CaO} \underset{\text{Methane}}{CH_4} + Na_2CO_3$$

Example

Q. Explain, how is glacial acetic acid is different from acetic acid provided to you in laboratory? Write its one characteristic which resembles its name.

Ans. Acetic acid provided in the laboratory contains higher water content than that of glacial acetic acid.

Pure ethanoic acid is oftenly called as glacial acetic acid because it often freezes to form ice-like crystals during winter in cold climates (the melting point is 290K).

Mind it

'Decarboxylation' is the term which is used when the elements of CO_2 are removed from a molecule.

Find it

Q. Why carbon and its compounds are widely used as fuels in most cases?

Uses of ethanoic acid

(i) 5-8% of aqueous solution of ethanoic acid (acetic acid) is known as vinegar, which is used for the preservation of food like pickles, sausage etc.

(ii) Ethanoic acid is used for making cellulose ethanoate, which is used in making photographic films and rayon.

(iii) Pure ethanoic acid is used as a solvent and chemical reagent.

(iv) It is widely used in the manufacture of textiles.

(v) It is used in the preparation of dyes, plastic, white lead etc.

Mind it

Tests for Ethanoic Acid

(i) Litmus test : Ethanoic acid is acidic in nature. Hence, if the given organic compound changes the colour of blue litmus solution to red then it indicates that the given organic compound is ethanoic acid.

(ii) $NaHCO_3$ test: When a small portion of the organic compound is taken in a test tube and a pinch of solid $NaHCO_3$ is added. Evolution of CO_2 with brisk effervescence shows the presence of carboxylic acid.

(iii) Ester formation : When a mixture of ethanoic acid and ethanol is heated in the presence of conc. H_2SO_4, a pleasant fruity smelling ester, ethyl ethanoate is formed.

NCERT Corner

1. How would you distinguish experimentally between an alcohol and a carboxylic acid?

Ans. Carboyxlic acid reacts with Na_2CO_3 to produce CO_2 gas, which turns lime water milky. On the other hand, alcohols do not give this reaction. Therefore, this experiment can be used to distinguish an alcohol and a carboxylic acid.

Reaction of Carboxylic acid with Na_2CO_3 is as follows:

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

2. What are oxidising agents?

Ans. Those compounds which are capable of either removing hydrogen or adding oxygen to a compound are known as oxidizing agents. For example: Potassium nitrate, halogens and nitric acid.

Find it

Q. Which compound is used in the manufacturing of perfumes?

Soaps and Detergent

Detergents are the substances which remove dirt and have cleansing action in water. Soap is also a detergent according to this definition and that has been used for over more than 2000 years. Two types of detergents are as follows:

(i) Soapy detergents or soaps

(ii) Non - soapy detergents or soapless soaps.

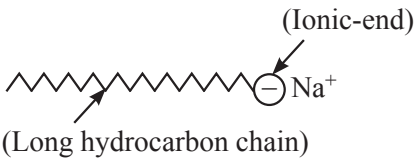
Soap

A soap is a sodium or potassium salts of long chain carboxylic acids (fatty acids) having cleansing properties in water. Soap consists of large non-ionic hydrocarbon group and an ionic group. The sodium salt of long chain fatty acids are known as hard soaps and the potassium salt of long chain fatty acids are knowns as soft soaps.

Mind it

Soap solution turn red litmus to blue, because soap is basic in nature.

The structure of soap molecule can be shown as:



Here, ⩘⩘⩘ represents the hydrocarbon chain and ⊖ represents negatively charged carboxyl group. Examples of soap are sodium stearate, $C_{17}H_{35}COO^-\ Na^+$, sodium palmitate, $C_{15}H_{31}COO^-\ Na^+$ etc.

Mind it

Calcium and magnesium salts present in water reacts with soap to form calcium and magnesium salts of fatty acid.

Table- 8: Examples of fatty acids

Molecular Formula	Name	Molecular Formula	Name
$C_{17}H_{35}COOH$	Stearic acid	$C_{15}H_{31}COOH$	Palmitic acid
$C_{17}H_{31}COOH$	Linoleic acid	$C_{13}H_{27}COOH$	Myristic acid
$C_{17}H_{33}COOH$	Oleic acid	$C_{11}H_{23}COOH$	Lauric acid

Preparation

Soap can be prepared by heating animal fat or vegetable oil with concentrated NaOH solution (caustic soda solution). When these fats and oils are heated, hydrolysis of fat takes place which results in a mixture of sodium salt of fatty acids and glycerol. The salt of fatty acids thus obtained are used as soap. Hence, alkaline hydrolysis of oils and fats is commonly known as **saponification**.

$$\begin{array}{l} CH_2OCOR \\ | \\ CHOCOR \\ | \\ CH_2OCOR \\ \text{Triglyceride} \\ \text{(fat or oil)} \end{array} + 3NaOH \longrightarrow \begin{array}{l} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \\ \text{(Glycerol)} \end{array} + \underset{\text{Soap}}{3RCOONa} + \text{Heat}$$

Limitation of soaps : It is not suitable for washing clothes with hard water due to the following reasons:

(i) Calcium and magnesium salts are present in hard water. When soap is added to hard water, Ca^{2+} and Mg^{2+} of hard water react with soap to form insoluble calcium and magnesium salts of fatty acids.

$$\underset{\text{Soap}}{2C_{17}H_{35}COONa} + \underset{\text{Magnesium chloride (hard water)}}{MgCl_2} \longrightarrow \underset{\text{White precipitate}}{(C_{17}H_{35}COO)_2Mg\downarrow} + 2NaCl$$

$$\underset{\text{Soap}}{2C_{17}H_{35}COONa} + \underset{\text{Calcium chloride } (CaCl_2)}{CaCl_2} \longrightarrow \underset{\text{White precipitate}}{(C_{17}H_{35}COO)_2Ca\downarrow} + 2NaCl$$

Hence, a lot of soap is wasted in hard water.

(ii) Soap forms insoluble precipitates of calcium and magnesium salts with hard water, which stick to the cloth being washed. Hence, the cleaning ability of the soap is interfered, which makes the cleaning process difficult.

Mind it

Calcium and magnesium salts of fatty acid are insoluble in water and hence, they get separated out as curdy white precipitate.

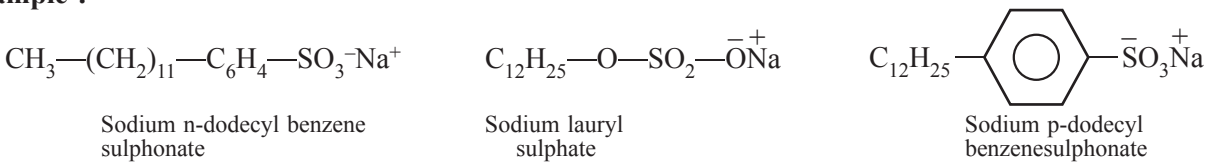
Detergents

Detergents are also known as 'soapless soaps' or synthetic detergents. A synthetic detergent is the **sodium salt of a long chain benzene sulphonic acid or the sodium salt of a long chain alkyl hydrogen sulphate.**

Preparation of Synthetic Detergents

Synthetic detergents can be prepared by **reacting hydrocarbons** obtained from petroleum with **conc. H_2SO_4**, and then converting the formed product into its **sodium salt.**

For example :



Sodium n-dodecyl benzene sulphonate

Sodium lauryl sulphate

Sodium p-dodecyl benzenesulphonate

Example

Q. Out of soaps and synthetic detergents, which one will you use for cleaning the dirt of clothes, if water contains dissolved calcium hydrogen carbonate.

Ans. The given sample of water is hard water because it contains calcium ions.Soap is not suitable for washing clothes in hard water as they produce scum (insoluble precipitate) with calcium ions (Ca^{2+}). Hence, synthetic detergents must be used for cleaning the dirt of clothes in hard water.

Mind it

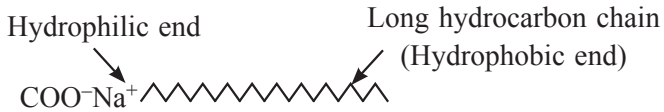
- ❒ Washing powders which are available in the market contain nearly about (15-30) % detergents by weight.
- ❒ The process of Alkaline hydrolysis of oils and fats is commonly known as saponification.

Cleansing Actions of Soaps and Detergents

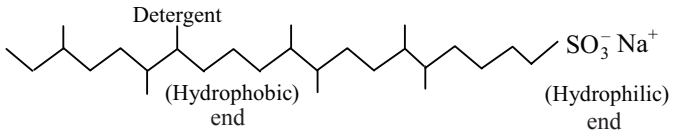
Soaps and detergents are made up of a large hydrocarbon chain (tail) with a negatively charged head as shown in the given figures below.

The hydrocarbon chain (tail) is hydrophobic (water repelling) and negatively charged head is hydrophilic (water-loving).

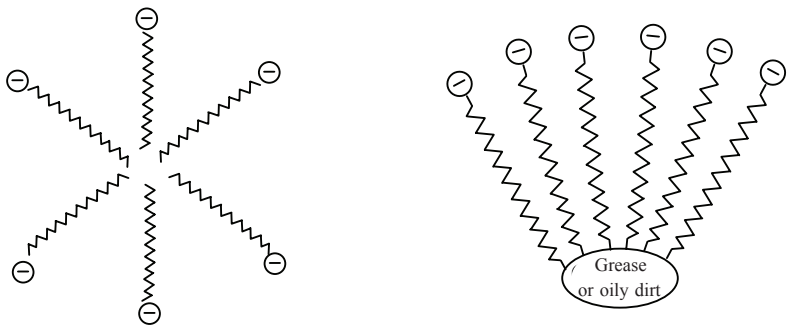
When soap or detergent is added into water, water molecules being polar in nature, surround the ions i.e., ionic end and not the hydrocarbon part of the molecule and thus, form structures called micelles, where one end of the molecules is towards the oil droplet or dirt while the ionic-end faces outside.



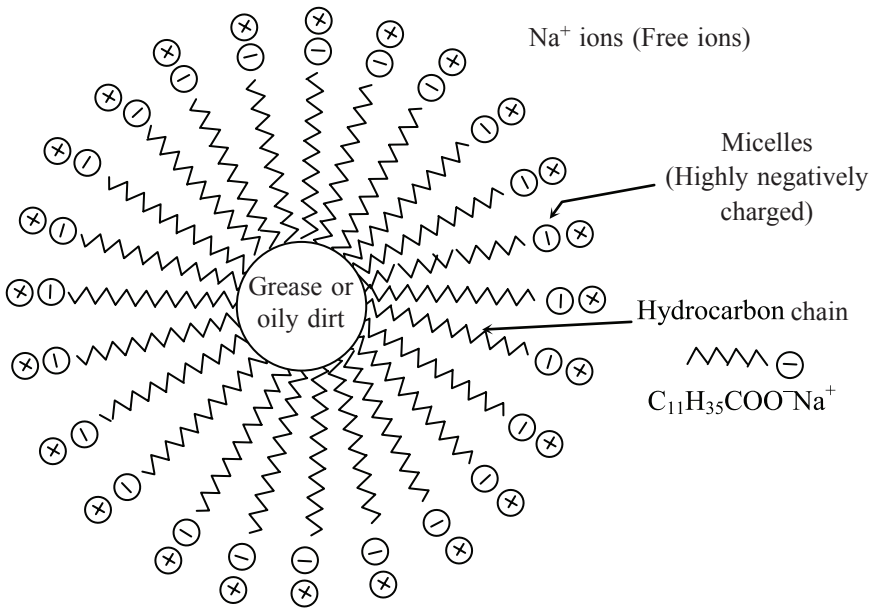
(a) Soap molecule



(b) Detergent molecule



(c) Micelle formation by detergent molecule



(d) Micelle formation by soap molecule

Fig. 5: Cleansing action of soaps and detergents

The tails (hydrocarbon chain) stick inwards and the heads faces outwards.

