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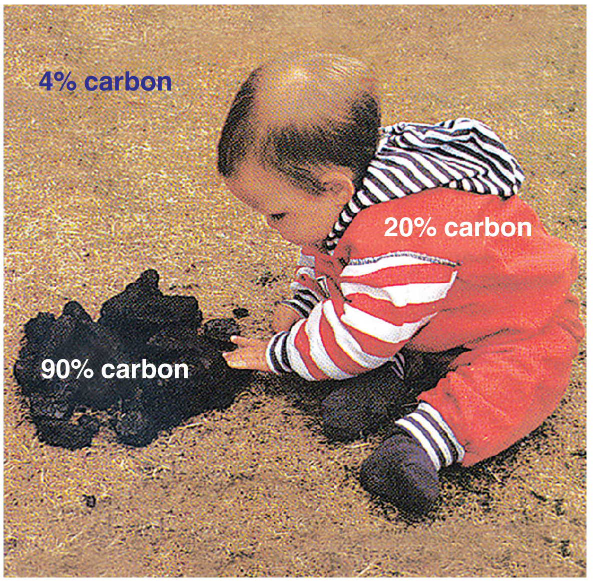


CARBON AND ITS COMPOUNDS

Carbon is an element (see Figure 1). The symbol of carbon is C. **It is a non-metal**. The name carbon is derived from the Latin word '*carbo*' which means '*coal*'. This is because carbon is the main constituent of coal. **The amount of carbon present in the earth's crust and atmosphere is very small**. For example, the earth's crust contains only 0.02% carbon in the form of minerals (like carbonates, coal and petroleum, etc.) and the atmosphere has only 0.03% of carbon dioxide gas. In spite of this small amount of carbon available in nature, carbon element has an immense importance in every sphere of life. The importance of carbon can be gauged from the fact that we are ourselves made of carbon compounds called organic compounds (see Figure 2). In fact, **all the living things, plants and animals, are made up of carbon based compounds which are called organic compounds**. Thus, carbon element is present in all living things.

Figure 1. This is carbon element (in powder form).

Figure 2. Carbon compounds called organic compounds form the basis of all life (including human life).

Figure 3. Most of our food materials are made up of carbon compounds called organic compounds.

A large number of things which we use in our daily life are made of carbon compounds. Our food materials like grains, pulses, sugar, tea, coffee, fruits and vegetables, etc., are carbon compounds (see Figure 3). The materials like cotton, silk, wool, nylon and polyester which are used for making clothes are carbon compounds. The fuels like wood, coal, kerosene, LPG (Liquefied Petroleum Gas), natural gas, CNG (Compressed Natural Gas), petrol and diesel which we use for cooking food and running vehicles are carbon compounds. And paper, rubber, plastics, leather, drugs and dyes, are also made of carbon compounds. It is clear that **carbon element plays a very important role in our daily life**.

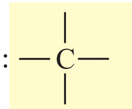
We can test the presence of carbon in a material on the basis of the fact that carbon and its compounds burn in air to give carbon dioxide gas which turns lime water milky. This test can be performed as follows : Burn the given material in air. Pass the gas formed through lime water. If the lime water turns milky, then the given material contains carbon.

Carbon Always Forms Covalent Bonds

The atomic number of carbon is 6 which means that a neutral atom of carbon contains 6 electrons. So, **the electronic configuration of carbon is** $\underset{2,}{\mathbf{K}}\ \underset{4}{\mathbf{L}}$. It is clear that carbon has 4 electrons in the outermost shell (L shell) of its atom. Since a carbon atom has 4 electrons in its outermost shell, so it should either lose 4 electrons or gain 4 electrons to achieve the inert gas electron configuration and become stable. Now, carbon atom is very small due to which its outermost electrons are strongly held by the nucleus. So, **it is not possible to remove 4 electrons from a carbon atom** to give it the inert gas electron arrangement**. It is also not possible to add as many as 4 electrons to a carbon atom** due to energy considerations, and acquire the inert gas configuration. It is obvious that the carbon atoms have to acquire the inert gas structure of 8-electrons in their outermost shell by the sharing of electrons. **Since carbon atoms can achieve the inert gas electron arrangement only by the sharing of electrons, therefore, carbon always forms covalent bonds**.

Carbon is Tetravalent

A carbon atom has 4 electrons in its outermost shell, so it requires 4 more electrons to achieve the stable, 8-electron inert gas electron arrangement, which it gets by sharing. **Since one carbon atom requires 4 electrons to achieve the eight-electron inert gas structure, therefore, the valency of carbon is 4**. That is, carbon is tetravalent (tetra = four; valent = valency). The four valencies of carbon are usually represented by putting four short lines on the symbol of carbon :



Self Combination

The most outstanding (or unique) property of carbon is its ability to combine with itself, atom to atom, to form long chains. For example, octane (C_8H_{18}), one of the constituents of petrol, has a chain of 8 carbon atoms, and some of the organic compounds like starch and cellulose contain chains of hundreds of carbon atoms. **The property of self combination of carbon atoms to form long chains is useful to us because it gives rise to an extremely large number of carbon compounds (or organic compounds)**. This is because a long chain of carbon atoms acts as a backbone to which other atoms can attach in a number of ways to form a very large number of carbon compounds (or organic compounds).

The covalent bonds between the various carbon atoms are very strong and do not break easily. The reason for the formation of strong bonds by the carbon atoms is their small size. Due to the small size of carbon atoms, their nuclei hold the shared pairs of electrons between atoms strongly, leading to the formation of strong covalent bonds. The carbon atoms also form strong covalent bonds with the atoms of other elements such as hydrogen, oxygen, nitrogen, sulphur, chlorine, and many other elements. **The formation of strong bonds by carbon atoms among themselves and with other elements makes the carbon compounds exceptionally stable.**

No other element exhibits the property of self combination (known as catenation) to the extent seen in carbon compounds. Silicon element shows some catenation property due to which it forms compounds with hydrogen having chains of up to seven or eight silicon atoms. But due to weak bonds, these compounds are unstable.

Occurrence of Carbon

Carbon occurs in nature in *'free state'* (as element) as well as in the *'combined state'* (in the form of compounds with other elements).

1. **In free state,** carbon occurs in nature mainly in two forms : diamond and graphite. Another naturally occurring form of carbon called buckminsterfullerene has been discovered recently. Please note that only a small amount of carbon occurs as free element in the earth's crust. Most of carbon occurs in the combined state.

2. **In the combined state,** carbon occurs in nature in the form of compounds such as : (*i*) Carbon dioxide gas in air (*ii*) Carbonates (like limestone, marble and chalk) (*iii*) Fossil fuels like coal, petroleum and natural gas (*iv*) Organic compounds like carbohydrates, fats and proteins, and (*v*) Wood, cotton and wool, etc.

Allotropes of Carbon

The various physical forms in which an element can exist are called allotropes of the element. The carbon element exists in three solid forms called allotropes. The three allotropes of carbon are :

1. Diamond,
2. Graphite, and
3. Buckminsterfullerene.

Diamond and graphite are the two common allotropes of carbon which are known to us for centuries. Buckminsterfullerene is the new allotrope of carbon which has been discovered recently. The properties of diamond and graphite are well known but the properties of buckminsterfullerene are still being investigated.

Diamond and Graphite

Diamond is a colourless transparent substance having extraordinary brilliance (*chamak*) (see Figure 4). Diamond is quite heavy. Diamond is extremely hard. It is the *hardest* natural substance known. Diamond does not conduct electricity. Diamond burns on strong heating to form carbon dioxide. *If we burn diamond in oxygen, then only carbon dioxide gas is formed and nothing is left behind. This shows that diamond is made up of carbon only.* The carbon dioxide formed by burning diamond can turn lime water milky. Since diamond is made up of carbon atoms only, its symbol is taken to be C.

Figure 4. Diamond

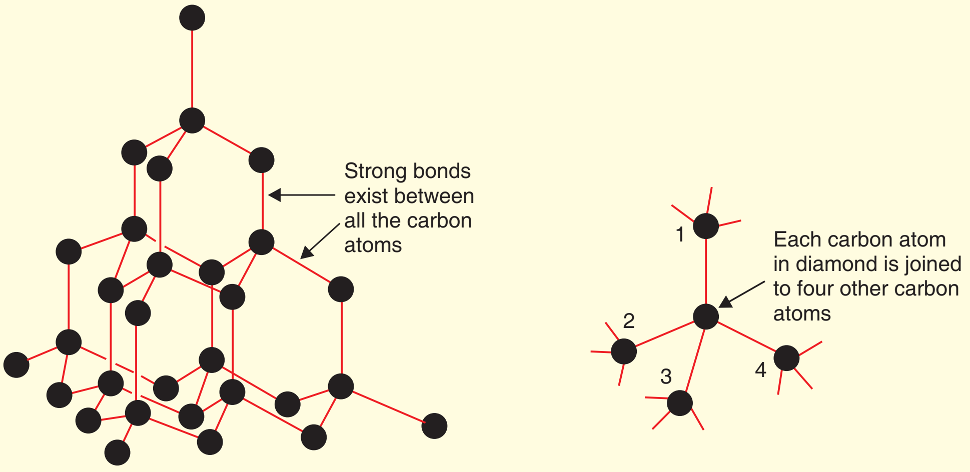
Figure 5. Graphite

Graphite is a greyish-black opaque substance (see Figure 5). Graphite is lighter than diamond. Graphite is soft and slippery to touch. Graphite conducts electricity. Graphite burns on strong heating to form carbon dioxide. *If we burn graphite in oxygen, then only carbon dioxide gas is formed and nothing is left behind. This shows that graphite is made up of carbon only.* The carbon dioxide formed by burning graphite can turn lime water milky. Since graphite is made up of carbon atoms only, its symbol is taken to be C.

From the above discussion we conclude that **the two common allotropes of carbon, diamond and graphite, have entirely different physical properties.** For example, diamond is extremely *hard* whereas graphite is *soft*; diamond is a *non-conductor of electricity* whereas graphite is a *good conductor of electricity*. The chemical properties of diamond and graphite are, however, the same. For example, both diamond as well as graphite, form only carbon dioxide on burning in oxygen. **The difference in the physical properties of diamond and graphite arises because of the different arrangements of carbon atoms in them.** In other words, the difference in the physical properties of diamond and graphite is due to the *difference* in their structures. This is discussed below :

Structure of Diamond

A diamond crystal is a giant molecule (very big molecule) of carbon atoms [see Figure 6(*a*)]. Each carbon atom in the diamond crystal is linked to four other carbon atoms by strong covalent bonds. The four surrounding carbon atoms are at the four vertices (four corners) of a regular tetrahedron [see Figure 6(*b*)].



(*a*) Structure of diamond (The black balls represent carbon atoms)

(*b*) Arrangement of carbon atoms in diamond

Figure 6.

The diamond crystal is, therefore, made up of carbon atoms which are powerfully bonded to one another by a network of covalent bonds. Due to this, diamond structure is very rigid. **The rigid structure of diamond makes it a very hard substance**. It is the great hardness of diamond which makes it useful for making rock borers for drilling oil wells, etc., and for making glass cutters. Please note that a diamond crystal has a tetrahedral arrangement of carbon atoms. The compact and rigid three-dimensional arrangement of carbon atoms in diamond gives it a high density. The melting point of diamond is also very high, being more than 3500°C. This is because a lot of heat energy is required to break the network of strong covalent bonds in the diamond crystal. **Diamond is a non-conductor of electricity**. This can be explained as follows : We know that a carbon atom has 4 valence electrons in it. Now, in a diamond crystal, each carbon atom is linked to four other carbon atoms by covalent bonds, and hence all the 4 valence electrons of each carbon atom are used up in forming the bonds. **Since there are 'no free electrons' in a diamond crystal, it does not conduct electricity**.

Structure of Graphite

The structure of graphite is very different from that of diamond. A graphite crystal consists of layers of carbon atoms or sheets of carbon atoms (see Figure 7).

Each carbon atom in a graphite layer is joined to three other carbon atoms by strong covalent bonds to form flat hexagonal rings. The various layers of carbon atoms in graphite are quite far apart so that no covalent bonds can exist between them. The various layers of carbon atoms in graphite are held together by weak Van der Waals forces. Since the various layers of carbon atoms in graphite are joined by weak forces, they can slide over one another. **Due to the sheet like structure, graphite is a comparatively soft substance**. It is the softness of graphite which makes it useful as a dry lubricant for machine parts. **Graphite is a good conductor of electricity**. This can be explained as follows : We know that a carbon atom has 4 valence electrons in it. Now, in a graphite crystal, each carbon atom is joined to only three other carbon atoms by covalent bonds. Thus, only the three valence electrons of each carbon atom in graphite are used in bond formation. The fourth valence electron of each carbon atom is 'free' to move. **Due to the 'presence of free electrons' in a graphite crystal, it conducts electricity**. Just like diamond, graphite has also a very, very high melting point.

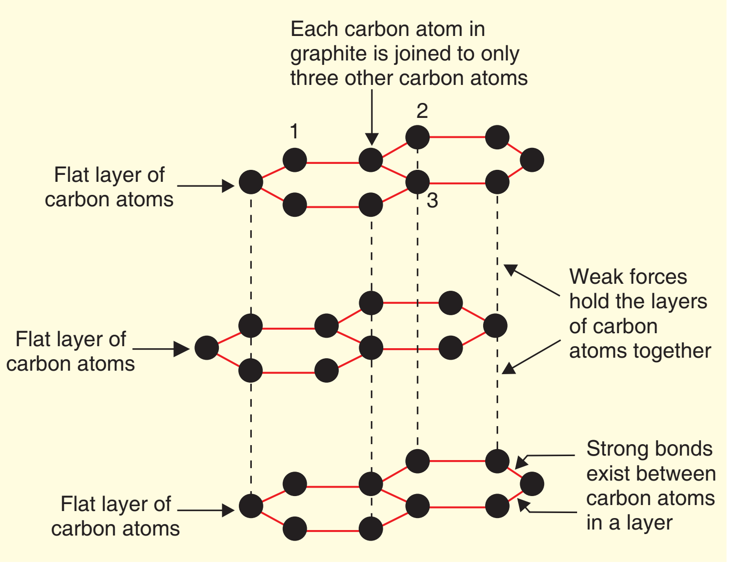
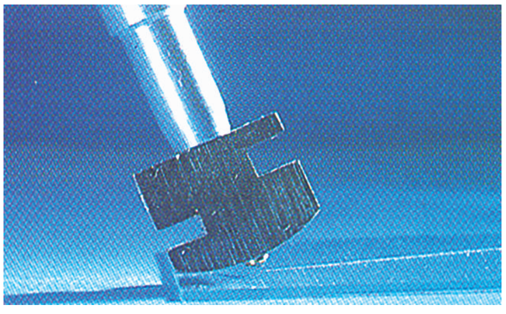


Figure 7. Structure of graphite (The black balls represent carbon atoms).

Uses of Diamond

1. Since diamond is extremely hard, therefore, it is the right material for cutting and grinding other hard materials, and for drilling holes in the earth's rocky layers. Thus, **diamonds are used in cutting instruments like glass cutters, saw for cutting marble and in rock drilling equipment** [see Figure 8(*a*)]. Diamond 'dies' are used for drawing thin wires like the tungsten filament of an electric bulb. All these uses of diamond are because of its great hardness.

2. **Diamonds are used for making jewellery** [see Figure 8(*b*)]**.** The use of diamonds in making jewellery is because of their extraordinary brilliance, which is due to their great ability to reflect and refract light.



(*a*) Diamond is harder than glass. The tip of this glass cutter is made of synthetic diamond (which is not good enough for making jewellery)

(*b*) Diamonds are used for making jewellery. This bracelet contains many small diamonds.

(*c*) A sharp, diamond edged knife (called keratome) is used by eye-surgeons to remove cataract from the eye.

Figure 8. Some of the uses of diamond.

3. Sharp-edged diamonds are used by eye-surgeons as a tool to remove cataract from eyes with a great precision [see Figure 8(*c*)].

Diamonds can also be made artificially. **Diamonds can be made artificially by subjecting pure carbon to very high pressure and temperature.** These are called synthetic diamonds. The synthetic diamonds are small but are otherwise indistinguishable from natural diamonds. The diamonds which are not suitable for making jewellery are used in glass cutters, diamond-studded saws and drill bits.

Uses of Graphite

1. Due to its softness, **powdered graphite is used as a lubricant for the fast moving parts of machinery**. Since graphite is non-volatile, **it can be used for lubricating those machine parts which operate at very high temperatures** (where ordinary oil lubricants cannot be used). Graphite can be used as a dry lubricant in the form of graphite powder or mixed with petroleum jelly to form graphite grease. Graphite powder can also be mixed with lubricant oils [see Figure 9(*a*)].

2. Graphite is a good conductor of electricity due to which **graphite is used for making carbon electrodes or graphite electrodes in dry cells and electric arcs**. The black coloured 'anode' of a dry cell is made of graphite [see Figure 9(*b*)]. The carbon brushes of electric motors are also made of graphite.

(*a*) The lubricant oil in this 'can ' contains graphite powder

(*b*) The black electrode in this dry cell is made of graphite

(*c*) Graphite (mixed with clay) is used in making pencil 'leads'

(*d*) Since graphite does not melt easily, the tiles on the nose cone of space shuttle contain graphite

Figure 9. Some of the uses of graphite.

3. **Graphite is used for making the cores of our pencils called 'pencil leads' and black paints** [see Figure 9(*c*)]. Graphite is black in colour and quite soft. So, it marks black lines on paper. Due to this property graphite is used for making the black cores of our pencils called pencil leads. For making pencil leads, graphite is usually mixed with clay.

Buckminsterfullerene

Buckminsterfullerene is an allotrope of carbon containing clusters of 60 carbon atoms joined together to form spherical molecules. Since there are 60 carbon atoms in a molecule of buckminsterfullerene, so its formula is C_{60} (C-sixty). Buckminsterfullerene is a football-shaped spherical molecule in which 60 carbon atoms are arranged in interlocking hexagonal and pentagonal rings of carbon atoms (see Figure 10). There are twenty hexagons and twelve pentagons of carbon atoms in one molecule of buckminsterfullerene. This allotrope was named buckminsterfullerene after the American architect Buckminster Fuller because its structure resembled the framework of domeshaped halls designed by Fuller for large international exhibitions. The arrangement of carbon atoms in buckminsterfullerene resembles a football

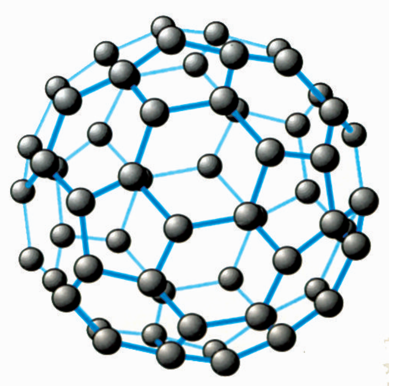


Figure 10. Structure of buckminsterfullerene. The balls shown in this picture represent carbon atoms.

Figure 11. The structure of buckminsterfullerene is similar to this football made of hexagonal and pentagonal panels, with each corner of panel representing a carbon atom.

made of twenty hexagonal and twelve pentagonal panels, each corner of every panel representing a carbon atom (see Figure 11).

Buckminsterfullerene is a dark solid at room temperature. It differs from the other two allotropes of carbon, diamond and graphite, in the fact that diamond and graphite are giant molecules which consist of an unending network of carbon atoms, but buckminsterfullerene is a very small molecule made up of only 60 carbon atoms. Just like diamond and graphite, buckminsterfullerene also burns on heating to form carbon dioxide. *If we burn buckminsterfullerene in oxygen, then only carbon dioxide is formed and nothing is left behind. This shows that buckminsterfullerene is made up of carbon only.* An important physical property in which the three allotropes of carbon differ is their hardness. **Diamond is extremely hard whereas graphite is soft. On the other hand, buckminsterfullerene is neither very hard nor soft.** Other properties of buckminsterfullerene are still being investigated. We will now solve some problems based on the allotropes of carbon.

Sample Problem 1. An element belonging to group 14 of the periodic table has two common allotropes A and B. A is very hard and a non-conductor of electricity while B is soft to touch and a good conductor of electricity. Identify the element. Name each of these allotropes.

Solution. The element of group 14 having two common allotropes is carbon. These two allotropes (A and B) of carbon element are diamond and graphite. This is confirmed by the fact that diamond is very hard and a non-conductor of electricity whereas graphite is soft to touch and a good conductor of electricity.

Sample Problem 2. A boy sharpens a pencil at both the ends and then uses its back ends to complete an electric circuit. Will the current flow through the electric circuit ? Give reason for your answer. Name the black substance of the pencil.

Solution. Yes, the current will flow through the electric circuit. This is because the black substance of a pencil is graphite, and being a good conductor of electricity, the graphite core of pencil allows the electric current to flow through it.

Sample Problem 3. A piece of black electrode used in dry cell on strong heating in air gave a colourless gas which turned lime water milky. What was the material of the electrode ?

Solution. We know that graphite is used for making the electrodes. So, the piece of black electrode used in the dry cell is made of graphite (which is an allotrope of carbon element). This is confirmed by the fact that the piece of electrode, on strong heating in air, gave a colourless gas carbon dioxide which turned lime water milky. Thus, the material of the electrode is graphite.

ORGANIC COMPOUNDS

The compounds of carbon are known as organic compounds. Apart from carbon, most of the organic compounds contain hydrogen and many organic compounds contain oxygen or other elements. So, most of the organic compounds are hydrocarbons (containing only carbon and hydrogen), or their derivatives. Some of the examples of organic compounds are : Methane (CH_4), Ethane (C_2H_6), Ethene (C_2H_4), Ethyne (C_2H_2), Trichloromethane ($CHCl_3$), Ethanol (C_2H_5OH), Ethanal (CH_3CHO), Ethanoic acid (CH_3COOH), and Urea [$CO(NH_2)_2$]. **Carbon compounds (or organic compounds) are covalent compounds having low melting points and boiling points.** This is shown in the following table.

Carbon compound (Organic compound)	*Melting point*	*Boiling point*	*Physical state at room temperature (25°C)*
1. Methane	–182°C	–161°C	Gas
2. Trichloromethane (Chloroform)	– 63°C	61°C	Liquid
3. Ethanol (Ethyl alcohol)	–114°C	78°C	Liquid
4. Ethanoic acid (Acetic acid)	17°C	118°C	Liquid

The low melting points and boiling points of the above carbon compounds show that the forces of attraction between their molecules are not very strong. So, they are *covalent* compounds. **Most of the carbon compounds are non-conductors of electricity.** This also shows that carbon compounds are *covalent* in nature. They do not contain ions.

Organic compounds occur in all living things like plants and animals. Initially, all the organic compounds (or carbon compounds) were extracted from natural materials obtained from living things. It was, therefore, thought that the organic compounds could only be formed within a living body (plant or animal body) and hence a *'vital force'* which creates living things was necessary for their preparation. This vital force theory of organic compounds was disproved by a scientist Freidrich Wohler in 1828 as follows : Urea is an organic compound which was thought to be made only inside the bodies of living beings (like animals). Wohler prepared the organic compound 'urea' [$CO(NH_2)_2$] in the laboratory from an inorganic compound 'ammonium cyanate' (NH_4CNO). This led to the rejection of the vital force theory for the synthesis of organic compounds.

Please note that **though oxides of carbon (like carbon monoxide and carbon dioxide), carbonates, hydrogencarbonates and carbides are also carbon compounds but they are not considered to be organic compounds.** This is because their properties are very different from those of the common organic compounds. **The study of carbon compounds (such as hydrocarbons and their derivatives) is called organic chemistry**. The oxides of carbon, carbonates, hydrogencarbonates and carbides are inorganic compounds which are studied in inorganic chemistry.

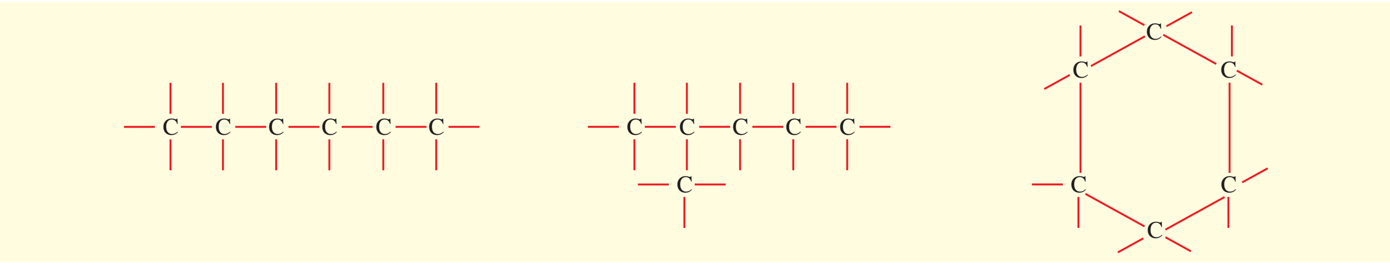
The Large Number of Organic Compounds (or Carbon Compounds)

The number of carbon compounds already known at present is more than 5 million. Many more new carbon compounds are being isolated or prepared in the laboratories every day. In fact, the number of carbon compounds alone is much more than the number of compounds of all other elements taken together. We will now discuss the reasons for the extremely large number of carbon compounds (or organic compounds).

Reason for the Large Number of Organic Compounds (or Carbon Compounds)

The two characteristic properties of carbon element which lead to the formation of a very large number of organic compounds (or carbon compounds) are : (*i*) *catenation* (self-linking), and (*ii*) *tetravalency* (four valency). Let us discuss this in detail.

1. One reason for the existence of a large number of organic compounds or carbon compounds is that carbon atoms can link with one another by means of covalent bonds to form long chains (or rings) of carbon atoms. The property of carbon element due to which its atoms can join with one another to form long carbon chains is called 'catenation'. So, it is the property of 'catenation' of carbon element which is responsible for a very large number of organic compounds (catenation means 'self-linking'). When carbon atoms combine with one another, three types of chains can be formed. These are : (*i*) straight chains, (*ii*) branched chains, and (*iii*) closed chains or ring type chains (see Figure 12).



(*a*) Straight chain of carbon atoms

(*b*) Branched chain of carbon atoms

(*c*) Closed chain of carbon atoms

Figure 12. Diagrams to show the variety of carbon chains formed when carbon atoms join together.