In cleansing, the hydrocarbon chain (tail) get itself attached to the oily dirt or grease. When it is shaken vigorously with water, the oily dirt or grease tends to leave the dirty surface and get dissociated into fragments. This provides opportunity to other tails to get attached to oil. The solution now contains small globules of oil dirt surrounded by detergent molecules.

The small globules were prevented from coming together and forming aggregates by the negatively charged heads present in water. Hence, the oily dirt or grease is removed.

Example

Q. Why soap solution appears cloudy?

Ans. Soap when get added to water, forms clusters of molecules known as micelles. The soap micelles are large enough to scatter light and hence, a soap solution appears cloudy.

Difference Between Soaps and Synthetic Detergents

	Soaps	Synthetic detergents
1.	Soaps are sodium or potassium salts of long-chain carboxylic acids.	Synthetic detergents are sodium alkyl sulphates or sodium alkyl benzene sulphonates with alkyl group containing more than 10 carbon atoms.
2.	These are prepared form natural oils and fats.	These are prepared form the hydrocarbons of petroleum.
3.	These are not suitable for washing in hard water	These can be used for washing even in hard water.
4.	In acidic medium, soaps are decomposed into carboxylic acids, hence cannot be used in acidic medium.	Detergents are the salt of strong acids and are not decomposed in acidic medium and hence, can be used in acidic medium.
5.	Relatively weak cleansing action	Strong cleansing action
6.	Soaps are biodegradable.	Some of the synthetic detergents are not biodegradable.

Merits of Synthetic Detergents Over Soap

Some of the advantages of synthetic detergents over soaps are:

(1) Synthetic detergents are more soluble in water than that of soaps.

(2) Synthetic detergents can even be used for washing purposes in hard water, but soaps are not suitable for washing in hard water.

(3) Synthetic detergents can even be used in acidic medium but soaps cannot be used in acidic medium.

(4) Synthetic detergents have a stronger cleansing action than that of soaps.

Demerits of Detergents over Soaps

(1) Detergents are more expensive than soaps.

(2) Synthetic detergents which contain branched hydrocarbon chain are not completely biodegradable, and cause water pollution.

Mind it

Synthetic Detergent : A Serious Issue

Earlier detergents caused water pollution. The long carbon chain present in detergents which were used in the past contained lot of branching.

These branched chain detergent molecules were not biodegradable and were degraded very slowly by the micro-organims present in sewage and water bodies.

Hence, the detergents remained in water for long time, due to which water becomes unfit for aquatic life.

For e.g., detergents containing phosphates deplete the dissolved oxygen present in the water of lakes and rives, by causing rapid growth of algae. Because of this, fish and other aquatic animals may die due to lack of oxygen.

But nowadays, the detergents consist of molecules in which branching is kept at minimum. These detergents are degraded more easily by micro-organisms than branched chain detergents.

Find it

Q. Soaps are prepared by treating the esters of fatty acid with alkali. Sometimes common salt is also added to it during preparation. What is the reason for adding common salt during the process?

NCERT Corner

1. Would you be able to check if water is hard by using a detergent?

Ans. No, we would not be able to check if water is hard by using a detergent because detergents are ammonium or sulphonates salts of long chain carboxylic acids. They produce lather in any type of water unlike soaps. Hence, detergents cannot distinguish the nature of water.

2. People use a variety of methods to wash clothes. Usually after adding the soap, they 'beat' the clothes on a stone, or beat it with a paddle, scrub with a brush or the mixture is agitated in a washing machine. Why is agitation necessary to get clean clothes?

Ans. Agitation is necessary to get clean clothes, because agitation helps soap micelles to trap the grease, oily dirt or any other impurities that needs to be removed. When clothes are being beaten or agitated, the dirt particles tend to lift off from the clothes' surfaces and go into the water, thus cleaning the clothes.

Hence, agitation is necessary to get clean clothes.

Summary

Carbon

Carbon is a non metal with atomic number 6 and atomic mass 12.011 g. It occurs in native state as well as in combined state. Carbon is most essential element as it forms largest number of compounds that are useful in our daily life

Types of covalent bonds

A covalent bond is formed by sharing of electron pair between two atoms.

1. If two atoms share one pair of electrons, then bond formed is known as **single covalent bond (—)**
2. If two atoms share two pairs of electrons, then bond formed is known as **double covalent bond (═)**
3. If two atoms share three pairs of electrons, then bond formed is known as **triple covalent bond (≡)**

Verstaile Nature of Carbon

1. Carbon always form covalent bond.
2. Catenation: The property of elements by virtue of which they form long chains or rings by self linking of their own atoms through covalent bond.
3. Tetravalency: Carbon has four valence electrons, hence it can make 4 bonds with other atoms
4. Allotropes: Carbon exists in two allotropic forms which are: (i) crystalline (ii) amorphous.

The crystalline forms of carbon are

Diamond: It is hardest natural substance known, its crystals are octahetdral and it is poor conductor of electricity.

Graphite: It is soft and slippery, its crystal has hexagonal crystals and it is a very good conductor of electricity.

Fullerene: Fullerene consists of 60 carbon atoms which are linked in shape of a football.

The **amorphous forms of carbon** are: coal, charcoal, lamp black etc.

Hydrocarbons

Hydrocarbons are the compounds which are made up of carbon and hydrogen only. For example: CH_4, C_2H_6 etc.

Types of hydrocarbon

(i) **Saturated hydocarbon:** Saturated hydrocarbons contain single bonds only. For example: Methane (CH_4), Ethane (C_2H_6) etc.

(ii) **Unsaturated hydrocarbons:** In unsaturated hydrocarbons, valency of carbon is satisfied by double or triple bonds. For example: C_2H_4 (ethene), C_2H_2(ethyne) etc.

Classifications of Organic Compounds

1. **Open chain compounds:** Open chain compounds consist of an open chain of carbon atoms that is either straight chain or branched chain in nature. For example: methane, butane
2. **Closed chain or Cyclic compounds:** Closed chain organic compounds have cyclic or ring structures.

Two types of cyclic compound are:

(a) Alicyclic compounds: Alicyclic compounds contain carbon atoms joined in the form of a ring. Eg: cyclopropane etc.

(b) Aromatic compounds: Aromatic compounds contain one or more fused or isolated benzene rings. Eg: phenol, aniline etc.

Functional group

Functional group may be defined as an atom or group of atoms joined in a specific manner which is responsible for the characteristic chemical properties of the organic compounds. E.g. —OH (alcohol), —CHO (aldehyde), –COOH (carboxylic acid), > C = C < (alkene), — C ≡ C — (alkyne) etc.

Homologous Series

Homologus series is a series of compounds in which same functional group substitutes for hydrogen in a carbon chain. E.g. CH_4 and C_2H_6 differ by a —CH_2 unit.

Nomenclature

In simple aliphatic compounds, the normal saturated hydrocarbons are considered as the parent compounds and the other compounds are considered as their derivatives which are obtained by the replacement of one or more hydrogen atoms with various functional groups.

(i) Word root: Word root is the basic unit which represents linear or continuous number of carbon atoms.

(ii) Suffix: There are two types of suffixes:

(a) Primary suffix: The nature of linkage in the carbon atoms is indicated by primary suffix.

(b) Secondary suffix: The presence of a particular functional group in the carbon chain, is indicated by secondary suffix.

Some functional groups and classes of organic compounds

Class of compounds	Functional Group	General Formulae	IUPAC group Prefix	IUPAC group Suffix	IUPAC Name
Aldehyde	—CHO	R—CHO	Formyl or oxo	- al	Alkanal
Ketone	—C(=O)—	R—C(=O)—R	oxo	- one	Alkanone
Carboxylic acid	—C(=O)—OH	R—C(=O)—OH ($R = C_nH_{2n+1}$)	Carboxy	- oic acid	Alkanoic acid
Ester	—C(=O)—OR	R—C(=O)—O—R' ($R \neq R'$)	Alkoxycarbonyl	Alkyl (r;) – oate	Alkyl alkanoate
Alcohol	—OH	R—OH	Hydroxy	- ol	Alkanol
Alkenes	C═C	C_nH_{2n}	-	- ene	Alkene
Alkynes	C≡C	C_nH_{2n-2}	-	- yne	Alkyne
Halides	—X (X = F, Cl, Br, I)	R—X	Halo	-	Haloalkane

Chemical Properties of Carbon Compounds:

(i) Combustion: Carbon in all its allotropic forms, burns in oxygen to give CO_2 and H_2O with the evolution of heat and light.

$CH_4 + O_2 \rightarrow CO_2 + H_2O$ + heat and light

(ii) Oxidation: Some substances are capable of adding oxygen to others. These substances are known as oxidising agent. For example: alkaline $KMnO_4$, acidified $K_2Cr_2O_7$.

$$CH_3CH_2OH \xrightarrow{\text{Alk. } KMnO_4} CH_3COOH$$

(iii) Addition reaction: Unsaturated hydrocarbons (alkenes and alkynes) undergo addition reaction in the presence of catalysts like palladium or nickel to give saturated hydrocarbons.

$$CH_2 = CH_2 + H_2 \xrightarrow{\text{Ni, 573K}} CH_3CH_3$$

(iv) Substitution reaction: In substitution reactions, an atom or group of atoms of a compound is replaced by another atom or group of atoms.

$$CH_4(g) + Cl_2(g) \xrightarrow{\text{light}} CH_3Cl(g) + HCl(g)$$

Some Important Carbon Compounds

Ethanol

It is a colouless liquid having a pleasant smell. It's chemical formula is C_2H_5OH.

Reactions of ethanol

1. **Combustion:** In air, ethanol burns with a blue flame to produce CO_2 & H_2O.
   $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$
2. **Oxidation**
   (a) By mild oxidizing agent
   $$CH_3CH_2OH\ CrO_3. \xrightarrow{CrO_3 \text{ in glacial acetic acid}} CH_3CHO$$
   (b) By strong oxidizing agent
   $$CH_3CH_2OH \xrightarrow{\text{Alkaline } KMnO_4} CH_3COOH$$
3. **Reaction with sodium:** $2\ C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2(\uparrow)$
4. **Dehydration:**
   $$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow{\text{Conc. } H_2SO_4\ 443K} \underset{\text{ethene}}{CH_2{=}CH_2} + H_2O$$
5. **Reaction with carboxylic acids:**
   $$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Ethanol}}{C_2H_5OH} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\text{Ethyl Ethanoate (ester)}}{CH_3COOC_2H_5} + H_2O$$

Ethanoic Acid

Ethanoic acid is also known as acetic acid. (5-8)% solution of acetic acid in water is known as **vinegar**. It's chemical formula is CH_3COOH.

Reactions of Ethanoic Acid

1. **Reaction with a base :** Ethanoic acid is a monobasic acid. –COOH group in ethanoic acid contains a replaceable hydrogen atom. Hence, it neutralizes alkalies.
   $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

2. **Reaction with Na_2CO_3 and $NaHCO_3$:** It reacts with Na_2CO_3 and $NaHCO_3$ with the evolution of CO_2 gas.