In Figure 12(*a*), the six carbon atoms are in the same straight chain. In Figure 12(*b*), five carbon atoms are in the straight chain but the sixth carbon atom is in the form of a branch. So, it is called a branched chain. In Figure 12(*c*), the six carbon atoms are linked to form a closed chain or ring type chain.

2. Another reason for the existence of a large number of organic compounds or carbon compounds is that the valency of carbon is 4 (which is quite large). Due to its large valency of 4, a carbon atom can form covalent bonds with a number of carbon atoms as well as with a large number of other atoms such as hydrogen, oxygen, nitrogen, sulphur, chlorine, and many more atoms. This leads to the formation of a large number of organic compounds.

Types of Organic Compounds

Some of the common types of organic compounds are :

1. Hydrocarbons	2. Haloalkanes (Halogenated hydrocarbons)
3. Alcohols	4. Aldehydes
5. Ketones	6. Carboxylic acids (Organic acids)

We will discuss all these compounds one by one. Let us start with hydrocarbons.

HYDROCARBONS

A compound made up of hydrogen and carbon only is called hydrocarbon (Hydrogen + Carbon = Hydrocarbon). Methane (CH_4), ethane (C_2H_6), ethene (C_2H_4), and ethyne (C_2H_2), are all hydrocarbons because they are made up of only two elements : carbon and hydrogen. **The most important natural source of hydrocarbons is petroleum (or crude oil)** which is obtained from underground oil deposits by drilling oil wells. The natural gas which occurs above petroleum deposits also contains hydrocarbons.

Types of Hydrocarbons. Hydrocarbons are of two types : *Saturated* hydrocarbons and *Unsaturated* hydrocarbons.

1. Saturated Hydrocarbons (Alkanes)

A hydrocarbon in which the carbon atoms are connected by only single bonds is called a saturated hydrocarbon. Saturated hydrocarbons are also called alkanes. We can now say that : **An alkane is a hydrocarbon in which the carbon atoms are connected by only single covalent bonds (There are no double or triple bonds in an alkane).** Thus, the hydrocarbons methane, ethane, propane and butane form a series of compounds known as alkanes. The names of all these saturated hydrocarbons end with '*ane*'.

Methane (CH_4), ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}), are all saturated hydrocarbons which contain only carbon-carbon single bonds as shown in Figure 13.

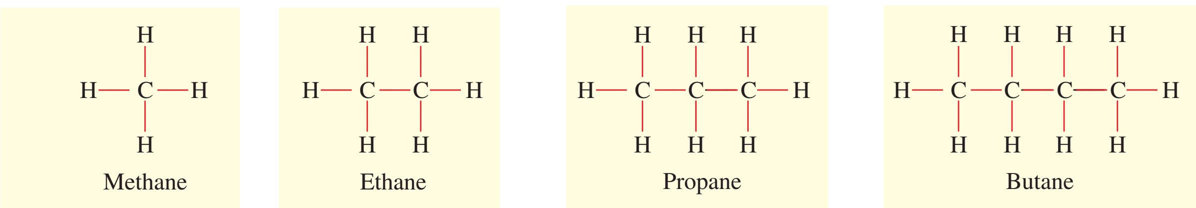


Figure 13. Structural formulae of some saturated hydrocarbons (or alkanes). They all contain single bonds.

The general formula of saturated hydrocarbons or alkanes is C_nH_{2n+2} where *n* is the number of carbon atoms in one molecule of the alkane.

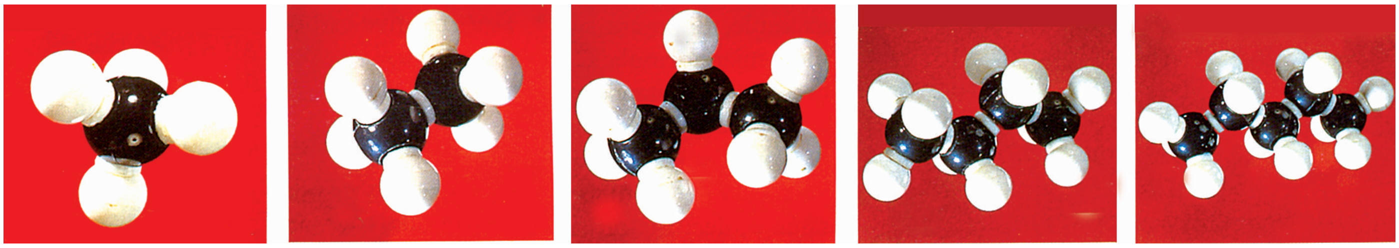
(*i*) If an alkane has 1 carbon atom in its molecule, then $n = 1$, and its molecular formula will be $C_1H_{2\times1+2}$ or CH_4.

(*ii*) If an alkane has 2 carbon atoms in its molecule, then $n = 2$, and its molecular formula will be $C_2H_{2\times2+2}$ or C_2H_6.

The names and molecular formulae of the first five saturated hydrocarbons or alkanes are given below.

Name of alkane (Saturated hydrocarbon)	*Number of carbon atoms (n)*	*Molecular formula*
1. Methane	1	CH_4
2. Ethane	2	C_2H_6
3. Propane	3	C_3H_8
4. Butane	4	C_4H_{10}
5. Pentane	5	C_5H_{12}

The alkane molecules methane, ethane, propane, butane and pentane look like the models shown in the photographs given below :



(*a*) Methane (CH_4) (*b*) Ethane (C_2H_6) (*c*) Propane (C_3H_8) (*d*) Butane (C_4H_{10}) (*e*) Pentane (C_5H_{12})

Figure 14. Models of first five alkanes, methane, ethane, propane, butane and pentane (In these models, black balls represent carbon atoms whereas white balls represent hydrogen atoms).

The saturated hydrocarbons (or alkanes) are chemically not very reactive. They are quite unreactive.

2. Unsaturated Hydrocarbons (Alkenes and Alkynes)

A hydrocarbon in which the two carbon atoms are connected by a 'double bond' or a 'triple bond' is called an unsaturated hydrocarbon. Ethene ($H_2C{=}CH_2$) and ethyne ($HC{\equiv}CH$) are two important unsaturated hydrocarbons, because ethene contains a double bond and ethyne contains a triple bond between two carbon atoms (see Figure 15).

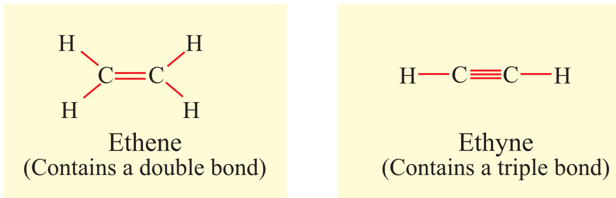


Figure 15. Structural formulae of two unsaturated hydrocarbons. They contain double bond or triple bond.

A double bond is formed by the sharing of two pairs of electrons between the two carbon atoms whereas a triple bond is formed by the sharing of three electron pairs between two carbon atoms. The unsaturated hydrocarbons are obtained mostly from petroleum by a process called cracking. Unsaturated hydrocarbons are of two types : (*i*) those containing carbon-carbon double bonds (alkenes), and (*ii*) those containing carbon-carbon triple bonds (alkynes). Let us discuss them in detail.

(i) Alkenes

An unsaturated hydrocarbon in which the two carbon atoms are connected by a double bond is called an alkene. Thus, alkenes contain a double bond between two carbon atoms which is formed by the sharing of two electron pairs (or four electrons). That is, an alkene contains the $>C{=}C<$ group. Ethene $H_2C{=}CH_2$, and propene $CH_3{-}CH{=}CH_2$ are two alkenes because they contain double bond between the two carbon atoms. Since an alkene has a double bond between two carbon atoms, it is obvious that the simplest alkene will have two carbon atoms in its molecule. There can be no alkene having only one carbon atom.

The general formula of an alkene is C_nH_{2n} where n is the number of carbon atoms in its one molecule.

(*i*) If an alkene has 2 carbon atoms in its molecule, then $n = 2$, and its molecular formula will be $C_2H_{2\times2}$ or C_2H_4.

(*ii*) If an alkene has 3 carbon atoms in its molecule, then $n = 3$, and its molecular formula will be $C_3H_{2\times3}$ or C_3H_6.

The names and molecular formulae of the first three alkenes are given alongside. The simplest alkene is ethene having the molecular formula C_2H_4. **The common name of ethene is ethylene.**

Name of alkene (Unsaturated hydrocarbon)	*Number of carbon atoms (n)*	*Molecular formula*
Ethene	2	C_2H_4
Propene	3	C_3H_6
Butene	4	C_4H_8

(ii) Alkynes

An unsaturated hydrocarbon in which the two carbon atoms are connected by a triple bond is called an alkyne. Thus, alkynes contain a triple bond between two carbon atoms which is formed by the sharing of three electron pairs (or six electrons). That is, an alkyne contains the —C≡C— group. Ethyne HC≡CH, and propyne CH_3—C≡CH, are alkynes because they contain a triple bond between two carbon atoms. Since an alkyne has a triple bond between two carbon atoms, it is obvious that the simplest alkyne will have two carbon atoms in its molecule. There can be no alkyne having only one carbon atom.

The general formula of alkynes is C_nH_{2n-2} where n is the number of carbon atoms in one molecule of the alkyne.

(*i*) If an alkyne has 2 carbon atoms in its molecule, then $n = 2$, and its molecular formula will be $C_2H_{2\times2-2}$ or C_2H_2.

(*ii*) If an alkyne has 3 carbon atoms in its molecule, then $n = 3$, and its molecular formula will be $C_3H_{2\times3-2}$ or C_3H_4.

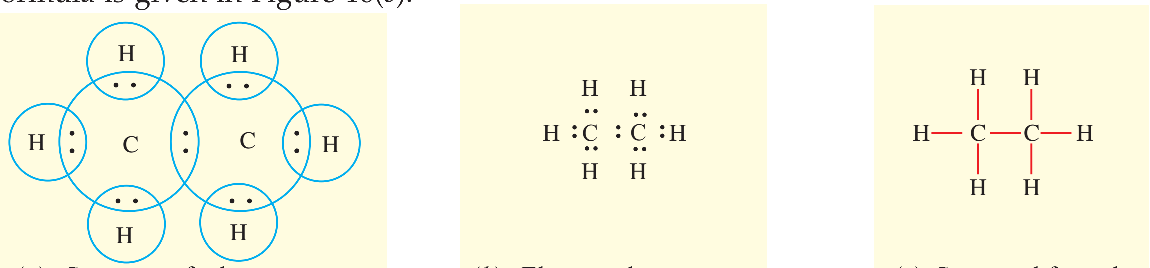
The names and molecular formulae of the first three alkynes are given below.

The simplest alkyne is ethyne having the molecular formula C_2H_2. **The common name of ethyne is acetylene.** Please note that the unsaturated hydrocarbons (having double bonds or triple bonds between the carbon atoms) are more reactive than saturated hydrocarbons. In other words, alkenes and alkynes are chemically more reactive than alkanes. Another point to be noted is that the valency of each carbon atom in an alkane, alkene or alkyne is just the same, which is 4.

Name of alkyne (Unsaturated hydrocarbon)	*Number of carbon atoms (n)*	*Molecular formula*
Ethyne	2	C_2H_2
Propyne	3	C_3H_4
Butyne	4	C_4H_6

The alkane having 2 carbon atoms in its molecule is ethane, the alkene having 2 carbon atoms is ethene whereas the alkyne having 2 carbon atoms is ethyne. **Ethane, ethene and ethyne are covalent molecules which are formed by the sharing of electrons between various atoms.** This is described below.

The ethane molecule (C_2H_6) is made up of 2 carbon atoms and 6 hydrogen atoms. The structure of ethane molecule is shown in Figure 16(*a*), the electron-dot structure is given in Figure 16(*b*) whereas its structural formula is given in Figure 16(*c*).

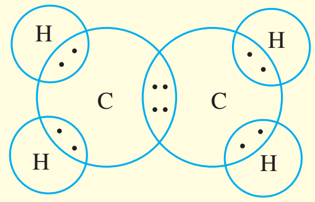


(*a*) Structure of ethane molecule, C_2H_6 (*b*) Electron-dot structure of ethane, C_2H_6 (*c*) Structural formula of ethane, C_2H_6

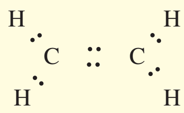
Figure 16.

In ethane, the two carbon atoms share one pair of electrons among themselves to form one carbon-carbon single covalent bond. Each carbon atom shares three electrons with three hydrogen atoms to form three carbon-hydrogen single covalent bonds. So, in ethane we have 1 carbon-carbon single covalent bond and 6 carbon-hydrogen single covalent bonds. So, the total number of covalent bonds in an ethane molecule is 1 + 6 = 7 [see Figure 16(*c*)].

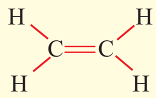
The ethene molecule (C_2H_4) is made up of 2 carbon atoms and 4 hydrogen atoms. The structure of ethene molecule is shown in Figure 17(*a*), the electron-dot structure is given in Figure 17(*b*) whereas its structural formula is given in Figure 17(*c*).



(*a*) Structure of ethene molecule, C_2H_4



(*b*) Electron-dot structure of ethene, C_2H_4

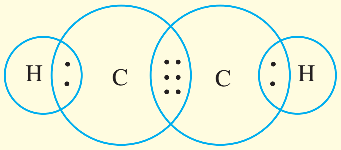


(*c*) Structural formula of ethene, C_2H_4

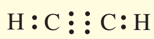
Figure 17.

In ethene, the two carbon atoms share two pairs of electrons among themselves to form a carbon-carbon double bond. Each carbon atom shares two electrons with two hydrogen atoms to form two carbon-hydrogen single bonds. So, the total number of carbon-hydrogen single bonds in ethene is 2 + 2 = 4 [see Figure 17(*c*)].

The ethyne molecule (C_2H_2) is made up of 2 carbon atoms and 2 hydrogen atoms. The structure of ethyne molecule is shown in Figure 18(*a*), the electron-dot structure is given in Figure 18(*b*) whereas its structural formula is given in Figure 18(*c*).



(*a*) Structure of ethyne molecule, C_2H_2



(*b*) Electron-dot structure of ethyne, C_2H_2

(*c*) Structural formula of ethyne, C_2H_2

Figure 18.

In ethyne, the two carbon atoms share three pairs of electrons among themselves to form a carbon-carbon triple bond. Each carbon atom shares one electron with each hydrogen atom to form two carbon-hydrogen single bonds [see Figure 18(*c*)]. Please note that in the electron-dot structure of a molecule, a single bond is represented by putting 2 dots, a double bond is shown by putting 4 dots, whereas a triple bond is indicated by putting 6 dots between the two combining atoms.

Points to Remember

(*i*) Ethane, C_2H_6, is an alkane containing a single bond between two carbon atoms. So, it should be written as $H_3C—CH_3$. This formula shows that the single bond is between the two carbon atoms. For the sake of convenience in writing, however, we usually represent ethane as $CH_3—CH_3$ (and not as $H_3C—CH_3$). Both are just the same.

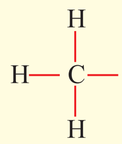
(*ii*) Though the more correct formula of ethene is $H_2C{=}CH_2$, but for the sake of convenience in writing on paper, we usually put it as $CH_2{=}CH_2$.

(*iii*) Again, though we should write ethyne as $HC{\equiv}CH$, but for the sake of convenience we write it as $CH{\equiv}CH$.

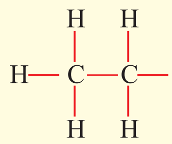
It is always understood that the single bond or double bond or triple bond is between the carbon atoms (and not between hydrogen and carbon atoms). We will be using both types of formulae in this book. Before we go further and solve some problems based on hydrocarbons, it is very important to know something about the alkyl groups. This is discussed below.

Alkyl Groups

The group formed by the removal of one hydrogen atom from an alkane molecule is called an alkyl group. Examples of alkyl group are methyl group (CH_3—) and ethyl group (C_2H_5—). Methyl group (CH_3—) is formed by the removal of one H atom from methane (CH_4); and ethyl group (C_2H_5—) is formed by the removal of one H atom from ethane (C_2H_6). The structural formulae of the methyl group and ethyl group are given on the right hand side.



Methyl group



Ethyl group

Please note that the free line (—) shown on the carbon atom of an alkyl group means that one valency of carbon atom is free in an alkyl group. The general formula of an alkyl group is C_nH_{2n+1} where n is the number of carbon atoms. The alkyl groups are usually denoted by the letter R. Let us solve some problems now.

Sample Problem 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 **(NCERT Book Question)**

Solution. The correct answer is : (*b*) 7 covalent bonds [see Figure 16(*c*) on page 208].

Sample Problem 2. Give the general formula of "alkynes". Identify the alkynes from the following :

CH_4, C_2H_6, C_2H_2, C_3H_4, C_2H_4

Solution. The general formula of alkynes is C_nH_{2n-2} where n is the number of carbon atoms in one molecule of the alkyne. Out of the above given hydrocarbons C_2H_2 and C_3H_4 are alkynes (because they correspond to the general formula C_nH_{2n-2} with $n = 2$ and $n = 3$, respectively). (Please note that in an alkyne molecule, "the number of hydrogen atoms" is "2 less than double the number of carbon atoms").

Sample Problem 3. What is the general formula of alkenes ? Identify the alkenes from the following :

C_2H_6, C_2H_4, C_3H_4, C_2H_2, C_3H_6

Solution. The general formula of alkenes is C_nH_{2n} where n is the number of carbon atoms in one molecule of the alkene. Out of the above given hydrocarbons C_2H_4 and C_3H_6 are alkenes (because they correspond to the general formula C_nH_{2n} with $n = 2$ and n = 3, respectively). (Please note that in an alkene molecule, the "number of hydrogen atoms" is exactly equal to "double the number of carbon atoms").

Sample problem 4. What is the general formula of alkanes ? Identify the alkanes from the following :

CH_4, C_2H_2, C_2H_6, C_3H_6, C_3H_8

Solution. The general formula of alkanes is C_nH_{2n+2} where n is the number of carbon atoms in one molecule of the alkane. Out of the above given hydrocarbons CH_4, C_2H_6 and C_3H_8 are alkanes (because they correspond to the general formula C_nH_{2n+2} with $n = 1$, $n = 2$ and $n = 3$, respectively). (Please note that in an alkane molecule, the "number of hydrogen atoms" is "2 more than double the number of carbon atoms").

A Golden Rule. We are now going to tell you a golden rule which will help you to know at once whether the given hydrocarbon is an alkane, an alkene or an alkyne. It is like this : Look at the formula of the given hydrocarbon and compare the number of hydrogen atoms with the number of carbon atoms present in it :

(*i*) If the number of hydrogen atoms is "2 more" than double the number of carbon atoms, then it will be an alkane.

(*ii*) If the number of hydrogen atoms is "exactly equal" to double the number of carbon atoms, then it will be an alkene.

(*iii*) And if the number of hydrogen atoms is "2 less" than double the number of carbon atoms, then it will be an alkyne.

(*a*) Motor cars use petrol as fuel which is a mixture of alkanes

(*b*) An alkene called ethene is used to prepare polythene (to make carry bags, etc.)

(*c*) An alkyne called ethyne (or acetylene) is used as a fuel in acetylene lamps

Figure 19. Alkanes, alkenes and alkynes are very useful hydrocarbons.

Sample Problem 5. Which of the following organic compounds is unsaturated ?

CH_4, C_2H_4

Solution. We know that alkenes and alkynes are unsaturated compounds. So, all that we have to do here is to find out which of the above compounds is an alkene or alkyne. That will be the unsaturated compound. Now, out of the above compounds, C_2H_4 is unsaturated (because it is an alkene corresponding to the general formula of alkenes C_nH_{2n} with $n = 2$).

Sample Problem 6. Which of the following compounds can have a double bond ?

C_3H_8, C_3H_6

Solution. The compound having a double bond is called an alkene. So, all that we have to do here is to find out which of the above given compounds is an alkene. Here, C_3H_6 is an alkene (because it corresponds to the general formula for alkenes C_nH_{2n} with $n = 3$). Thus, the compound C_3H_6 will have a double bond in it.

Sample Problem 7. A hydrocarbon molecule has 3 carbon atoms. Write down its molecular formula if it is an : (*i*) alkane, (*ii*) alkene, (*iii*) alkyne.

Solution. The number of carbon atoms in the molecule of this hydrocarbon is 3, that is, $n = 3$.

(*i*) The general formula of an alkane is C_nH_{2n+2} where n is the number of carbon atoms in one molecule of the alkane. Here, $n = 3$. So, putting $n = 3$ in this general formula, we get $C_3H_{2\times3+2}$ or C_3H_8. Thus, the molecular formula of the given hydrocarbon, if it is an alkane, is C_3H_8. Please solve the remaining two parts of this problem yourself. The answers will be C_3H_6 for alkene and C_3H_4 for alkyne.

Sample Problem 8. A hydrocarbon molecule contains 4 hydrogen atoms. Give its molecular formula, if it is an : (*i*) alkane, (*ii*) alkene, (*iii*) alkyne.

Solution. (*i*) An alkane containing 4 hydrogen atoms in its molecule is methane, CH_4.

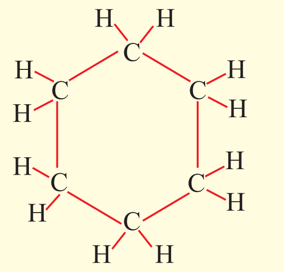
(*ii*) An alkene containing 4 hydrogen atoms in its molecule is ethene, C_2H_4.

(*iii*) An alkyne containing 4 hydrogen atoms in its molecule is propyne, C_3H_4.

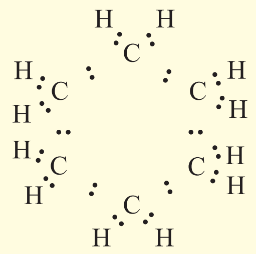
CYCLIC HYDROCARBONS

In addition to the straight chain hydrocarbons and branched chain hydrocarbons, there are some other hydrocarbons in which the carbon atoms are arranged in the form of a ring. Such hydrocarbons are called *cyclic* hydrocarbons. The cyclic hydrocarbons may be saturated or unsaturated. This will become clear from the following examples.

1. A saturated cyclic hydrocarbon is 'cyclohexane'. The formula of cyclohexane is C_6H_{12}. A molecule of cyclohexane contains 6 carbon atoms arranged in a hexagonal ring with each carbon atom having 2 hydrogen atoms attached to it. The structural formula of cyclohexane is shown in Figure 20(*a*) and its electron-dot structure is given in Figure 20(*b*).



(*a*) Structural formula of cyclohexane, C_6H_{12}



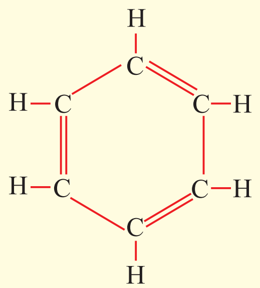
(*b*) Electron-dot structure of cyclohexane, C_6H_{12}

Figure 20.

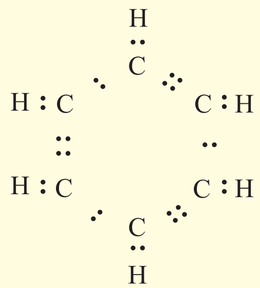
We can see from the structure shown in Figure 20 (*a*) that the cyclohexane molecule has 6 carbon-carbon single bonds and 12 carbon-hydrogen single bonds. Please note that the **electron-dot structure of cyclohexane has been obtained by putting two electron dots in place of every single bond in its structural formula.** This is because every single bond consists of two shared electrons between the atoms.

The saturated cyclic hydrocarbons are called 'cycloalkanes'. Cyclohexane is a cycloalkane having 6 carbon atoms in its molecule. We can also have cycloalkanes with less than 6 (or more than 6) carbon atoms in the ring. Thus, the cycloalkane having 3 carbon atoms in the ring is called **cyclopropane (C_3H_6),** the cycloalkane with 4 carbon atoms in the ring is called **cyclobutane (C_4H_8)** whereas the cycloalkane having 5 carbon atoms in the ring is called **cyclopentane (C_5H_{10}).** Write the structures of cyclopropane, cyclobutane and cyclopentane yourself. Please note that the general formula of cycloalkanes is C_nH_{2n} which is the same as that of *alkenes*.

2. An unsaturated cyclic hydrocarbon is 'benzene'. The formula of benzene is C_6H_6. A molecule of benzene is made up of 6 carbon atoms and 6 hydrogen atoms. The structural formula of benzene is shown in Figure 21(*a*) and its electron-dot structure is given in Figure 21(*b*).



(*a*) Structural formula of benzene, C_6H_6



(*b*) Electron-dot structure of benzene, C_6H_6

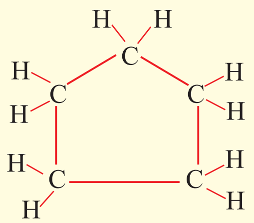
Figure 21.

We can see from the structure shown in Figure 21(*a*) that a benzene molecule has 3 carbon-carbon double bonds and 3 carbon-carbon single bonds. It also has 6 carbon-hydrogen single bonds. Please note that **the electron-dot structure of benzene has been obtained by putting two electron dots in place of every single bond and four electron dots in place of every double bond in its structural formula.** This is because a single bond consists of two shared electrons whereas a double bond consists of four shared electrons between any two atoms. The unsaturated cyclic compounds like benzene are called *aromatic* compounds. We will discuss the cycloalkanes and aromatic hydrocarbons in detail in higher classes. Let us solve one problem now.

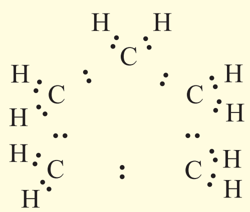
Sample Problem. What will be the formula and electron-dot structure of cyclopentane ?

(NCERT Book Question)

Solution. The molecular formula of cyclopentane is C_5H_{10}. Cyclopentane has 5 carbon atoms in the form of a pentagonal ring which are connected by single bonds. The structural formula and electron-dot structure of cyclopentane are given alongside.