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

3. **Reaction with sodium:**

   $2CH_3COOH + 2Na \rightarrow 2CH_3COONa + H_2$

4. **Ester formation:**

   $$CH_3COOH + HOC_2H_5 \xrightarrow{H^+} \underset{\text{Ethyl ethanoate}}{CH_3COOC_2H_5} + H_2O$$

A **soap** is a sodium or potassium salt of long chain carboxylic acids (fatty acid). For example: sodium stearate

A **synthetic detergent** is the sodium salt of a long chain benzene sulphonic acid or the sodium salt of a long chain alkyl hydrogen sulphate. For example: Sodium lauryl sulphate.

Quick Recall

Fill in the blanks

1. Next homologous of ethane is _____
2. Valency of carbon in ethene is _____
3. The ability of carbon to form chains give rise to a _____ series of compounds.
4. _____ is the soft crystalline form of carbon.
5. _____ is the purest form of carbon.
6. _____ and _____ are the two allotropes of carbon.
7. Ethene burns in air to give CO_2 and _____
8. Vinegar is _____ % solution of acetic acid in water.
9. _____ is the newly discovered allotrope of carbon.
10. The molecular mass of any two adjacent homologous differ by _____ amu.
11. Hydrogenation of vegetable oil is _____ reaction.

True and False Statements

1. Carbon is a versatile element
2. Methanol is the first member of the alcohol homologous series.
3. Saturated hydrocarbon has double or triple covalent bond.
4. Graphite is a bad conductor of electricity.
5. Methane is the simplest saturated hydrocarbon.
6. The next higher homologue of ethanol is propanol.
7. Carbon forms covalent bonds with itself and other elements such as hydrogen, oxygen, sulphur, nitrogen and chlorine.
8. Carbon and its compounds are some of our most important sources of energy.
9. The functional group of bromo alkane is –Br.
10. When hydrocarbon burn in air, CO_2 and H_2O are produced with heat energy.

Match The Followings

In this section each question has two matching lists. Choices for the correct combination from column-I and Column-II are given as option (a), (b), (c) and (d) out of which one is correct.

1.

Column I	Column II
(P) –CHO	(1) Alcohol
(Q) $-CONH_2$	(2) Aldehydes
(R) $-NH_2$	(3) Acid amides
(S) –OH	(4) Amines

a. P-1, Q-2, R-3, S-4
b. P-4, Q-1, R-3, S-2
c. P-2, Q-3, R-4, S-1
d. P-3, Q-1, R-2, S-4

2.

Column I	Column II
(P) Halogenation	(1) $C_{15}H_{31}COONa$
(Q) Oxidising agent	(2) Dehydration
(R) Soap	(3) Cl_2 + UV light
(S) Ethylene	(4) Fumming HNO_3

a. P-3, Q-4, R-1, S-2
b. P-4, Q-1, R-2, S-3
c. P-2, Q-1, R-3, S-4
d. P-1, Q-2, R-4, S-3

3.

Column I	Column II
(P) $CH_3COOH + C_2H_5OH \xrightarrow{H^+} CH_3COOC_2H_5 + H_2O$	(1) Addition reaction
(Q) $CH_2 = CH_2 \xrightarrow{Ni} CH_3–CH_3$	(2) Substitution reaction
(R) $CH_4 + Cl_2 \xrightarrow{Sunlight} CH_3Cl + HC_l$	(3) Neutralisation reaction
(S) $HCl + NaOH \rightarrow NaCl + H_2O$	(4) Esterification reaction

a. P-3, Q-4, R-1, S-2
b. P-1, Q-3, R-4, S-2
c. P-4, Q-1, R-2, S-3
d. P-2, Q-4, R-1, S-3

4.

Column I	Column II
(P) Alcohol	(1) -al
(Q) Ketone	(2) -one
(R) Aldehyde	(3) -ol
(S) Carboxylic acid	(4) -oic acid

a. P-1, Q-2, R-3, S-4
b. P-2, Q-1, R-4, S-3
c. P-4, Q-3, R-2, S-1
d. P-3, Q-2, R-1, S-4

5.

Column I	Column II
(P) Good lubricant	(1) Hydrocarbons
(Q) Compounds of carbon and hydrogen	(2) Unsaturated hydrocarbons
(R) n-butane and iso-butane	(3) Graphite
(S) Alkenes	(4) Isomers

a. P-3, Q-1, R-4, S-2

b. P-1, Q-2, R-3, S-4

c. P-3, Q-2, R-1, S-4

d. P-2, Q-4, R-1, S-3

Answers

Fill in the Blanks

1. Propane

2. 4

3. Homologous

4. Graphite

5. Diamond

6. Diamond, graphite

7. H_2O

8. 5 to 8%

9. Fullerene

10. 14

11. addition

True and False

1. True

2. True

3. False

4. False

5. True

6. True

7. True

8. True

9. True

10. True

Match the Followings

1. (c) **2.** (a) **3.** (c) **4.** (d) **5.** (a)

NCERT Exercise

1. Ethane, with the molecular formula C_2H_6 has

a. 6 covalent bonds. b. 7 covalent bonds.

c. 8 covalent bonds. d. 9 covalent bonds

Exp. (b) Ethane, with the molecular formula C_2H_6 has 7 covalent bonds

2. Butanone is a four-carbon compound with the functional group

a. carboxylic acid b. aldehyde

c. ketone d. alcohol

Exp. (c) Ketone is the functional group present in butanone.

3. While cooking, if the bottom of the vessel is getting blackened on the outside, it means that

a. the food is not cooked completely.

b. the fuel is not burning completely.

c. the fuel is wet.

d. the fuel is burning completely.

Ans. (b) While cooking, if the bottom of the vessel is getting blackened on the outside, it means that the fuel is not burning completely.

4. Explain the nature of the covalent bond using the bond formation in CH_3Cl

Exp. A covalent bond is a chemical bond that involves the sharing of electron pairs between atoms.

In CH_3Cl, carbon needs 4 electrons to complete its octet, and each of the three hydrogen atoms need one electron to complete its duplet. Also, Cl needs one electron to complete the octet. Hence, all of these share the electrons and therefore, carbon forms 3 bonds with hydrogen and one with Cl.

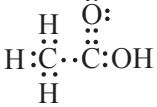
5. Draw the electron dot structures for

a. ethanoic acid b. H_2S

c. propanone d. F_2

Exp. Electron dot structure for ethanoic acid,

(a)

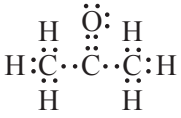


ethanoic acid

(b) Electron dot structure for H_2S,

H_2S

(c) Electron dot structure for propanone,



Propanone

(d) Electron dot structure for F_2,

F_2

6. What is a homologous series? Explain with an example.

Exp. A homologous series is a series of compounds, which differ in the number of carbon atoms but contains the same functional group. Compounds of homologous series differ by a $-CH_2$ units.

For example: methane, ethane, propane etc. are the compounds of the alkane homologous series.

7. How can ethanol and ethanoic acid be differentiated on the basis of their physical and chemical properties?

Exp.

Ethanol	Ethanoic acid
Does not react with $NaHCO_3$	Forms bubbles and fizzes with $NaHCO_3$.
Pleasant smell	Vinegar like smell
Burning taste	Sour taste
No effect on litmus paper	Turns blue litmus paper to red

8. Why does micelle formation take place when soap is added to water? Will a micelle be formed in other solvents such as ethanol also?

Exp. Due to the presence of the dirt particles in water, micelle formation takes place when soap is added to water and thus clean the water. Two mediums that are involved: pure water and dirt particles. The soap also has two mediums:

(i) organic tail and

(ii) ionic head

The organic tail gets mixed and dissolved with the dirt or oil or grease and ionic head gets dissolved and mixed with the water. Hence, when the material to be cleaned is removed from the water, the dirt is taken off by the soap molecules present in the water.

Other solvents like C_2H_5OH, in which sodium salt of fatty acids does not get dissolved, hence is not able to form such micelles.

9. Why are carbon and its compounds used as fuels for most applications?

Exp. Carbon and its compounds used as fuels for most applications because of having high calorific values and hence, give out a lot of energy. Most of the carbon compounds when burnt in air, produce a lot of heat and light.

10. Explain the formation of scum when hard water is treated with soap?

Exp. When hard water is teated with soap, scum is produced. Ca and Mg present in the hard water form an insoluble precipitate which is known as scum, when reacts with soap molecules.

11. What change will you observe if you test soap with litmus paper (red and blue)?

Exp. Soap when dissolved in water forms alklaine solution, because of the formation of alkaline NaOH or KOH. Hence, the solution changes the colour of the red litmus to blue, but the blue litmus remains blue in the soap solution.

12. What is hydrogenation? What is its industrial application?

Exp. A chemical reaction between hydrogen and other compounds is known as hydrogenation process. It usually occurs in the presence of catalysts like nickel, palladium or platinum. Hydrogenation process is mainly used to saturate organic compounds. This reaction is widely used in the hydrogenation of vegetable oils in industry.

Vegetable oil contains long unsaturated carbon chains, which are converted into saturated fatty acids (i.e., vegetable ghee).

13. Which of the following hydrocarbons undergo addition reactions: C_2H_6, C_3H_8, C_3H_6, C_2H_2 and CH_4.

Exp. Unsaturated hydrocarbons undergo addition reactions to give saturated hydrocarbons. As, C_3H_6 and C_2H_2 are unsaturated hydrocarbons, hence will undergo addition reactions.

14. Give a test that can be used to differentiate between saturated and unsaturated hydrocarbons.

Exp. Bromine water test can be used to differentiate between the unsaturated compounds and the saturated compounds. In this test, Br is used in the form of bromine water. A solution of Br in water is known as bromine water. Due to the presence of Br, bromine water has a red-brown color. This red-brown colour of bromine water gets discharged, when bromine water is added to an unsaturated compound, as Br gets added to an unsaturated compound. But, saturated compounds do not decolorize bromine water.

Hence, bromine water test can be used to differentiate between the unsaturated compounds (like alkenes and alkynes) and the saturated compounds (like alkanes).

15. Explain the mechanism of the cleaning action of soaps.

Exp. Most dirt is oily in nature, and oil does not get dissolved in water. The molecules of soap are sodium and potassium salts of long-chain carboxylic acids.

The soap molecule has two parts i.e., carbon chain (hydrophobic) and ionic end (hydrophilic). The ionic end of soap dissolves in water while the carbon chain dissolves in oil. Hence, the soap molecules form structures called micelles, where one end of the molecules is towards the oil droplet and ionic end faces outside. This forms an emulsion in water, and soap micelles thus helps in dissolving the dirt in water, hence cleans the clothes when washed..