Structural formula of cyclopentane, C_5H_{10}



Electron-dot structure of cyclopentane, C_5H_{10}

NAMING OF HYDROCARBONS

A child may be called 'Bunty' at home but his name in the school register may be 'Birender Kumar'. Just as most of us have two names : one at home and another at school, in the same way, organic compounds have two names : common names, and official names (IUPAC names). The official names or systematic names of organic compounds were given by International Union of Pure and Applied Chemistry in 1958, so they are called IUPAC names or IUPAC nomenclature. We will now discuss the IUPAC nomenclature for hydrocarbons but side by side we will also give their common names. In order to name hydrocarbons by the IUPAC method, we should remember the following points :

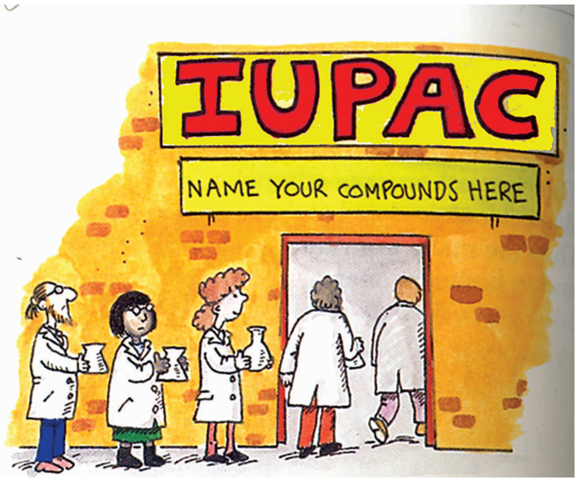


Figure 22. International Union of Pure and Applied Chemistry (IUPAC) devised the sytematic method of naming organic compounds.

1. The number of carbon atoms in a hydrocarbon (or any other organic compound) is indicated by using the following stems :

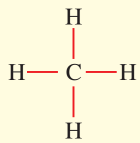
   One carbon atom is indicated by writing '**Meth**'
   Two carbon atoms are indicated by writing '**Eth**'
   Three carbon atoms are indicated by writing '**Prop**'
   Four carbon atoms are indicated by writing '**But**' (read as Bute)
   Five carbon atoms are indicated by writing '**Pent**'
   Six carbon atoms are indicated by writing '**Hex**'
   Seven carbon atoms are indicated by writing '**Hept**'
   Eight carbon atoms are indicated by writing '**Oct**'
   Nine carbon atoms are indicated by writing '**Non**'
   Ten carbon atoms are indicated by writing '**Dec**' (read as Dek)
2. A saturated hydrocarbon containing **single bonds** is indicated by writing the word '**ane**' after the stem.
3. An unsaturated hydrocarbon containing a **double bond** is indicated by writing the word '**ene**' after the stem.
4. An unsaturated hydrocarbon containing a **triple bond** is indicated by writing the word '**yne**' after the stem.

Keeping these points in mind, we will now name some of the hydrocarbons.

Naming of Saturated Hydrocarbons

1. Naming of CH_4. The structure of CH_4 is given alongside. This compound contains 1 carbon atom which is indicated by writing *'meth'*. This compound has all single bonds, so it is saturated. The saturated hydrocarbon is indicated by the ending *'ane'*. On joining *'meth'* and *'ane'*, the IUPAC name of this compound becomes *'methane'* (meth + ane = methane). The common name of CH_4 hydrocarbon is also methane. Thus, **the IUPAC name as well as the common name of the hydrocarbon CH_4 is the same, methane.**

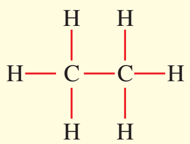
CH_4



IUPAC name : Methane
Common name : Methane

2. Naming of C_2H_6. The structrual formula of C_2H_6 is given below :

C_2H_6



Structural formula
IUPAC name : Ethane
Common name : Ethane

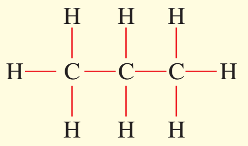
or

CH_3-CH_3
Condensed structural formula

This hydrocarbon contains 2 carbon atoms which are indicated by writing '*eth*'. This hydrocarbon has all single bonds, so it is saturated. The saturated hydrocarbon is indicated by using the suffix or ending '*ane*'. Now, by joining '*eth*' and '*ane*', the IUPAC name of the above hydrocarbon becomes '*ethane*' (eth + ane = ethane). Please note that the common name of C_2H_6 hydrocarbon is also ethane. Again, **the IUPAC name as well as the common name of C_2H_6 hydrocarbon is the same, ethane.**

3. Naming of C_3H_8. The structural formula of the C_3H_8 hydrocarbon is given below :

C_3H_8



IUPAC name : Propane
Common name : Propane

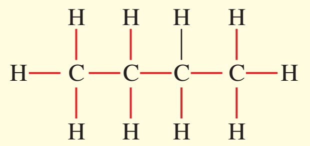
or

$CH_3—CH_2—CH_3$

This hydrocarbon contains 3 carbon atoms which are indicated by the word '*prop*'. This hydrocarbon has all single bonds, so it is saturated. The saturated hydrocarbon is indicated by using the ending '*ane*'. On joining '*prop*' and '*ane*', the IUPAC name of the above hydrocarbon becomes '*propane*' (prop + ane = propane). The common name of C_3H_8 hydrocarbon is also propane. Please note that in this case also **the IUPAC name and common name of the C_3H_8 hydrocarbon is the same, propane**. From the above discussion we conclude that for the saturated hydrocarbons containing up to 3 carbon atoms, the IUPAC names and common names are just the same. But this is not so for the saturated hydrocarbons containing 4 or more carbon atoms. This point will become more clear from the following examples.

4. Naming of C_4H_{10}. One of the structural formula of C_4H_{10} hydrocarbon is given below :

C_4H_{10}



IUPAC name : Butane
Common name : *n*-butane

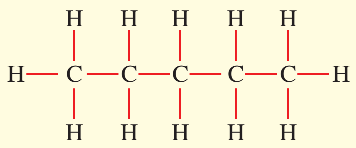
or

$CH_3—CH_2—CH_2—CH_3$

This hydrocarbon has 4 carbon atoms in one continuous chain which are represented by the word '*but*'. This hydrocarbon has all single bonds, so it is saturated. A saturated hydrocarbon is represented by using the ending '*ane*'. So, joining '*but*' and '*ane*', IUPAC name of the above given hydrocarbon structure becomes '*butane*' (but + ane = butane). Now, the above structure has 4 carbon atoms in one continuous chain. Such straight chain compounds are termed 'normal' in the common names. So, the common name of the hydrocarbon having the above structure is 'normal-butane' which is written in short as '*n*-butane' (*n* for normal). Thus, **the IUPAC name of the above hydrocarbon is butane but its common name is *n*-butane.** (We have given here only the straight chain structure of the C_4H_{10} hydrocarbon but it can have another structure with a side chain. Please wait a little for the naming of that structure).

5. Naming of C_5H_{12}. This hydrocarbon can have three possible structures. The simplest one is given below (others will be given later on) :

C_5H_{12}



IUPAC name : Pentane
Common name : *n*-pentane

or

$CH_3—CH_2—CH_2—CH_2—CH_3$

This hydrocarbon has 5 carbon atoms in one continuous chain which are indicated by the word '*pent*'. This hydrocarbon has all single bonds, so it is saturated. A saturated hydrocarbon is indicated by using the ending '*ane*'. Now, by joining *pent* and *ane*, the IUPAC name of the above given hydrocarbon structure becomes *pentane* (pent + ane = pentane). The common name of this hydrocarbon is normal-pentane (which is written in short as *n*-pentane). Thus, **the IUPAC name of the above hydrocarbon is pentane but its common name is *n*-pentane.**

So far we have discussed the naming of saturated hydrocarbons having straight chains only. We will now take up the nomenclature of branched chain saturated hydrocarbons.

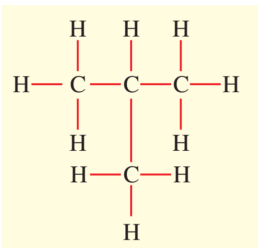
IUPAC Nomenclature for Branched-Chain Saturated Hydrocarbons

In order to name the saturated hydrocarbons having branched chains by the IUPAC method, we should remember the following rules :

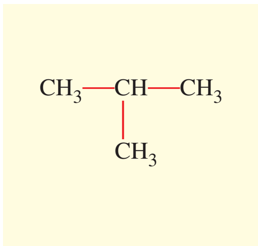
1. The longest chain of carbon atoms in the structure of the compound (to be named) is found first. The compound is then named as a derivative of the alkane hydrocarbon which corresponds to the longest chain of carbon atoms (This is called parent hydrocarbon).
2. The alkyl groups present as side chains (branches) are considered as substituents and named separately as methyl (CH_3—) or ethyl (C_2H_5—) groups.
3. The carbon atoms of the longest carbon chain are numbered in such a way that the alkyl groups (substituents) get the lowest possible number (smallest possible number).
4. The position of alkyl group is indicated by writing the number of carbon atom to which it is attached.
5. The IUPAC name of the compound is obtained by writing the 'position and name of alkyl group' just before the name of 'parent hydrocarbon'.

We will now take some examples to understand how the above rules are applied in the naming of branched chain hydrocarbons.

Example 1. We have already named the straight chain structure of C_4H_{10} hydrocarbon as butane. We will now name the branched chain structure of C_4H_{10} hydrocarbon. Now, the branched chain saturated hydrocarbon having 4 carbon atoms has the following structure with three carbon atoms in the straight chain and the fourth carbon atom in the side chain :



or

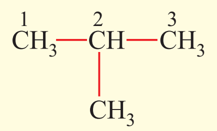


We will now find out its IUPAC name. This can be done as follows :

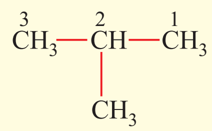
(*i*) There are 3 carbon atoms in the longest chain in the above structure. Now, the alkane containing 3 carbon atoms is propane. So, this compound is to be named as a derivative of propane. That is, the parent hydrocarbon of the above compound is propane (and not butane).

(*ii*) In the above structure, one methyl group (CH_3 group) is present in the side chain of propane. So, the above compound is a methyl derivative of propane.

(*iii*) Let us number the carbon chain in such a way that the methyl group (present in the side chain) gets the lowest possible number. Here, whether we number the carbon chain from left to right or from right to left, the position of methyl group remains the same : the methyl group falls on carbon number 2 (as shown alongside). So, it is actually a '2-methyl' group.



2-methylpropane
(Left to right numbering)

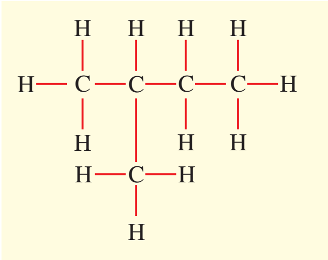


2-methylpropane
(Right to left numbering)

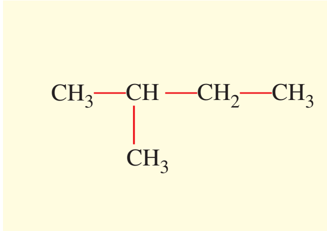
(*iv*) If we join '2-methyl' and 'propane', **the IUPAC name of the above hydrocarbon becomes**

'2-methylpropane'. Please note that 2-methylpropane is also sometimes named as just methylpropane because only one position of the methyl group is possible in this case. **The common name of the hydrocarbon having the above structure is iso-butane.**

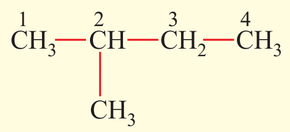
Example 2. We have already named the straight chain structure of C_5H_{12} hydrocarbon. We will now name its branched chain structures (which are called structural isomers). One of the branched chain structures of the C_5H_{12} hydrocarbon is given below. It has four carbon atoms in the straight chain and one carbon atom in the side chain :



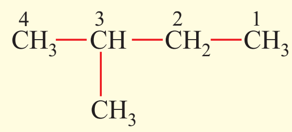
or



This hydrocarbon has a total of five carbon atoms. Let us find out its IUPAC name. There are 4 carbon atoms in the longest carbon chain, so this compound is a derivative of butane. But there is also one extra methyl group (CH_3 group) on one of the carbon atoms of butane and we have to indicate the position of this methyl group. We have to number the carbon chain in such a way that this CH_3 group gets the smallest possible number. There are two ways of numbering this carbon chain, either from left to right or from right to left as shown below.