Subjective Questions

Very Short Answer Type Questions

1. Give reason, why ethanoic acid is used in the preservation of pickles.
2. Draw the electron dot structure for ethene molecule (C_2H_4).
3. Which compound is formed when ethanol is warmed with ethanoic acid in the presence of a few drops of conc.H_2SO_4?
4. What is the difference in the molecular formula of any two consecutive members of a homologous series of organic compounds?
5. Give reason, why washing clothes with hard water is not effective?
6. Name the carbon compound which on heating with excess of conc. H_2SO_4 at 443 K gives ethylene.
7. Write the formula and name of the second member of the series of carbon compounds whose general formula is C_nH_{2n}.
8. What is meant by a saturated hydrocarbon?
9. What will happen if a small piece of sodium is dropped into ethanol?
10. Which two characteristic features of carbon when put together give rise to large number of carbon compounds?
11. Write the valency of each carbon atom in
    (i) an alkane and
    (ii) an alkyne.
12. Write the structural formula of chloroethane.
13. Will a micelle be formed, if soap is dissolved in organic solvent?
14. Give reason, why do alkanes burn with blue flame?
15. Write the names of the given functional groups: (i) —CHO (ii) —COOH

Short Answer Type Questions

1. Name an element, other than carbon, which exhibits property of catenation up to seven or eight atoms. Are these compounds stable?
2. Complete the given reactions
    (i) $CH_4 + O_2 \rightarrow$
    (ii) $CH_3COOH + NaOH \rightarrow$
3. Give reasons, why
    (a) The element carbon forms a very large number of compounds.
    (b) Air holes of a gas burner have to be adjusted when the heated vessels get blackened by the flame.
4. If the name of an organic compound is suffixed with '–ol' and contains two carbon atoms in the molecule, then write the name and molecular formula of that organic compound. What happens when this is heated with excess of conc. H_2SO_4, explain this with the help of a balanced chemical equation.
5. (a) Write chemical name and formula of vinegar?
    (b) What happens when sodium reacts with ethanol? Explain this with the help of chemical equation.
6. What do you understand by homologous series? Which two of the following organic compounds belong to the same homologous? CH_3 ,C_2H_6, C_2H_6O, $C_2H_6O_2$,CH_4O
7. What do you understand by esterification and saponification reactions of organic compounds. Explain this with the help of the chemical equation for each.
8. Name the organic compound which is added to make ethanol unfit for drinking purposes. What is the name of the mixture formed?
9. Explain the hydrogenation process with the help of a suitable example mentioning the conditions of the reaction and also state any one physical property of substances changes due to hydrogenation.
10. (a) Give a chemical test to distinguish between saturated and unsaturated hydrocarbons.
    (b) (i) Name the products formed when C_2H_5OH burns in air. ‘
    (ii) What two forms of energy are liberated on burning C_2H_5OH?

Long Answer Type Questions

1. Identify the compounds 'P' to 'T' in the following sequence:

a. $CH_3CH_2OH \xrightarrow[\text{dil.HCl}]{KMNO_4/KOH} P + H_2O$

b. $CH_3CH_2OH + P \xrightarrow[\Delta]{\text{Conc.}H_2SO_4} Q + H_2O$

c. $Q + NaOH \rightarrow R + CH_3CH_2OH$

d. $P + NaHCO_3 \rightarrow R + S + H_2O$

e. $CH_3CH_2OH + T \rightarrow CH_3CH_2ONa + H_2$

2. Give reasons:

(i) Element carbon forms compounds mainly by covalent bonding.

(ii) Graphite is a good conductor of electricity.

(iii) Diamond has a high melting point.

(iv) Acetylene burns with a sooty flame.

(v) Kerosene does not decolourise bromine water while cooking oils do.

3. What are detergents chemically? Write any two merits and two demerits of using detergents for cleansing. Explain the reason, why detergents are suitable for washing, even in the case of water having calcium and magnesium ions?

4. (a) In tabular form, distinguish between ethanol and ethanoic acid under the following headings:

(i) Physical state

(ii) Smell

(iii) Taste

(iv) $NaHCO_3$ test

(v) Ester test

(b) Write a chemical reaction to show the dehydration of ethanol.

5. Explain

(a) CO_2 is released on burning diamond as well as graphite.

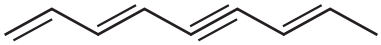
(b) Why does micelle formation take place when soap is added to water? Why are micelles not formed when soap is added to ethyl alcohol?

Integer Type Questions

1. How many hydrogen atoms are present in a molecule of acetylene.

2. Find the number of primary carbon atoms present in 2, 3, 4 – trimethyl pentane.

3. How many ϖ-bonds are present in the following.



4. Find the number of carbon atoms present in the first member of ketone family.

5. Write the degree of the following alcohol 2-methy-2-propanol.

Multiple Choice Questions

Level-I

1. Which among the following will contain covalent double bond between its atoms?

a. H_2 b. O_2

c. KCl d. Cl_2

2. Which among the following can give addition reaction?

a. C_2H_4 b. CH_3OH

c. C_2H_5OH d. $CH_3CH_2CH_3$

3. Select the one, which is not the property of homologous series.

a. They differ by-CH_2 units

b. They differ by 14 units by mass

c. They all contain triple bond

d. They can be represented by a general formula

4. Which of the following property is not shown by carbon?

a. Carbon compounds are good conductor of heat and electricity

b. Carbon compounds are bad conductor of heat and electricity

c. Most of the carbon compounds are covalent compounds

d. Melting and boiling point of carbon compounds are relatively lower than those of ionic compounds

5. In the atmosphere carbon exists in the form of,

a. CO only b. CO in traces and CO_2

c. CO_2 only d. Graphite

6. Which among the following compounds can give addition reaction with chlorine?

a. C_2H_4 b. C_2H_5OH

c. C_3H_8 d. None of these

7. Which among the following is not the use of graphite?

a. Used as lubricant

b. Used in the manufacturing of lead-pencil

c. Used in the manufacturing of artificial diamonds

d. Used for making insulated plates.

8. What happens when bromine water is added to ethene?

a. $CH_2 = CH_2 + Br_2(aq) \longrightarrow Br—CH_2—CH_2—Br$

b. $CH_2 = CH_2 + Br_2(aq) \longrightarrow CH_2=CH—Br$

c. $CH_2 = CH_2 + Br_2(aq) \longrightarrow H_3C—HC(Br)(Br)$

d. None of these

9. Which among the following reactions is known as saponification reaction?

a. $CH_3COOH + C_2H_5OH \longrightarrow CH_3COOC_2H_5 + H_2O$

b. $CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$

c. $CH_3COOC_2H_5 \xrightarrow{NaOH} C_2H_5OH + CH_3COO^-Na^+$

d. $CH_3CH_2OH + [O] \longrightarrow CH_3COOH$

10. Name the allotrope of carbon which is in the form of the geodesic globe.

a. Graphite b. Diamond

c. Fullerene d. Coal

11. Which among the following contains a double bond?

a. H_2 molecule b. CO_2 molecule

c. N_2 molecule d. None of these

12. Because of the presence of double bonds, alkenes are

a. Unsaturated b. Saturated

c. Polar d. Polar-aprotic

13. Which among the following reactions is known as esterification reaction?

a. $CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$

b. $CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$

c. $C_2H_5OH + CH_3COOH \xrightarrow{H^+} CH_3COOC_2H_5 + H_2O$

d. $CH_3COOC_2H_5 + NaOH \rightarrow CH_3COONa + C_2H_5OH$

14. A hydrocarbon should contain at least how many carbon atoms to show isomerism?

a. 2 b. 4

c. 1 d. 6

15. Two carbon atoms when share two electron pairs then they form

a. Single bond b. Double bond

c. Triple bond d. Dative bond

16. When propanoic acid is treated with aqueous sodium bicarbonate, CO_2 is liberated. The 'C' of CO_2 comes from?

a. Methyl group b. Carboxylic acid

c. Alcohol group d. None of these

17. Propane, with the molecular formula C_3H_8 contains:

a. 4 covalent bonds b. 10 covalent bonds

c. 8 covalent bonds d. 15 covalent bonds

18. Sugars are finally converted to ethanol and CO_2 in the presence of enzymes (present in yeast)

a. Invertase, zymase b. Only invertase

c. Only zymase d. None of these

19. Ethylene is produced when

a. Ethanol reacts with ethanoic acid in presence of a few drops of conc. H_2SO_4

b. Ethanol is oxidised with acidified $K_2Cr_2O_7$

c. Ethanol is heated with excess of conc. H_2SO_4 at 443 K

d. Ethanoic acid reacts with sodium carboante

20. Which among the following salts when dissolved in water produce hard water?

a. $CaSO_4$ b. $Mg(HCO_3)_2$

c. $CaCl_2$ d. Any of the above

21. Which among the following is not an example of a saturated hydrocarbon?

a. Cyclohexane b. Benzene

c. Butane d. Propane

22. Benzene molecule is _____ molecule

a. Planar b. Linear

c. Tetrahedral d. Tetragonal bipyramidal

23. An organic compound 'P' with molecular formula $C_2H_4O_2$ turns blue litmus to red and gives brisk effervescence with $NaHCO_3$. Identify the compound

a. Methanoic acid b. Ethanoic acid

c. Propanol d. Butanoic acid

24. When ethanoic acid reacts with ethanol a sweet smelling product is formed. What the functional group of the product formed?

a. Aldehyde b. Carboxylic acid

c. Alcohol d. Ester

25. Vinegar is a solution of

a. 40-50% acetic acid in alcohol

b. 5-8% acetic acid in alcohol

c. 5-8% acetic acid in water

d. 40-50% acetic acid in water

26. Select the pair of isomers.

a. Butane and isobutene

b. Ethane and ethene

c. Methane and ethane

d. Butane and isobutane

27. _____ is added in shaving creams to prevent rapid drying.

a. Methanol b. Glycerol

c. Ethanol d. Propanol

28. During the preparation of soap, NaCl is used as

a. Precipitate the soap b. Dehydration of soap

c. As a catalyst d. None of these

29. Which among the following is an example of aromatic hydrocarbon?

a. C_2H_2 b. C_3H_8

c. C_5H_{12} d. C_6H_6

30. Identify A in the following reaction-

$$CH_3 - CH_2 - OH \xrightarrow[H_2SO_4]{\text{Hot, conc.}} (A) + H_2O$$

a. Ethane b. Methane

c. Ethene d. Ethyne

31. Which among the following is the by-product of soap?

a. Isoprene b. Glycerol

c. Propene d. Ethylene glycol

Level-II

1. A compound Y on treatment with alkaline $KMnO_4$ followed by acidification gives a compound X. Compound X also reacts with compound Y in presence of few drops of H_2SO_4 to form a sweet smelling compound Z. The compound X, Y and Z are, respectively.

a. Ethanoic acid, Sodium ethanoate, Ethane

b. Ethanoic Acid, Ethanol, Ethylethanoate

c. Ethanoic Acid, Ethanal, Ethene

d. Ethanol, Ethanoic Acid, Sodium Ethanoate

2. During laboratory preparation CH_4 gas is collected by downward displacement of water because

a. CH_4 is lighter than Air

b. CH_4 is poisonous gas

c. It does not dissolve in water

d. CH_4 is heavier than Air

3. One mole of a hydrogen X reacted completely with one mole of H_2 gas in the presence of a heated catalyst.

The formula of X could be,

a. CH_4 b. C_5H_{10}

c. C_3H_8 d. C_7H_{16}

4. C^{4+} does not exist but Pb^{4+} exists although both belong to the same group. The reason behind this is:

1. Size of C is much smaller than Pb.
2. Large amount of energy is required in case of carbon.
3. Inert pair effect.
4. None of these

Select the correct statement(s)

a. Only 2 b. 1 and 2

c. Only 3 d. 1, 3 and 4

5. Select the organic compounds, whose both melting and boiling points are either positive or negative values only.

1. Methane 2. Propanol
3. Ethanol 4. Ethanoic acid

a. 1 and 2 b. 3 only

c. 1 and 4 d. 3 and 4

6. Which among the following is an example of substitution reaction?

a. $CH_2 = CH_2 + H_2 \xrightarrow{-hv} CH_3 - CH_3$

b. $CH_3CH_2OH + H_2 \xrightarrow{KMnO_4\,(alk.)} CH_3COOH$

c. $CH_4 + Cl_2 \xrightarrow{hv} CH_3Cl + HCl$

d. $C + O_2 \rightarrow CO_2 +$ heat and light

7. Which of the following statement is incorrect?

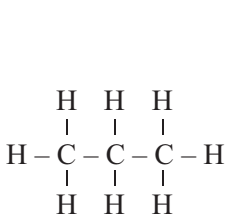
a. C_3H_2 does not have any isomer.

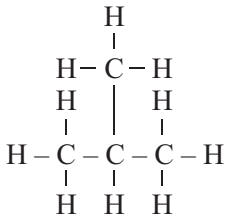
b. $HCOOCH_3$ and CH_3COOH are not same organic compounds.

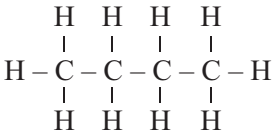
c. Organic compound with formula CH_2O does not exist.

d. C_3H_4 has two π-bonds.

8. The structure of three hydrocarbons are given below.







Select the statement which is correct for all the above three compounds?

a. They are isomers of each other

b. They have the same general formula

c. They have the same physical properties

d. None of these

9. Compound X is a six carbon compound. When it is burnt, light is generated. Because of the presence of carbon particles, the colour of the flame is yellow. Compound X cannot be

a. C_2H_2 b. C_6H_{14}

c. C_6H_6 d. C_7H_{10}

10. In the given sequence of reaction,

$$\text{Ethylene} + \text{Steam} \xrightarrow{\text{Catalyst}} P \xrightarrow[\text{pottasium dichromate}]{\text{Acidified}} Q \xrightarrow{P} R$$

The final product R is?

a. A carboxylic acid b. An alcohol

c. An aldehyde d. An ester

11. The molecular formula of a hydrocarbon is C_6H_{12}. It does not react with H_2 to give C_6H_{14} nor does it react with Cl to give $C_6H_{12}Cl_2$. The hydrocarbon C_6H_{12} is

1. A saturated hydrocarbon
2. A branched hydrocarbon
3. An open chain hydrocarbon
4. A cycloalkane

a. 1 and 2 b. 3 and 4

c. 3 only d. 1 and 4

12. A compound of carbon, hydrogen and nitrogen contains these elements in the ratio of their atomic mass 9 : 1 : 3.5, if its molecular mass is 108 u. Find its molecular formula.

a. C_2H_2N b. C_3H_4N

c. $C_3H_5N_2$ d. $C_6H_8N_2$

13. Consider the given statements about carbon and choose the correct option:

1. It has small atomic size
2. Its boiling & melting point is less as compared to other members of group
3. It exihibits electropositive character
4. It shows maximum tendency of catenation

a. 1 and 2 are correct

b. 2 only

c. 1, 3 and 4 are correct

d. 1 and 4 are correct

14. Which among the following in incorrect?

a. $CH_3—CH_2—\underset{\underset{O}{\|}}{C}—CH_3$ Butanone

b. $CH_3—CH_2—\underset{\underset{H}{|}}{C}=O$ Propanal

c. $CH_3—CH_2—\overset{\overset{O}{\|}}{C}—OH$ Butanal

d. $CH_3—CH_2—CH_2—CH_2—OH$ Butanol

15. Observe the following table carefully

Samples	Hard water	Soap or detergent added	Observation (After shaking 5 minutes)
A	10 mL	Soap (5 drops)	White curd like Scum formed
B	15 mL	Detergent (5 drops)	White curd like Scum is formed
C	8 mL	Soap (5 drops)	Lot of leather is formed
D	12 mL	Detergent (5 drops)	Lot of leather is formed

Which among the given test tubes give correct result?

a. A & B b. C & D

c. A & D d. B & D

16. A hydrocarbon 'X' (C_3H_8) on treatment with chlorine in presence of sunlight yielded compound 'Y' as major product Reaction of 'Y' with aqueous KOH gave 'Z' which on treatment with concentrated H_2SO_4 yielded 'D'. Hydrogenation of 'D' gave back 'X'. The sequence of reactions involved in above consersion is:

a. Addition, dehydration, addition, dehydration

b. Substitution, substitution, dehydration, addition

c. Substitution, dehydration, addition, addition

d. Addition, substitution, dehydration, substitution

17. Consider the following statements related to diamond and graphite.

1. Both diamond and graphite are used as abrasives.
2. Graphite and diamond have different arrangements of carbon atoms.
3. Number of neutrons present in the carbon atoms in graphite are different from those in diamond.
4. The carbon atoms in both graphite and diamond have 4 single covalent bonds.

Select the incorrect statement(s).

a. 1 and 3 b. 2 only

c. 1, 3 and 4 d. All of these

Assertion & Reason Type Questions

Direction: In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice.

a. Both assertion and reason are true and Reason is the correct explanation of Assertion.

b. Both assertion and reason are true but reason is not the correct explanation of Assertion.

c. Assertion is true but reason is false.

d. Assertion is false but reason is true.

1. Assertion: Graphite is slippery to touch.

Reason: In graphite, the various layers of carbon atoms are held together by weak van der waal's forces of attraction.

2. Assertion: Propane (C_3H_8) is the third member of alkane.

Reason: It is obtained from general formula C_nH_{2n+2}.

3. Assertion: CH_3Cl is obtained from CH_4 by the action of Cl_2 in the presence of sunlight.

Reason: It is obtained by addition reaction.

4. Assertion: Isopropyl bromide is formed, when propene reacts with HBr.

Reason: Addition of Br_2 to alkene takes place faster in presence of ionizing substance.

5. Assertion: In esterification reaction, carboxylic acid and alcohol reacts in the presence of acid to give ester.

Reason: Esterification is the reverse of saponification.

Case-Based Type Questions

Case-Based-I: An organic compound 'X' is an essential component of wine and beer. Compound 'X' on oxidation gives an organic acid 'Y' which is present in vinegar. Compound 'X' and organic acid 'Y' react together in the presence of an acid catalyst, to give a compound 'Z'.

1. The compound 'X' is,
   a. Methanol b. Ethanol
   c. Propanol d. Propanal
2. The formed compound 'Y' is,
   a. Acetic acid b. Propanoic acid
   c. Ethanol d. Methanol
3. Write structural formula of 'Z'
   a. CH_3COONa b. $CH_3COOC_2H_5$
   c. $CH_3CH_2COOCH_3$ d. CH_3CH_2OH

Case-Based-II: Compound 'X' works well with hard water. It is used for making shampoos & products for cleaning clothes. Compound 'X' is not 100% biodegradable and causes water pollution. Compound 'Y' does not work well with hard water and it is 100% biodegradable and does not cause water pollution.

1. Identify compound 'X'.
   a. Detergent b. Soap
   c. Washing soda d. Baking soda
2. Identify Y.
   a. Washing soda b. Soap
   c. Detergent d. Sulfates

Case-Based-III: The molecular formula of an organic compound 'X' is C_2H_6O, it is an active ingredient of all alcoholic drinks. It is also used in medicines such as tincture iodine, cough syrups. A small piece of Na is dropped into the test tube containing 'X'. A new compound 'Y' is formed with the evolution of colorless and odorless gas .

1. Identity the compound 'X'
   a. Ethanol b. Ethanoic acid
   c. Methanol d. Diethylether
2. Identify the compound 'Y'
   a. CH_3COOH b. CH_3CH_2OH
   c. CH_3CH_2ONa d. $CH_3CH_2CH_2ONa$
3. Name the gas evolved with compound 'Y'
   a. H_2 b. CO_2
   c. Cl_2 d. N_2

Case-Based-IV: The molecular formula of an organic compound 'P' is C_2H_6O, which is used as an antifreeze. Compound 'P' on oxidation gives a compound 'Q' which gives effervescence on treatment with a baking soda solution.

1. Identify compound 'P'
   a. Methanol b. Ethanol
   c. Ethanoic acid d. Ethyl methyl ester
2. Identify compound 'Q'.
   a. Propanoic acid b. Ethanoic acid
   c. Methanol d. Pentanol
3. Which gas is formed when Q reacts with baking soda solution ?
   a. Nitrogen b. Hydrogen
   c. Carbon dioxide d. chlorine

Multi Correct MCQ's

1. A molecule of acetic acid contains
   a. One double bond b. One π-bond
   c. Seven σ bonds d. Six π-bonds
2. Functional group – CHO represents
   a. An aldehyde group
   b. An alcohol group
   c. A carbonyl family group
   d. An ether group
3. An alcohol can directly be converted into carboxylic acid in the presence of
   a. Chromic anhydride
   b. Alkaline $KMnO_4$
   c. Concentrated HCl
   d. Acidified $K_2Cr_2O_7$
4. Dehydration of an alcohol involves
   a. Reaction of alcohol in the presence of conc. H_2SO_4
   b. Formation of H_2O molecule
   c. Formation of an alkene
   d. Formation of an alkyne
5. Which among the following is true for CH_4 (methane)?
   a. Polar in nature b. Non-polar
   c. Saturated d. None of these

Olympiad & NTSE Type Questions

1. Select the correct statement/s regarding CO_2
   I. It is prepared on large scale by the action of water on lime.
   II. In the solid form it can be used as a refrigerant.
   Select the correct answer using the code given below:
   a. I only b. II only
   c. Both I and II d. None of these

2. Which one of the following statement is incorrect about graphite and diamond? **[NTSE 2017]**

a. Graphite is smooth and slippery.

b. Graphite is a good conductor of electricity.

c. Diamond is good conductor

d. Physical and chemical properties of graphite and diamond are different.