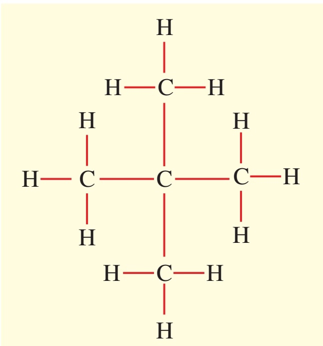
2-methylbutane
(Correct name)
(*i*)



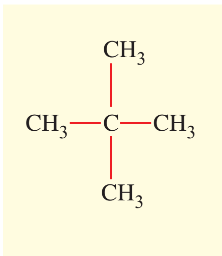
3-methylbutane
(Wrong name)
(*ii*)

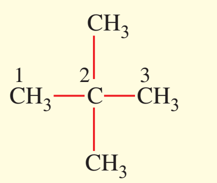
If we number the carbon chain from left hand side to right hand side, then the methyl group comes on carbon number 2 [see structure (*i*)]. Thus, the above compound is butane having a methyl group on carbon number 2. So, its IUPAC name is 2-methylbutane. If, however, we number the carbon chain from right to left, then the methyl group falls on carbon number 3 and hence the name becomes 3-methylbutane [see structure (*ii*)]. Now, out of 2 and 3, figure 2 is the smallest, so the correct name will be 2-methylbutane. Thus, **the IUPAC name of the above branched chain hydrocarbon is 2-methylbutane**. The common name of the above hydrocarbon is **iso-pentane.**

Example 3. A yet another branched chain structure of C_5H_{12} hydrocarbon has three carbon atoms in the straight chain and two carbon atoms in the sides. This is given below :



or





2,2-dimethylpropane

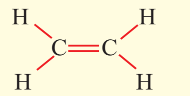
This hydrocarbon contains a total of five carbon atoms. Let us find out its IUPAC name. There are 3 carbon atoms in the longest chain, so this compound is a derivative of propane. But there are two extra methyl groups on the middle carbon atom, so it is actually a dimethylpropane. Now, whether we number this carbon chain from left to right or from right to left, the two methyl groups fall on the same carbon atom, number 2. Since both the methyl groups are on the same carbon atom, number 2, we write the name as 2,2-dimethylpropane. Please note that we cannot write it as 2-dimethylpropane. We have to write 2 two times to show that both the methyl groups are on carbon number 2. Thus, **the IUPAC name of the above branched chain hydrocarbon is 2,2-dimethylpropane.** The common name of the above hydrocarbon is **neo-pentane.**

Naming of Unsaturated Hydrocarbons Containing a Double Bond

In the naming of hydrocarbons containing a double bond by IUPAC method, the presence of double bond is indicated by using the ending 'ene'. Here are some examples.

1. Naming of C_2H_4. The structure of C_2H_4 hydrocarbon is given below :

C_2H_4



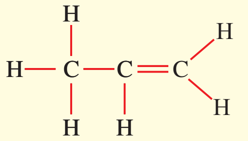
IUPAC name : Ethene
Common name : Ethylene

or $H_2C{=}CH_2$

This hydrocarbon contains 2 carbon atoms which are indicated by writing '*eth*'. This hydrocarbon has a carbon-carbon double bond so it is unsaturated. The double bond is indicated by using the ending '*ene*'. Now, by combining '*eth*' and '*ene*', the IUPAC name of the above hydrocarbon becomes '*ethene*' (eth + ene = ethene). Thus, **the IUPAC name of the unsaturated hydrocarbon containing 2 carbon atoms and a double bond is ethene**. Please note that *the name of an alkene is derived from the name of the corresponding alkane by replacing the suffix ane by ene*. For example, the name ethene is derived from the alkane called ethane having the same number of carbon atoms as ethene. **The common name of ethene ($CH_2{=}CH_2$) is ethylene.**

2. Naming of C_3H_6. The structure of C_3H_6 hydrocarbon is given below :

C_3H_6



IUPAC name : Propene
Common name : Propylene

or $CH_3{-}CH{=}CH_2$

This hydrocarbon has 3 carbon atoms in its molecule which are indicated by writing '*prop*'. This hydrocarbon has also a carbon-carbon double bond, so it is unsaturated. The double bond is indicated by using the ending '*ene*'. So, by joining '*prop*' and '*ene*', the IUPAC name of the above hydrocarbon becomes '*propene*' (prop + ene = propene). Thus, **the IUPAC name of an unsaturated hydrocarbon containing 3 carbon atoms and a double bond is propene**. The common name of propene ($CH_3{-}CH{=}CH_2$) is **propylene**.

The IUPAC name of an unsaturated hydrocarbon containing 4 carbon atoms and a double bond is *butene*. And the IUPAC name of the unsaturated hydrocarbon containing 5 carbon atoms and a double bond is *pentene*.

Naming of Unsaturated Hydrocarbons Containing a Triple Bond

In the naming of unsaturated hydrocarbons containing a triple bond by IUPAC method, the presence of triple bond is indicated by writing the word 'yne' after the stem. Here are some examples.

1. Naming of C_2H_2. The structure of C_2H_2 hydrocarbon is given below :

C_2H_2

$H{-}C{\equiv}C{-}H$

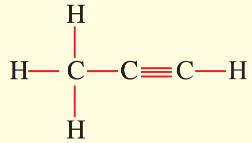
IUPAC name : Ethyne
Common name : Acetylene

or $HC{\equiv}CH$

This hydrocarbon contains 2 carbon atoms which are indicated by writing '*eth*'. This hydrocarbon has a carbon-carbon triple bond in it so it is unsaturated. The triple bond is indicated by using the suffix or ending '*yne*'. Now, by joining '*eth*' and '*yne*', the IUPAC name of the above hydrocarbon becomes '*ethyne*' (eth + yne = ethyne). Thus, **the IUPAC name of an unsaturated hydrocarbon containing 2 carbon atoms and a triple bond is ethyne**. Please note that *the name of an alkyne is derived from the name of the corresponding alkane by replacing the suffix ane by yne.* For example, the name ethyne is derived from the alkane called ethane having the same number of carbon atoms as ethyne. **The common name of ethyne** ($CH\equiv CH$) **is acetylene**.

2. Naming of C_3H_4. The structure of C_3H_4 hydrocarbon is given below :

C_3H_4



IUPAC name : Propyne
Common name : Methyl-acetylene

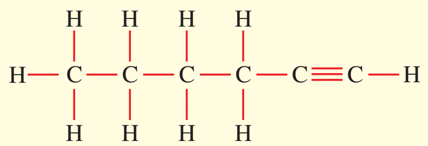
or

$CH_3—C\equiv CH$

This hydrocarbon has 3 carbon atoms in its molecule which are represented by writing '*prop*'. This is an unsaturated hydrocarbon containing a carbon-carbon triple bond. The triple bond is represented by using the ending '*yne*'. So, by joining '*prop*' and '*yne*', the IUPAC name of the above hydrocarbon becomes *propyne* (prop + yne = propyne). Thus, **the IUPAC name of an unsaturated hydrocarbon containing 3 carbon atoms and a triple bond is propyne**. The common name of propyne ($CH_3—C\equiv CH$) is **methyl acetylene**.

The IUPAC name of an unsaturated hydrocarbon containing 4 carbon atoms and a triple bond is *butyne*. And the IUPAC name of the unsaturated hydrocarbon containing 5 carbon atoms and a triple bond is *pentyne*. Let us solve one problem now.

Sample Problem. How would you name the following compound ?



(NCERT Book Question)

Solution. This compound is a hydrocarbon which contains 6 carbon atoms in its molecule. The 6 carbon atoms are indicated by writing '*hex*'. This compound also contains a triple bond which is indicated by the suffix '*yne*'. Now, by combining *hex* and *yne*, the IUPAC name of the above compound becomes *hexyne* (hex + yne = hexyne).

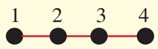
Note. The name hexyne for the above given hydrocarbon does not tell us the position of triple bond in the carbon chain. When we go to higher classes and study position isomerism, we will learn that the above compound is actually 1-hexyne. This is because if we number the carbon chain of this compound from right side to left side, then the triple bond starts from carbon atom number 1 (lowest number rule). The triple bond is actually between carbon number 1 and carbon number 2.

ISOMERS

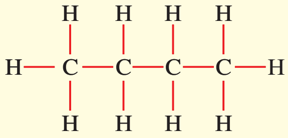
In inorganic chemistry, a given molecular formula represents only one compound. For example, H_2SO_4 represents only one compound, sulphuric acid. In organic chemistry, however, a given molecular formula can represent two or more different compounds. This is because in organic compounds, the same carbon atoms can be arranged in several ways to give different structures and hence different compounds. For example, in organic chemistry, the same molecular formula C_4H_{10} represents two compounds : normal-butane and iso-butane. This point will become more clear from the following example.

Consider an organic compound C_4H_{10} called butane. This compound contains 4 carbon atoms which can be joined in two different ways to give two different structures.

(*i*) First, all the four carbon atoms are joined in a continuous straight chain to give the following structure :

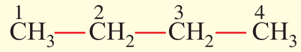


Straight chain of carbon atoms



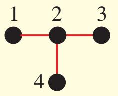
n-butane (C_4H_{10})

or

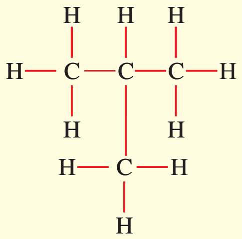


This structure represents the compound normal-butane (which is written in short form as n-butane).

(*ii*) In the second case, three carbon atoms can be put in a straight chain and the fourth carbon atom can be joined in the side chain to give another structure shown below :

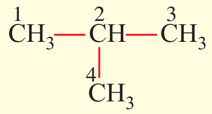


Branched chain of carbon atoms



Iso-butane (C_4H_{10})

or



The compound having this structure is called iso-butane.

We find that both n-butane and iso-butane have the same molecular formula (C_4H_{10}) but they have different structures. They are called isomers. **The organic compounds having the same molecular formula but different structures are known as isomers**. In other words, the organic compounds having the same molecular formula but different arrangements of carbon atoms in them, are known as isomers. Normal-butane and iso-butane are examples of isomers because they have the same molecular formula but different structures (or different arrangements of carbon atoms). Please note that ***normal-butane has a straight chain structure whereas iso-butane has a branched chain structure***. Another point to be noted is that the IUPAC name of n-butane is butane and that of iso-butane is 2-methylpropane (or just methylpropane).

Figure 23. The butane fuel present in LPG cylinders (cooking gas cylinders) is a mixture of both its isomers : n-butane and iso-butane (LPG also contains smaller amounts of propane and ethane).

The existence of two (or more) different organic compounds having the same molecular formula but different structures is called isomerism. **Isomerism is possible only with hydrocarbons having 4 or more carbon atoms**, because only then we can have two or more different arrangements of carbon atoms. No isomerism is possible in hydrocarbons containing 1, 2 or 3 carbon atoms per molecule because then only one arrangement of carbon atoms is possible. For example, **no isomerism is possible in methane, ethane and propane because they contain only one, two or three carbon atoms respectively**. And with only 1, 2 or 3 carbon atoms, it is not possible to have different arrangements of carbon atoms in methane, ethane or propane. **Two isomers of the compound butane (C_4H_{10}) are possible.** The two isomers of butane have been discussed above. **Three isomers of the compound pentane (C_5H_{12}) are possible**. And **five isomers of the compound hexane (C_6H_{14}) are possible**. As the number of carbon atoms in an alkane molecule increases, the number of possible isomers increases rapidly.

In order to draw the structural formulae of all the isomers of an alkane, we should first write all the carbon atoms present in alkane molecule in a straight chain and attach hydrogen atoms to all the free valencies of carbon atoms. This will give us the first isomer which is said to be normal-alkane (say, normal pentane or n-pentane). After this we have to work out as many branched chain isomers of alkane as possible by drawing different arrangements of its carbon atoms. This point will become clear from the following sample problem.

Sample Problem 1. How many structural isomers are possible for pentane ? Draw the structural formulae of all the possible isomers of pentane. **(NCERT Book Question)**

Solution. The molecular formula of pentane is C_5H_{12}. It has 5 carbon atoms. We have to arrange these 5 carbon atoms in different possible ways to obtain all the isomers of pentane.

(*i*) First we write all the 5 carbon atoms in one straight chain [see Figure 24(*a*)]. This will give us an isomer called *n*-pentane (normal-pentane).

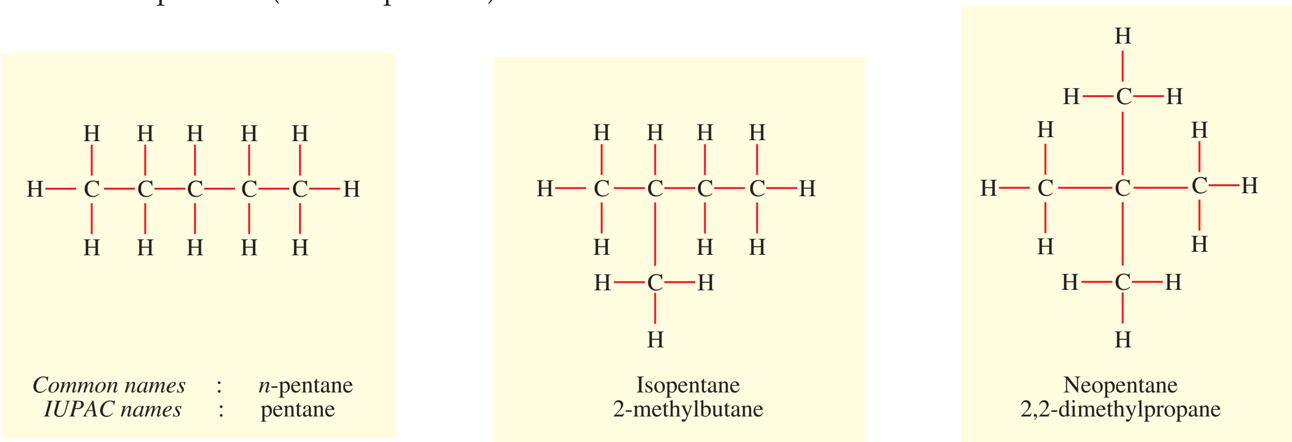


Figure 24. Isomers of pentane (C_5H_{12}).

(*ii*) Next we write 4 carbon atoms in the straight chain and 1 carbon atom in the side chain [see Figure 24(*b*)]. This will give us a second isomer called isopentane.

(*iii*) And finally we put 3 carbon atoms in the straight chain and the remaining 2 carbon atoms in two side chains [see Figure 24(*c*)]. This gives us a third isomer of pentane called neopentane. We cannot have any more arrangements of 5 carbon atoms of pentane. So, **only 3 structural isomers are possible for pentane**.

Sample Problem 2. Write the structural formulae of any two isomers of hexane (C_6H_{14}), other than *n*-hexane.

Solution. Hexane (C_6H_{14}) has 6 carbon atoms in its molecule. Since we are not supposed to write the structural formula of *n*-hexane (normal hexane), so we cannot put all the 6 carbon atoms in one straight chain. Now, first we write 5 carbon atoms in one straight chain and the remaining 1 carbon atom in side chain to obtain one isomer of hexane (called 2-methylpentane) [see Figure 25(*a*)]. Then we write 4 carbon atoms in one straight chain and the remaining 2 carbon atoms in two side chains to get the second isomer (called 2,3-dimethylbutane) [see Figure 25(*b*)].

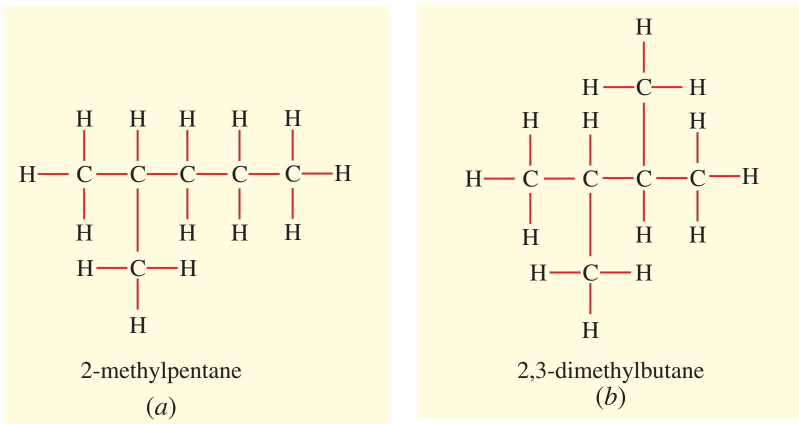


Figure 25. The two isomers of hexane (C_6H_{14}).

Before we go further and describe the classification of organic compounds into homologous series, **please answer the following questions :**

Very Short Answer Type Questions

1. Name the element whose one of the allotropic forms is buckminsterfullerene.
2. What are the two properties of carbon which lead to the formation of a large number of carbon compounds ?
3. State whether the following statement is true or false :
   Diamond and graphite are the covalent compounds of carbon element (C).

4. Name the scientist who disproved the 'vital force theory' for the formation of organic compounds.

5. Name the element whose allotropic form is graphite.

6. In addition to some propane and ethane, LPG cylinders contain mainly two isomers of another alkane. Name the two isomers and write their condensed structural formulae.

7. Buckminsterfullerene is a spherical molecule in which 60 carbon atoms are arranged in interlocking hexagonal and pentagonal rings of carbon atoms.

(*a*) How many hexagons of carbon atoms are present in one molecule of buckminsterfullerene ?

(*b*) How many pentagons of carbon atoms are present in one molecule of buckminsterfullerene ?

8. Name the black substance of pencil. Will the current flow through the electrical circuit when we use the sharpened ends of the pencil to complete the circuit ?

9. How does graphite act as a lubricant ?

10. Name the hardest natural substance known.

11. Which of the following molecule is called buckminsterfullerene ?

C_{90} C_{60} C_{70} C_{120}

12. Give the name and structural formula of an alkyl group.

13. Write the electron-dot structures for : (*i*) ethane, (*ii*) ethene, and (*iii*) ethyne.

14. Give the IUPAC name of the following compound :

C_2H_6

15. Write the structural formula of propene.

16. Write the structural formula of propyne.

17. Write the structural formula of butane.

18. What do you call the compounds having the same molecular formula but different structural arrangements of atoms ?

19. Write the names of any two isomers represented by the molecular formula C_5H_{12}.

20. Write down (*i*) structural formula, and (*ii*) electron-dot formula, of any one isomer of hexane (C_6H_{14}), other than *n*-hexane.

21. Fill in the following blanks with suitable words :

(*a*) The form of carbon which is known as black lead is ....

(*b*) The form of carbon which is used as a lubricant at high temperature is ....

(*c*) Compounds of carbon with hydrogen alone are called ....

(*d*) C_nH_{2n} is the general formula of .... hydrocarbons.

(*e*) Hydrocarbons having the general formula C_nH_{2n-2} are called ....

(*f*) Ethene and ethyne are examples of .... hydrocarbons.

(*g*) Ethyne has .... carbon-hydrogen single bonds.

(*h*) Carbon compounds have usually .... melting points and boiling points because they are .... in nature.

(*i*) The property of carbon atoms to form long chains in compounds is called ....

(*j*) The general formula C_nH_{2n} for cycloalkanes is the same as that of ....

(*k*) The IUPAC name of ethylene is ....

(*l*) The IUPAC name of acetylene is ....

Short Answer Type Questions

22. (*a*) What is the atomic number of carbon. Write its electronic configuration.

(*b*) What type of chemical bonds are formed by carbon ? Why ?

(*c*) Name the three allotropic forms of carbon.

23. (*a*) What is the general name of all the compounds made up of carbon and hydrogen ?

(*b*) Why does carbon form compounds mainly by covalent bonding ?

24. (*a*) What is meant by catenation ? Name two elements which exhibit the property of catenation.

(*b*) Write the names and structural formulae of all the possible isomers of hexane.

25. (*a*) What is buckminsterfullerene ? How is it related to diamond and graphite ?

(*b*) Why is diamond used for making cutting tools (like glass cutters) but graphite is not ?

(*c*) Why is graphite used for making dry cell electrodes but diamond is not ?

26. (*a*) Give the general formula of an : (*i*) alkane (*ii*) alkene (*iii*) alkyne.

(*b*) Classify the following compounds as alkanes, alkenes and alkynes :

C_2H_4, C_3H_4, C_4H_8, C_5H_{12}, C_5H_8, C_3H_8, C_6H_6

27. (*a*) Friedrich Wohler converted an inorganic compound into an organic compound in the laboratory.

(*i*) Give the name and formula of inorganic compound.

(*ii*) Write the name and formula of organic compound formed.

(*b*) Give the molecular formula of butane and mention the names of its two isomers. Name one fuel which contains both these isomers.

28. (*a*) Give IUPAC names and formulae of an organic compound containing single bonds and the other containing a triple bond.

(*b*) Which of the following is the molecular formula of benzene ?

C_6H_6, C_6H_{10}, C_6H_{12}, C_6H_{14}

(*c*) Which of the two has a branched chain : isobutane or normal butane ?

29. Catenation is the ability of an atom to form bonds with other atoms of the same element. It is exhibited by both carbon and silicon. Compare the ability of catenation of the two elements. Give reasons.

30. (*a*) How can diamonds be made artificially ? How do synthetic diamonds differ from natural ones ?

(*b*) Give any two differences between the properties of diamond and graphite. What causes these differences ?

31. (*a*) Why does the element carbon from a large number of carbon compounds ?

(*b*) Write down the structures and names of two isomers of butane (C_4H_{10})

32. (*a*) Give the name and structural formula of one member each of the following :

(*i*) alkane (*ii*) alkene (*iii*) alkyne (*iv*) cycloalkane

(*b*) Give the common name of (*i*) ethyne, and (*ii*) ethene.

(*c*) Write the molecular formula and structure of benzene.

33. (*a*) What is the unique property of carbon atom ? How is this property helpful to us ?

(*b*) Explain why, diamond is hard while graphite is soft (though both are made of carbon atoms).

34. (*a*) Giving their structures, state the number of single bonds, double bonds and triple bonds (if any) in the following compounds :

(*i*) ethyne (*ii*) ethene (*iii*) benzene

(*b*) Write the molecular formula and structure of cyclohexane. How many covalent bonds are there in a molecule of cyclohexane ?

35. (*a*) Write two points of difference in the structures of diamond and graphite.

(*b*) Explain why, graphite can be used as a lubricant but diamond cannot.

(*c*) Explain why, diamond can be used in rock drilling equipment but graphite cannot.

(*d*) State one use of diamond which depends on its 'extraordinary brilliance' and one use of graphite which depends on its being 'black and quite soft'.

Long Answer Type Questions

36. (*a*) What is diamond ? Of what substance is diamond made ?

(*b*) Describe the structure of diamond. Draw a simple diagram to show the arrangement of carbon atoms in diamond.

(*c*) Explain why, diamond has a high melting point.

(*d*) State any two uses of diamond.

37. (*a*) What is graphite ? Of what substance is graphite made ?

(*b*) Describe the structure of graphite with the help of a labelled diagram.

(*c*) Why is graphite a good conductor of electricity but diamond is a non-conductor of electricity ?

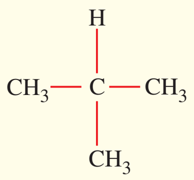
(*d*) State any two uses of graphite.

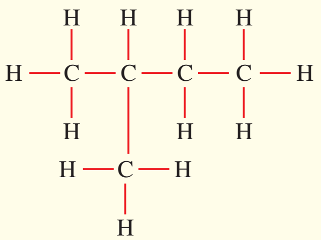
38. (*a*) Explain the term 'isomers'. Give one example of isomers.

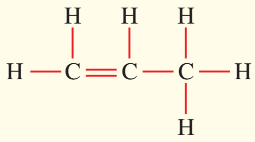
(*b*) Write (*i*) structural formula, and (*ii*) electron-dot structure, of any one isomer of *n*-heptane (C_7H_{16}) .

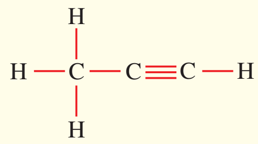
(*c*) Write IUPAC name of the compound having the formula n-C_4H_{10}.

(*d*) Give the IUPAC names for the following :

(*i*) 

(*ii*) 

(*iii*) 

(*iv*) 

39. (*a*) What are hydrocarbons ? Explain with examples.

(*b*) Explain the meaning of saturated and unsaturated hydrocarbons with two examples each.

(*c*) Give the names and structural formulae of one saturated cyclic hydrocarbon and one unsaturated cyclic hydrocarbon.

(*d*) Give one example of a hydrocarbon, other than pentane, having more than three isomers.

(*e*) How many isomers of the following hydrocarbons are possible ?

(*i*) C_3H_8 (*ii*) C_4H_{10} (*iii*) C_5H_{12} (*iv*) C_6H_{14}

Multiple Choice Questions (MCQs)

40. Buckminsterfullerene is an allotropic form of the element :
(*a*) phosphorus (*b*) fluorine (*c*) carbon (*d*) sulphur

41. Out of the following pairs of compounds, the unsaturated compounds are :
(*a*) C_2H_6 and C_4H_6 (*b*) C_6H_{12} and C_5H_{12} (*c*) C_4H_6 and C_6H_{12} (*d*) C_2H_6 and C_4H_{10}

42. The number of covalent bonds in pentane (molecular formula C_5H_{12}) is :
(*a*) 5 (*b*) 12 (*c*) 17 (*d*) 16

43. The property of self-combination of the atoms of the same element to form long chains is known as :
(*a*) protonation (*b*) carbonation (*c*) coronation (*d*) catenation

44. A cyclic hydrocarbon having carbon-carbon single bonds as well as carbon-carbon double bonds in its molecule is :
(*a*) C_6H_{12} (*b*) C_6H_{14} (*c*) C_6H_6 (*d*) C_6H_{10}

45. The hydrocarbon 2-methylbutane is an isomer of :
(*a*) *n*-pentane (*b*) *n*-butane (*c*) propane (*d*) iso-butane

46. An unsaturated hydrocarbon having a triple covalent bond has 50 hydrogen atoms in its molecule. The number of carbon atoms in its molecule will be :
(*a*) 24 (*b*) 25 (*c*) 26 (*d*) 28

47. An alkyne has seventy five carbon atoms in its molecule. The number of hydrogen atoms in its molecule will be :
(*a*) 150 (*b*) 148 (*c*) 152 (*d*) 146

48. A diamond-toothed saw is usually used for cutting :
(*a*) steel girders (*b*) logs of wood (*c*) marble slabs (*d*) asbestos sheets

49. The organic compound prepared by Wohler from an inorganic compound called ammonium cyanate was :
(*a*) glucose (*b*) urea (*c*) uric acid (*d*) vinegar

50. One of the following is not an allotrope of carbon. This is :
(*a*) diamond (*b*) graphite (*c*) cumene (*d*) buckministerfullerene

51. The number of carbon atoms in the organic compound named as 2,2-dimethylpropane is :
(*a*) two (*b*) five (*c*) three (*d*) four

52. The pair of elements which exhibits the property of catenation is :
(*a*) sodium and silicon (*b*) chlorine and carbon (*c*) carbon and sodium (*d*) silicon and carbon

53. A saturated hydrocarbon has fifty hydrogen atoms in its moleucle. The number of carbon atoms in its molecule will be :
(*a*) twenty five (*b*) twenty four (*c*) twenty six (*d*) twenty seven

54. A hydrocarbon having one double bond has 100 carbon atoms in its molecule. The number of hydrogen atoms in its molecule will be :
(*a*) 200 (*b*) 198 (*c*) 202 (*a*) 196

55. The hydrocarbon which has alternate single and double bonds arranged in the form of a ring is :
(*a*) cyclobutane (*b*) benzene (*c*) butene (*d*) hexene

56. Which of the following cannot exhibit isomerism ?
(*a*) C_4H_{10} (*b*) C_5H_{12} (*c*) C_3H_8 (*d*) C_6H_{14}

57. The pencil leads are made of mainly :
(*a*) lithium (*b*) charcoal (*c*) lead (*d*) graphite

58. The number of isomers formed by the hydrocarbon with molecular formula C_5H_{12} is :
(*a*) 2 (*b*) 5 (*c*) 3 (*d*) 4

59. The number of carbon atoms joined in a spherical molecule of buckminsterfullerene is :
(*a*) fifty (*b*) sixty (*c*) seventy (*d*) ninety

Questions Based on High Order Thinking Skills (HOTS)

60. A solid element X has four electrons in the outermost shell of its atom. An allotrope Y of this element is used as a dry lubricant in machinery and also in making pencil leads.
(*a*) What is element X ?
(*b*) Name the allotrope Y.
(*c*) State whether allotrope Y is a good conductor or non-conductor of electricity.
(*d*) Name one use of allotrope Y (other than lubrication and pencil leads)
(*e*) Name two other allotropes of element X.