3. Consider the following statements regarding diamond and graphite:

I. Diamond and graphite are isotopes of carbon.

II. C-C bond length in diamond is greater than that in graphite.

III. Graphite is poor conductor of electricity than diamond

Select the correct statement/s

a. I and II b. Only III

c. Only II d. I, II and III

4. The total number of electrons and the number of electrons involved in the formation of various bonds present in one molecule of propanal (C_2H_5CHO) are respectively. **[NTSE 2015]**

a. 24 and 18 b. 24 and 20

c. 32 and 20 d. 32 and 18

5. Acetic acid was added to $NaHCO_3$ solution and the gas evolved was tested with a burning candle. Four observations were reported as follow:

I. The evolved gas burns with the pop sound and the flame gets extinguished.

II. The gas does not burn but the candle burns with a pop sound.

III. The flame extinguishes and the gas does not burn.

IV. The gas burns with a red flame and the candle burns brightly.

The correct observations is reported in

a. I b. II

c. III d. I and II

6. The number of structural isomers of the compound having molecular formula C_4H_9Br is **[NTSE 2015]**

a. 3 b. 5

c. 2 d. 4

7. Consider the following statements:

Soap does not form lather with hard water because hard water contains:

A. Sodium chloride

B. Magnesium bicarbonate

C. Chlorides of calcium and magnesium

D. Sulphates of calcium and magnesium

Which of these statements are correct?

a. B and C b. C and D

c. A, B and C d. All are correct

8. On washing with soap, a turmeric stain on the cloth turns to red because **[NTSE 2011]**

A. Soap solution is alkaline.

B. Soap solution is acidic.

C. Turmeric contains a natural indicator.

D. Turmeric contains litmus

Select the correct alternative.

a. A and C b. B and D

c. C and B d. A and D

9. Percentage of nitrogen present in urea (NH_2CONH_2) is

a. 46.7% b. 31.6%

c. 69.9% d. 11.66%

10. A compound 'X' reacts with a compound 'Y', to produce a colourless and odourless gas. The gas turns lime water milky. When 'X' reacts with methanol in the presences of concentrated H_2SO_4, a sweet smelling substance is produced. The molecular formula of the compound 'X' is- **[NTSE 2017]**

a. C_2H_4O b. $C_2H_4O_2$

b. C_2H_6O c. $C_2H_6O_2$

11. An organic compound is a clear liquid having a molecular formula C_4H_8O. It has an open chain structure. Without any carbon-carbon double bond. The compound can be **[NTSE 2014]**

(A) an alcohol (B) an ester

(C) an aldehyde (D) a ketone

a. (A) and (B) b. (C) and (D)

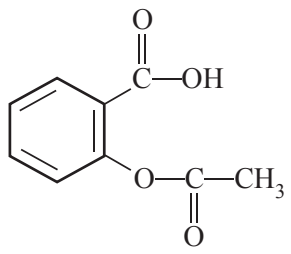
c. (B) and (D) d. (D) and (A)

12. The molecular formula of carboxylic acid that differs from the rest is **[NTSE 2016]**

a. $C_{13}H_{26}O_2$ b. $C_7H_{12}O_2$

c. $C_9H_{18}O_2$ d. $C_2H_4O_2$

13. The functional groups present in the following compound are- **[NTSE 2017]**



a. Alcohol, ketone and ester

b. Ester and carboxylic acid

c. Carboxylic acid and ketone

d. Ester and alcohol

14. How many grams of oxygen gas will be needed for complete combustion of 2 moles of 3rd member of alkyne series? **[NTSE 2018]**

a. 186 g b. 256 g

c. 352 g d. 372 g

15. An organic liquid 'P' with acidified potassium dichromate gave product 'Q'. The compound 'Q' on when heated with methanol in presence of conc. H_2SO_4 formed compound 'R' which on subsequent treatment with NaOH formed two product 'D' and 'E'. The product 'D' is known to affect the optic nerve causing blindness. Intake of 'D' even in very small amount can cause death. What are compound 'P', 'Q', 'R', 'D' and 'E'? **[NTSE 2018]**

a. P = Ethanol, Q = Ethanoic acid, R = Methanol, D = Sodium acetate, E = Methyl ethanoate

b. P = Ethanol, Q = Ethanoic acid, R = Methyl ethanoate, D = Methanol, E = Sodium acetate

c. P = Sodium acetate, Q = Ethanoic acid, R = Methyl ethanoate, D = Methanol, E = Ethanol

d. P = Methanol, Q = Ethanoic acid, R = Methyl ethanoate, D = Sodium acetate, E = Propanol

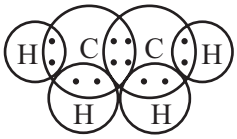
Explanations

Subjective Questions

Very Short Answer Type Questions

1. Ethanoic acid is used in the preservation of pickles, as it provides an acidic environment where bacteria cannot survive, hence, it preserves the pickles for a longer time.

2.



Ethene (C_2H_4)

3. Ethyl ethanoate.

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Ethanol}}{C_2H_5OH} \xrightarrow{\text{Conc. } H_2SO_4} CH_3COOC_2H_5 + \underset{\text{Water}}{H_2O}$$

4. The difference in the molecular formula of any two consecutive members of a homologous series of organic compounds is —CH_2 unit.

5. Hard water contains calcium and magnesium salts. Soap reacts with Ca^{2+} and Mg^{2+} ions present in hard water to form scum. Hence, washing clothes with hard water is not effective.

6. Ethanol

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[443K]{\text{Conc.}H_2SO_4} \underset{\text{Ethene}}{CH_2 = CH_2} + H_2O$$

7. C_3H_6, H_2C=CH—CH_3

Propene is the second member of series of carbon compounds whose general formula is C_nH_{2n}.

8. Saturated hydrocarbons are the compounds in which valency of carbon is satisfied by single bonds only.

9. H_2 gas will be evolved.

$2C_2H_5OH(l) + 2Na(s) \rightarrow 2C_2H_5ONa(l) + H_2(g)$

10. Carbon forms a large number of compounds, because of having the following two characteristics,

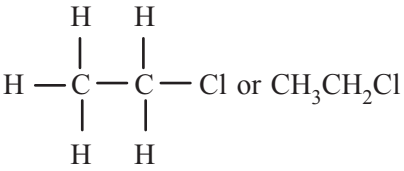
(i) Catenation

(ii) Tetravalency of carbon

11. (i) The valency of 'C' in alkane is 4.

(ii) The valency of 'C' in alkyne is also 4.

12.



13. No, micelle will not be formed if soap is dissolved in organic solvent.

14. Alkanes have less carbon and more hydrogen, hence, they undergo complete combustion and produce blue flame.

15. (i) Aldehyde group (ii) Carboxylic acid group

Short Answer Type Questions

1. Silicon (Si) and Sulphur (S_8)

No, these compounds are not stable.

2. (i) $CH_4 + 2O_2 \rightarrow CO_2(g) + 2H_2O(l)$

(ii) $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

3. (a) As, carbon is small in size and can form stable covalent bonds (catenation) and also it shows tetravalency, hence carbon forms large number of compounds.

(b) Air holes of gas burner need to be adjusted so that air can pass through, which is required for complete combustion, so that heated vessels do not get blackened by the flame.

4. The given organic compound is ethanol, its molecular formula is C_2H_5OH.

Ethanol when heated with conc. H_2SO_4 forms ethene.

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[\text{heat}]{\text{Conc. } H_2SO_4} \underset{\text{Ethene}}{CH_2 = CH_2} + H_2O$$

5. (a) Vinegar contains acetic acid.

Formula:

$$CH_3 - \overset{\overset{O}{\|}}{C} - OH$$

(b) Ethanol reacts with sodium to give sodium ethoxide and hydrogen gas .

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

6. Homologous series is a series of organic compounds which differ in number of carbon atoms but have same functional group and similar chemical properties. Compounds of this series differs by $-CH_2-$ in its molecular formula and 14u in its molecular mass.

Among the given organic compounds, $C_2H_6O(C_2H_5OH)$ and $CH_4O(CH_3OH)$ belongs to same homologous series.

7. Esterification: Esterification is a process in which alcohol and carboxylic acid react together in the presence of an acid catalyst to give an ester.

$$\underset{\text{Ethanoic Acid}}{CH_3COOH} + \underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow{\text{Conc. } H_2SO_4} CH_3COOC_2H_5 + H_2O$$

Ethyl ethanoate

Saponification: Saponification is the process, in which an ester reacts with sodium hydroxide to give sodium salt of acid and alcohol.

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

8. Methanol (poisonous substance) is added to make ethanol unfit for drinking purpose. And, the mixture so formed is known as methylated spirit or denatured alcohol

9. Hydrogenation is a process in which unsaturated hyrocarbons react with hydrogen in the presence of catalyst like Ni or Pd to form saturated compounds.

$$R-\underset{R}{C}=\underset{R}{C}-R + H_2 \xrightarrow[\text{Heat}]{\text{Ni}} R-\overset{H}{\underset{R}{C}}-\overset{H}{\underset{R}{C}}-R$$

Necessary conditions for the reaction are:

(a) Presence of an unsaturated hydrocarbon.

(b) Presence of a catalyst like nickel (Ni) or palladium (Pd).

Liquid oil changes to solid ghee.

10. (a) Bromine water test.

After addition of bromine water, unsaturated hydrocarbons will decolourise bromine water whereas saturated hydrocarbon will not decolorize it.

(b) (i) CO_2 and H_2O are formed

$$C_2H_5OH\ (l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) + \text{Heat} + \text{Light}$$

(ii) Heat energy and light energy

Long Answer Type Questions

1.

(a) $CH_3CH_2OH \xrightarrow[\text{Dil.HCl}]{KMnO_4/KOH} \underset{\text{'P'}}{CH_3COOH} + H_2O$

(b) $CH_3CH_2OH + \underset{\text{'P'}}{CH_3COOH} \xrightarrow[\Delta]{\text{Conc. } H_2SO_4} \underset{\text{'Q'}}{CH_3COOCH_2CH_3} + H_2O$

(c) $\underset{\text{'Q'}}{CH_3COOCH_2CH_3} + NaOH \longrightarrow \underset{\text{'R'}}{CH_3COONa} + CH_3CH_2OH$

(d) $CH_3COOH + NaHCO_3 \rightarrow \underset{\text{'R'}}{CH_3COONa} + \underset{\text{'S'}}{CO_2} + H_2O$

(e) $2CH_3CH_2OH + \underset{\text{'T'}}{2Na} \longrightarrow 2CH_3CH_2ONa + H_2$

Hence, 'P' is CH_3COOH, 'Q' is $CH_3COOCH_2CH_3$, 'R' is CH_3COONa, 'S' is CO_2, and 'T' is Na (Sodium metal)

2. (i) As, carbon has 4 valence electrons, it cannot gain or lose 4 electrons because high amount of energy is required. Hence, it can only share four electrons.

(ii) In graphite, each carbon is linked to three more carbon atoms. Hence, it is a good conductor of electricity due to the presence of free electrons.

(iii) Because of strong covalent bonds and compact structure of diamond it has high melting point.

(iv) Acetylene burns with sooty flame, because it contains high percentage of carbon.

(v) Kerosene oil contains saturated hydrocarbons hence, it does not decolourise bromine water while cooking oil contains unsaturated hydrocarbons and therefore decolourises bromine water.

3. Detergents are ammonium or sulphonate salts of long chain carboxylic acid.

Merits:

(i) Detergents can even work well in hard water.

(ii) They are more effective than soaps.

Demerits:

(i) They are expensive than soaps.

(ii) Some of them having branched hydrocarbons are non-biodegradable.

Detergents are suitable for washing even in hard water having Mg^{2+} and Ca^{2+} ions because they do not form insoluble precipitates with the calcium and magnesium ions.

4. (a)

Properties	Ethanol	Ethanoic Acid
Physical State	Colorless liquid	Colorless liquid
Smell	Pleasant smell.	Vinegar like smell.
Taste	Burning taste.	Sour taste
$NaHCO_3$ test	No reaction	Produce brisk effervescence due to CO_2
Ester test	Ethanol reacts with acetic acid in the presence of conc. H_2SO_4 to form fruity smelling compound, ester.	Ethanoic acid reacts with ethyl alcohol in the presence of conc. H_2SO_4 to form fruity smelling compound, ester.

(b) $\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[443K]{\text{Conc. } H_2SO_4} \underset{\text{Ethene}}{CH_2=CH_2} + H_2O$

5. (a) Diamond and graphite are both allotropes of carbon element. They have different physical properties due to the difference in their structure, but the chemical properties remain the same. As, we know that, when carbon is burnt in the presence of oxygen it produces carbon dioxide (CO_2). As, diamond and graphite both are chemically carbon, hence, both release CO_2 upon burning.

(b) Micelle formation takes place when soap is added to water, this is because large number of molecular ions of soaps get accumulated and form colloidal solution. Soap consists of hydrophobic tail (hydrocarbon) which dissolves in hydrocarbon part and hydrophilic part (ionic end) which dissolves in water. Ethyl alcohol is non-polar solvent, hence micelles are not formed because hydrocarbon part gets attracted towards ethyl alcohol and ionic end will not dissolve in ethyl alcohol.

Integer Type Questions

1. 2

Chemical formula of acetylene is C_2H_2. Hence, 2 hydrogen atoms are present in a molecule of acetylene.

2. 5

Carbon atom which is attached to only one other carbon atom is known as primary carbon atom. Hence, in the given compound, there are 5 primary carbon atoms present.

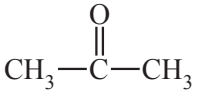
3. 5

5 double bonds are present in the given compound.

4. 3

There are three carbon atoms present in the first member of ketone series.

It is propanone



5. 3

2-Methyl-2-propanol or tert-butyl alcohol, or t-butyl alcohol or tert-butanol, is a three-carbon chain, having the OH group and a methyl group on the middle carbon

Multiple Choice Questions

Level-I

1. **(b)** Oxygen atom contains six valence electrons. Hence, in order to complete its octet it forms double bond (=) with another oxygen atom to obtain O_2 molecule.

2. **(a)** Presence of unsaturated hydrocarbon is the necessary condition to show addition reaction. Hence, among the given options, only $C_2H_4(CH_2=CH_2)$ can show the addition reaction

3. **(c)** They all contain triple bond.

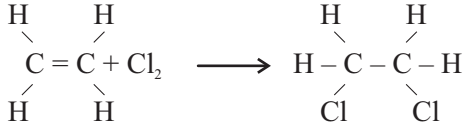
It's not necessary that compounds of a homologous series must contain the triple bond.

4. **(a)** Carbon compounds are good conductor of heat and electricity.

As, carbon compounds are covalently bonded hence, they are bad conductor of heat and electricity. Because of the presence of covalent bonds, their melting and boiling points are relatively lower than those of ionic compounds.

5. **(c)** In the atmosphere carbon exists in the form of CO_2 in air (only 0.03%).

6. **(a)** Presence of unsaturated hydrocarbon is the necessary condition to show addition reaction. Hence, compounds with general formula C_nH_{2n} or C_nH_{2n-2} can show addition reaction with chlorine. therefore, among the given options only C_2H_4 (C_nH_{2n}) gives an addition reaction with chlorine..



7. **(d)** It is used for making insulated plates.

As, graphite is a good conductor of electricity, hence it can not be used for making insulated plates.

8. **(a)** $CH_2 = CH_2 + Br_2(aq) \longrightarrow Br—CH_2—CH_2—Br$
(1, 2-Dibromoethane)

9. **(c)** $CH_3COOC_2H_5 \xrightarrow{NaOH} C_2H_5OH + CH_3COO^-Na^+$

10. **(c)** C_{60} (fullerene) is the allotrope of carbon which resembles the form of a geodesic dome (football).

11. **(b)** As, the structure of CO_2 molecule is:
O = C = O
Hence, CO_2 molecule contains 2 double bonds.

12. **(a)** Presence of double bond makes the hydrocarbon unsaturated

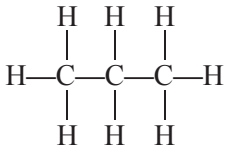
13. **(c)** $C_2H_5OH + CH_3COOH \xrightarrow{H^+} CH_3COOC_2H_5 + H_2O$

14. **(b)** A hydrocarbon should contain at least 4 carbon atoms to show isomerism.

15. **(b)** A double bond is formed by sharing of two electron pairs between two carbon atoms.

16. **(b)** $CH_3CH_2COOH + NaHCO_3 \rightarrow CH_3CH_2COONa + H_2O + CO_2 \uparrow$
Evolution of CO_2 indicates that carboxylic acid contains carboxyl group.

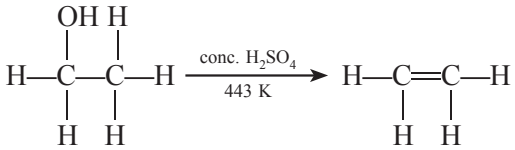
17. **(b)**



(10 covalent bonds)
Hence, propane contains 10 covalent bonds.

18. **(a)** Sugars are finally converted to ethanol and CO_2 in the presence of both invertase and zymase enzymes. And, these enzymes are present in yeast.

19. **(c)**



(Ethyl alcohol) (Ethene)

20. **(d)** Presence of Ca^{+2} and Mg^{+2} in the form of chlorides, sulphates and bicarbonates salts, causes the hardness of water.

21. **(b)** Benzene is not a saturated hydrocarbon, as it contains double bond.

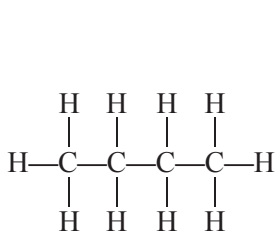
22. **(a)** All six carbon atoms in benzene have sp^2 hydridisation, which makes it to be planar hexagonal in shape.

23. **(b)** The molecular formulae of given compounds are:
methanoic acid, HCOOH i.e., CH_2O_2
ethanoic acid, CH_3COOH i.e., $C_2H_4O_2$
propanol, C_3H_7OH i.e., C_3H_8O
butanoic acid, C_3H_7COOH i.e., $C_4H_8O_2$
As, 'P' is acidic in nature. Brisk effervescence with $NaHCO_3$ shows CO_2 as one of the products. The molecular formula of 'P' contains 2 oxygen atoms.

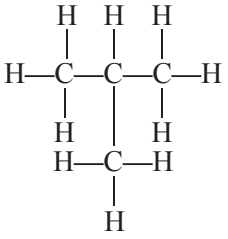
24. **(d)** ethanoic acid + ethanol → ethyl acetate + H_2O

25. **(c)** Vinegar is a solution of 5-8% of acetic acid in water

26. **(d)** Among the given options, butane and isobutane are isomers, as they have same chemical formula but different arrangement of atoms and have different structure.



(Butane)



(Isobutane)

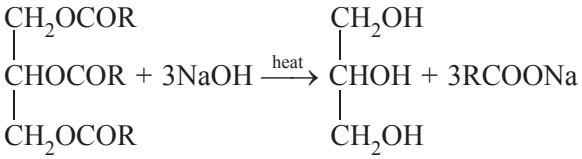
27. **(b)** In shaving creams, glycerol is added to prevent rapid drying.

28. **(a)** During the preparation of soap, NaCl is used for the precipitation of soap to separate out soap from the solution.

29. **(d)** C_6H_6 (benzene) belongs to aromatic hydrocarbons.

30. **(c)** $CH_3 - CH_2 - OH \xrightarrow[H_2SO_4]{Hot,\ conc.} \underset{(Ethene)}{CH_2 = CH_2} + H_2O$

31. **(b)** Soap is made by heating triesters of glycerol (oils or fats) with alkalies like NaOH or KOH. Glycerol is formed as the by product of soap.



(Present in oil or fat) Glycerol

Level-II

1. **(b)** As a sweet smelling compound Z is formed, hence this characteristic of compound Z shows that it is an ester which is formed by the reaction of an alcohol with a carboxylic acid in the presence of conc. H_2SO_4. Also, X is formed by acidification of compound Y, therefore Y should be an alcohol, X should be a carboxylic acid.

$$\underset{\substack{(Y)\\Ethanol}}{C_2H_5OH} \xrightarrow[KMnO_4]{alkaline} \underset{\substack{(X)\\Ethanoic\ acid}}{CH_3COOH}$$

$$\underset{(Y)}{C_2H_5OH} + \underset{(X)}{CH_3COOH} \xrightarrow[H_2SO_4]{Conc.} \underset{\substack{Z\\Ethylethanoate\\(ester)}}{CH_3COOC_2H_5}$$

2. **(c)** CH_4 does not get dissolved in water, because it is a non-polar compound.

3. (b) As, the compound reacts completely with one mole of H_2; hence X should be an alkene with one degree of unsaturation. As we know that, the general fomula of alkenes is C_nH_{2n}.

If n = 5, C_5H_{10}

Hence, X is C_5H_{10}.

4. (b) Size of carbon is much smaller as compared to Pb. And, a large amount of energy is required to remove 4 electrons from a nucleus containing 6 protons.

5. (c) Methane has negative melting and boiling point.

And, ethanoic acid has positive melting and boiling point.

6. (c) $CH_4 + Cl_2 \xrightarrow{hv} CH_3Cl + HCl$

Those reactions in which one atom or group of atoms of a compound is replaced by some other atom or group of atoms, is known as substitution reaction.

7. (c) CH_2O is the chemical formula of formaldehyde (HCHO).

8. (b) They have the same general formula

The given compounds contain only C – H and C – C single bonds and therefore, belongs to the same homologous series, hence, their general formula is same.

The given compounds belong to alkane series, whose general formula is C_nH_{2n+2}

9. (b) As, C_6H_{14} is saturated hydrocarbon, and colour of the flame during the combustion of saturated hydrocarbon will be blue. Hence, C_6H_{14} cannot be X.

10. (d)

Ethylene ($CH_2 = CH_2$) + Steam (H_2O) $\xrightarrow{\text{Catalyst}}$ C_2H_5OH Ethanol (P)

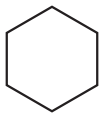
Ethanol (P) $\xrightarrow{\text{Acidified potassium dichromate (VI)}}$ CH_3COOH Ethanoic Acid (Q)

CH_3COOH Ethanoic Acid (Q) $\xleftarrow[(P)]{C_2H_5OH}$ $CH_3COOC_2H_5$ Ethyl acetate (Ester) (R)

11. (d) The molecular formula of hydrocarbon is C_6H_{12}, which can be an unsaturated, saturated, or cyclic hydrocarbon. As, the compound does not react with hydrogen and Cl to give C_6H_{14} and $C_6H_{12}Cl_2$, respectively. Hence, it can't be an unsaturated hydrocarbon.

Now, as the molecular formula does not satisfy general molecular formula of C_nH_{2n+2}, hence, it cannot be an open chain hydrocarbon too.

The given molecular formula satisfies with cyclohexane and cyclohexane is a saturated hydrocarbon.



(C_6H_{12})

Hence, both (1) and (4) are correct statements.

12. (d) $C_6H_8N_2$ i.e. $12 \times 6 + 8 \times 1 + 14 \times 2 = 108$ u.

13. (d) Carbon has small atomic size and it shows maximum catenation property.

14. (c) $CH_3—CH_2—\overset{\overset{O}{\|}}{C}—OH$

(Propanoic acid)

15. (c) Soaps do not form lather in hard water, it forms white scum. Detergent forms lather easily even with hard water.

16. (b) C_3H_8(X) is propane.

(i) $\underset{(X)}{CH_3CH_2CH_3} + Cl_2 \xrightarrow{\text{Sunlight}} \underset{(Y)}{CH_3CH_2CH_2Cl} + HCl$ (Substitution)

(ii) $\underset{(Y)}{CH_3CH_2CH_2Cl} + \text{aq. KOH} \longrightarrow \underset{(Z)}{CH_3CH_2CH_2OH} + KCl$ (Substitution)

(iii) $\underset{(Z)}{CH_3CH_2CH_2OH} \xrightarrow{\text{conc. } H_2SO_4} \underset{(D)}{CH_3CH = CH_2} + H_2O$ (Dehydration)

(iv) $\underset{(D)}{CH_3CH = CH_2} + H_2 \xrightarrow{Ni/Pt/Pd} \underset{(X)}{CH_3CH_2CH_3}$ (Addition)

17. (c) Graphite and diamond have different arrangement of carbon atoms. Diamond has tetrahedral arrangement whereas graphite has a hexagonal planar arrangement of carbon atoms. In both cases, C – C bond covalent.

Diamond is used as an abrasive, while graphite does not. Diamond and graphite do not differ in the nature of carbon atoms, therefore, the number of neutrons present in carbon atoms in both graphite and diamond are the same. In diamond, each carbon is covalently bonded to 4 other carbon atoms, while in graphite each carbon atom is joined to three other carbon atoms.

Assertion & Reason Type Questions

1. **(a)** In graphite, each carbon atom is joined to three other atoms by strong covalent bonds. The various layers of carbon atoms in graphite though have weak vander wall's forces of attraction between them, hence making them slippery to touch.
2. **(a)** C_3H_8 (propane) can be obtained from general formula C_nH_{2n+2}.
3. **(c)** CH_3Cl can be obtained from CH_4 (methane) by substitution reaction by the action of Cl_2 in the presence of sunlight.

   $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ (in the presence of sunlight)
4. **(c)** Addition of HBr to propene will take place according to Markownikoff's rule. The negative part of the addendum goes to less hydrogenated carbon atom.

   $$CH_3CH{=}CH_2 + HBr \longrightarrow \underset{\text{Isopropyl bromide}}{CH_3 - \underset{\displaystyle Br}{\underset{|}{CH}} - CH_3}$$

   And, the reason is false because the rate of addition of Br_2 to alkenes is enhanced, if addition takes place in presence of organic solvent like CCl_4 or in the presence of covalent compounds nor ionic compounds
5. **(c)** In esterification reaction, carboxylic acid reacts with alcohol in the presence of an acid catalyst to give a fruity smelling compound, ester. The alkaline hydrolysis of ester is known as saponification reaction. Hence, esterification is not reverse of saponification

Case-Based Type Questions

Case-Based-I

1. **(b)** ethanol
2. **(a)** acetic acid
3. **(b)** 'Z' is ethyl ethanoate $CH_3COOC_2H_5$

   'X' is ethanol (C_2H_5OH) which is essential component of wine and beer and 'Y' is acetic acid (CH_3COOH) which is present in vinegar.

   $$\underset{\substack{\text{(Present in wine and beer)}\\ \text{'X'}}}{CH_3CH_2OH} + 2[O] \xrightarrow[\text{Oxidation}]{\text{Alkaline } KMnO_4} \underset{\substack{\text{Acetic Acid}\\ \text{(Present in vinegar)}\\ \text{'Y'}}}{CH_3COOH} + H_2O$$

   'X' and 'Y' react together in the presence of an acid catalyst to give ethyl ethanoate.

   $$\underset{\text{'Y'}}{CH_3COOH}(l) + \underset{\text{'X'}}{C_2H_5OH}(l) \xrightarrow{\text{conc. } H_2SO_4}$$

   $$\underset{\text{'Z'}}{CH_3COOC_2H_5}\ (l) + H_2O(l)$$

Case-Based-II

1. **(a)** X is detergent.
2. **(b)** Y is soap

Case-Based-III

1. **(a)** ethanol
2. **(c)** CH_3CH_2ONa
3. (a) H_2

   $$2Na + 2\underset{\text{'X'}}{CH_3CH_2OH} \longrightarrow \underset{\substack{\text{Sodium ethoxide}\\ \text{'Y'}}}{2CH_3CH_2O^-Na^+} + H_2 \uparrow$$

Case-Based-IV

1. **(b)** ethanol
2. **(b)** ethanoic acid
3. **(c)** Carbon dioxide

   $$\underset{\text{'P'}}{C_2H_5OH} \xrightarrow{\text{oxidation}} \underset{\text{'Q'}}{CH_3COOH}$$

   $$NaHCO_3 + \underset{\text{(Q)}}{CH_3COOH} \rightarrow CH_3COONa + CO_2 \uparrow + H_2O$$

Multi Correct MCQs

1. **(a, b, c)** A molecule of acetic acid (CH_3COOH) contains 7 σ-bonds and 1 π-bond (in between oxygen and carbon).
2. **(a, c)** Functional group –CHO represents an aldehyde group. Both aldehydes and ketones contain a carbonyl group.
3. **(b, d)** Primary alcohols on oxidation give carboxylic acids using potassium dichromate(VI) solution in the presence of dilute H_2SO4 or alkaline $KMnO_4$.
4. **(a, b, c)** Three-step mechanism is followed in dehydration of alcohols, which are:

   Formation of protonated alcohol.

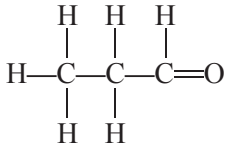
   Carbocation formation

   Alkenes formation
5. **(b, c)** CH_4 (methane) molecule is an example of a hydrophobic group which is non-polar. CH_4 is also a saturated molecule.

Olympiad & NTSE Type Questions

1. **(c)** In the solid form, carbon dioxide can be used as a refrigerant under the commercial name tricol.
2. **(c)** Diamond does not conduct electricity, hence it is poor conductor of electricity.
3. **(c)** Diamond and graphite are the two allotropes of carbon. The carbon-carbon (C—C) bond length in graphite is shorter (142 pm) than the carbon-carbon (C–C) bond length of diamond (154 pm).

4. (c)



Propanal

Number of electrons in 1 C atom = 6

Total no. of electrons in 3 C atoms = 3 × 6 = 18

Total no. of electrons of O atom = 1 × 8 = 8

Number of electrons in 1 H atom = 1

Total no. of electrons in 6 H atoms = 6 × 1 = 6

Total no. of electrons in one molecule of propanal

= 18 + 8 + 6 = 32 electrons

Total no. of bonds = 10

As, each bond contains $2e^-$. Hence, number of electrons involved in bonding.

= 2 × 10 = 20 electrons.

5. (c) When acetic acid reacts with $NaHCO_3$ solution, CO_2 gas is evolved, which is neither combustible nor a supporter of combustion. Hence, the gas does not burn and the flame gets extinguished.

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

6. (d) Structural isomers of compound C_4H_9Br are:

(i) $CH_3CH_2CH_2CH_2—Br$

1-Bromobutane

(ii) $CH_3—\underset{\displaystyle Br}{\underset{|}{CH}}—CH_2—CH_3$

2-Bromobutane

(iii) $\begin{matrix} & CH_3 & \\ & | & \\ CH_3— & CH & —CH_2—Br \end{matrix}$

1-Bromo-2-methyl propane

(iv) $\begin{matrix} & CH_3 & \\ & | & \\ CH_3— & CH & —CH_3 \\ & | & \\ & Br & \end{matrix}$

2-Bromo-2-methyl propane

7. (b) Soap does not form lather with hard water because hard water contains soluble chloride and sulphate salts of Ca and Mg which forms insoluble curdy precipitate.

$$\underset{\text{Sodium stearate (soap) (soluble)}}{2C_{17}H_{35}COONa} + \underset{\text{calcium chloride (in hard water)}}{CaCl_2} \longrightarrow \underset{\text{Calcium stearate (Insoluble)}}{(C_{17}H_{35}COO)_2\,Ca} + 2NaCl$$

$$\underset{\text{sodium stearate (soluble)}}{2C_{17}H_{35}COONa} + \underset{\text{magnesium sulphate (in hard water)}}{MgSO_4} \longrightarrow \underset{\text{Magnesium stearate (soap) (Insoluble)}}{(C_{17}H_{35}COO)_2\,Mg} + Na_2SO_4$$

8. (a) As turmeric is a natural indicator, hence, it gets turned red in basic solution but in acidic solution it remains yellow.

9. (a) NH_2CONH_2 → Molecular mass of urea = 60

Molecular mass of N_2 = 28

% of N = (28/60) × 100

= 46.7%

10. (b) X reacts with Y to give colourless and odourless gas

$$\underset{\text{(Acetic acid) (X)}}{CH_3COOH} + \underset{\text{(Y)}}{NaHCO_3} \rightarrow CH_3COONa + CO_2 \uparrow + H_2O$$

$$CO_2 \uparrow + \underset{\text{(lime water)}}{Ca(OH)_2} \rightarrow \underset{\text{(Milky water)}}{CaCO_3} + H_2O$$

$$\underset{\text{(X)}}{CH_3COOH} + CH_3OH \xrightarrow[H_2SO_4]{} \underset{\text{Ester}}{CH_3COOCH_3} + H_2O$$

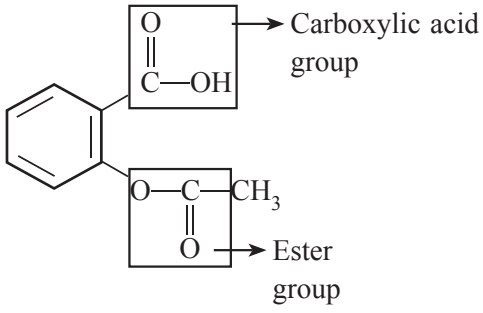
Thus, compound (X) is acetic acid

11. (b) Molecular formula of given organic compound is C_4H_8O that means it has $C_nH_{2n}O$ general formula. The compound must contain a double bond. Also, it is given that the compound does not contain carbon-carbon double bond, hence it cannot be an alcohol (R—OH) because it does not contain double bond, so there must be a —C═C—, Also, the compound cannot be an ester ($R—\overset{\displaystyle O}{\overset{\|}{C}}—O—R'$), because esters contain two oxygen atoms. Hence, the two possible compounds are aldehydes ($R—\overset{\displaystyle O}{\overset{\|}{C}}—H$) and ketones ($R—\overset{\displaystyle O}{\overset{\|}{C}}—R'$). Both compounds have general formula of $C_nH_{2n}O$ or C_4H_8O.

12. (b) $C_{13}H_{26}O_2$, $C_2H_4O_2$, $C_9H_{18}O_2$ → All these given acids have single bond between carbon atoms (C—C). $C_nH_{2n}O_2$ is its general formula.

$C_7H_{12}O_2$ → It contains double bond (C═C). And, ($C_nH_{2n-2}O_2$) is its general formula.

13. (b)



14. (c) $2C_4H_6 + 11O_2 \longrightarrow 8CO_2 + 6H_2O$

III[rd] member of alkyne series: Butyne (C_4H_6)

For 2 moles of hydrocarbon = 11 moles of O_2 is required

$\therefore$ 11 moles = $11 \times 32 = 352$ g

Hence, required amount of oxygen = 352 g

15. (b) $\underset{(P)}{CH_3CH_2OH} \xrightarrow[K_2Cr_2O_7]{\text{Acidified}} \underset{(Q)}{CH_3COOH}$

$$\underset{(Q)}{CH_3COOH} + \underset{(D)}{CH_3OH} \xrightarrow[H_2SO_4]{\text{conc.}} \underset{\substack{\text{Methyl ethanoate}\\(R)}}{CH_3COOCH_3} + H_2O$$

$$\downarrow \text{NaOH}$$

$$\underset{(E)}{CH_3COONa} + \underset{(D)}{CH_3OH}$$

CH_3OH (Methanol) is particularly toxic to the optic nerve, which leads to acute blindness.