61. Two organic compounds A and B have the same molecular formula C_6H_{12}. Write the names and structural formulae :
(*a*) if A is a cyclic compound
(*b*) if B is an open chain compound
(*c*) Which compound contains single bonds as well as a double bond ?
(*d*) Which compound contains only single bonds ?

62. The solid element A exhibits the property of catenation. It is also present in the form of a gas B in the air which is utilised by plants in photosynthesis. An allotrope C of this element is used in glass cutters.
(*a*) What is element A ?
(*b*) What is the gas B ?
(*c*) Name the allotrope C.
(*d*) State another use of allotrope C (other than in glass cutters).
(*e*) Name another allotrope of element A which exists as spherical molecules.
(*f*) Name a yet another allotrope of element A which conducts electricity.

63. An element E exists in three allotropic forms A, B and C. In allotrope A, the atoms of element E are joined to form spherical molecules. In allotrope B, each atom of element E is surrounded by three other E atoms to form a sheet like structure. In allotrope C, each atom of element E is surrounded by four other E atoms to form a rigid structure.
(*a*) Name the element E.
(*b*) What is allotrope A ?
(*c*) What is allotrope B ?
(*d*) What is allotrope C ?
(*e*) Which allotrope is used in making jewellery ?
(*f*) Which allotrope is used in making anode of a dry cell ?

64. You are given the following molecular formulae of some hydrocarbons :
C_5H_8 ; C_7H_{14} ; C_6H_6 ; C_5H_{10}; C_7H_{12} ; C_6H_{12}
(*a*) Which formula represents cyclohexane as well as hexene ?
(*b*) Which formula represents benzene ?
(*c*) Which three formulae represent open chain unsaturated hydrocarbons having double bonds ?
(*d*) Which two formulae represent unsaturated hydrocarbons having triple bonds ?
(*e*) Which three formulae can represent cyclic hydrocarbons ?

65. Which of the following compounds can have a triple bond ?

C_2H_4, C_3H_4, C_3H_6

66. Write the molecular and structural formula of a cyclic hydrocarbon whose molecule contains 8 atoms of carbon.

67. What is the molecular formula and structural formula of a cyclic hydrocarbon whose one molecule contains 8 hydrogen atoms ?

68. Write the molecular formula of : (*i*) an alkane (*ii*) an alkene, and (*iii*) an alkyne, each having 20 carbon atoms.

69. Which of the following compounds can have a double bond ?

C_4H_{10}; C_5H_8; C_5H_{10}

70. Which of the following hydrocarbons is unsaturated ?

C_3H_4; C_2H_6

ANSWERS

1. Carbon **2.** Catenation (Self linking of carbon atoms to form long chains) and Tetravalency **3.** False **4.** Friedrich Wohler **5.** Carbon **6.** *n*-butane and iso-butane **7.** (*a*) 20 hexagons (*b*) 12 pentagons **8.** Graphite ; Yes **10.** Diamond **11.** C_{60} **14.** Ethane **18.** Isomers **21.** (*a*) graphite (*b*) graphite (*c*) hydrocarbons (*d*) alkene (*e*) alkynes (*f*) unsaturated (*g*) two (*h*) low ; covalent (*i*) catenation (*j*) alkenes (*k*) ethene (*l*) ethyne **23.** (*a*) Hydrocarbons **24.** (*a*) Carbon and Silicon **26.** (*b*) Alkanes : C_5H_{12} , C_3H_8 ; Alkenes : C_2H_4, C_4H_8 ; Alkynes : C_3H_4, C_5H_8 **27.** (*i*) Ammonium cyanate, NH_4CNO (*ii*) Urea, $CO(NH_2)_2$ **28.** (*b*) C_6H_6 (*c*) isobutane **34.** (*a*) (*i*) Single bonds : Two ; Triple bond: One (*ii*) Single bonds : Four ; Double bond : One (*iii*) Single bonds : Nine ; Double bonds : Three (*b*) No. of covalent bonds : 18 **38.** (*c*) butane (*d*) (*i*) methylpropane (*ii*) 2-methylbutane (*iii*) propene (*iv*) propyne **39.** (*c*) Saturated cyclic hydrocarbon : Cyclohexane ; Unsaturated cyclic hydrocarbon : Benzene (*d*) Hexane, C_6H_{14} (*e*) (*i*) None (*ii*) Two (*iii*) Three (*iv*) Five **40.** (*c*) **41.** (*c*) **42.** (*d*) **43.** (*d*) **44.** (*c*) **45.** (*a*) **46.** (c) **47.** (*b*) **48.** (c) **49.** (*b*) **50.** (c) **51.** (*b*) **52.** (*d*) **53.** (*b*) **54.** (*a*) **55.** (*b*) **56.** (*c*) **57.** (*d*) **58.** (*c*) **59.** (*b*) **60.** (*a*) Carbon (*b*) Graphite (*c*) Good conductor of electricity (*d*) Electrodes (*e*) Diamond and Buckminsterfullerene **61.** (*a*) A is cyclohexane (*b*) B is hexene (*c*) B (*d*) A **62.** (*a*) Carbon (*b*) Carbon dioxide (*c*) Diamond (*d*) For making jewellery (*e*) Buckminsterfullerene (*f*) Graphite **63.** (*a*) Carbon (*b*) Buckminsterfullerene (*c*) Graphite (*d*) Diamond (*e*) C (*f*) B **64.** (*a*) C_6H_{12} (*b*) C_6H_6 (*c*) C_7H_{14}; C_5H_{10}; C_6H_{12} (*d*) C_5H_8 ; C_7H_{12} (*e*) C_7H_{14} ; C_5H_{10} ; C_6H_{12} **65.** C_3H_4 **66.** C_8H_{16} **67.** C_4H_8 **68.** (*i*) $C_{20}H_{42}$ (*ii*) $C_{20}H_{40}$ (*iii*) $C_{20}H_{38}$ **69.** C_5H_{10} **70.** C_3H_4

HOMOLOGOUS SERIES

Just as all the elements having similar electron structures show similar chemical properties and are placed in the same group of the periodic table, in the same way, all the organic compounds having similar structures show similar properties and they are put together in the same group or series. In doing so, the organic compounds are arranged in the order of increasing molecular masses. **A homologous series is a group of organic compounds having similar structures and similar chemical properties in which the successive compounds differ by CH_2 group.** The various organic compounds of a homologous series are called homologues. It is clear that the two adjacent homologues differ by 1 carbon atom and 2 hydrogen atoms (or CH_2 group).

Example of Homologous Series. All the alkanes have similar structures with single covalent bonds and show similar chemical properties, so they can be grouped together in the form of a homologous series. The first five members of the homologous series of alkanes are given alongside.

Homologous Series of Alkanes

Alkane	*Molecular formula*
1. Methane	CH_4
2. Ethane	C_2H_6
3. Propane	C_3H_8
4. Butane	C_4H_{10}
5. Pentane	C_5H_{12}

The general formula of the homologous series of alkanes is C_nH_{2n+2} where n is the number of carbon atoms in one molecule of alkane. Please note that :

First member of alkane series contains 1 carbon atom,

Second member of alkane series contains 2 carbon atoms,

Third member of alkane series contains 3 carbon atoms,

Fourth member of alkane series contains 4 carbon atoms, and

Fifth member of alkane series contains 5 carbon atoms.

Figure 24. The candle wax contains a mixture of heavier alkanes (having high molecular masses).

Characteristics of a Homologous Series

1. All the members of a homologous series can be represented by the same general formula. For example, all the members of the alkane series can be represented by the general formula C_nH_{2n+2}.

2. Any two adjacent homologues differ by 1 carbon atom and 2 hydrogen atoms in their molecular formulae. That is, any two adjacent homologues differ by a CH_2 group. For example, the first two adjacent homologues of the alkane series, methane (CH_4) and ethane (C_2H_6) differ by 1 carbon atom and 2 hydrogen atoms. The difference between CH_4 and C_2H_6 is CH_2.

3. The difference in the molecular masses of any two adjacent homologues is 14 u. For example, the molecular mass of methane (CH_4) is 16 u, and that of its next higher homologue ethane (C_2H_6) is 30 u. So, the difference in the molecular masses of ethane and methane is 30 – 16 = 14 u.

4. All the compounds of a homologous series show similar chemical properties. For example, all the compounds of alkane series like methane, ethane, propane, etc., undergo substitution reactions with chlorine.

5. The members of a homologous series show a gradual change in their physical properties with increase in molecular mass. For example, in the alkane series as the number of carbon atoms per molecule increases, the melting points, boiling points and densities of its members increase gradually.

The existence of homologous series of organic compounds has simplified the study of organic chemistry because instead of studying a large number of organic compounds separately, we have to study only a few homologous series.

Homologous Series of Alkenes

The general formula of the homologous series of alkenes is C_nH_{2n} where n is the number of carbon atoms in one molecule of alkene. The first five members of the homologous series of alkenes are given below.

Alkene	*Molecular formula*
1. Ethene	C_2H_4
2. Propene	C_3H_6
3. Butene	C_4H_8
4. Pentene	C_5H_{10}
5. Hexene	C_6H_{12}

Figure 25. These are raw bananas.

Figure 26. Ethene is used for ripening many raw fruits. These bananas have been ripened by ethene.

Please note that :

First member of alkene series contains 2 carbon atoms,

Second member of alkene series contains 3 carbon atoms,

Third member of alkene series contains 4 carbon atoms,

Fourth member of alkene series contains 5 carbon atoms, and

Fifth member of alkene series contains 6 carbon atoms.

Homologous Series of Alkynes

The general formula of the homologous series of alkynes is C_nH_{2n-2} where n is the number of carbon atoms in one molecule of alkyne. The first five members of the alkyne homologous series are given above.

Alkyne	*Molecular formula*
1. Ethyne	C_2H_2
2. Propyne	C_3H_4
3. Butyne	C_4H_6
4. Pentyne	C_5H_8
5. Hexyne	C_6H_{10}

Figure 27. The common name of ethyne is acetylene. Acetylene forms a polymer called polyacetylene. The flexible polyacetylene sheet shown in this picture was peeled from the walls of the reaction flask in which it was made from acetylene.

Please note that :

First member of alkyne series contains 2 carbon atoms,

Second member of alkyne series contains 3 carbon atoms,

Third member of alkyne series contains 4 carbon atoms,

Fourth member of alkyne series contains 5 carbon atoms, and

Fifth member of alkyne series contains 6 carbon atoms.

We have just given the homologous series of hydrocarbons : alkanes, alkenes and alkynes. **The organic compounds such as haloalkanes, alcohols, aldehydes, ketones and carboxylic acids (organic acids) also form the homologous series.** We will describe all these homologous series after a while. Let us now solve some problems based on the homologous series of hydrocarbons.

Sample Problem 1. Write the molecular formulae of the third and fifth members of homologous series of carbon compounds represented by the general formula C_nH_{2n-2}.

Solution. The general formula C_nH_{2n-2} is of the alkyne series. We know that the first member of the alkyne series is ethyne (C_2H_2) and it has 2 carbon atoms in its molecule.

(*i*) Since the first member of alkyne series has 2 carbon atoms in it, therefore, third member of alkyne series will have 4 carbon atoms in its molecule. So, if we put $n = 4$ in the general formula C_nH_{2n-2}, then the molecular formula of the third member of the alkyne series will be $C_4H_{2\times 4-2}$ or C_4H_6.

(*ii*) Since the first member of alkyne series has 2 carbon atoms in it, therefore, the fifth member of alkyne series will have 6 carbon atoms in it. So, if we put $n = 6$ in the general formula C_nH_{2n-2} then the molecular formula of the fifth member of the alkyne series will be $C_6H_{2\times 6-2}$ or C_6H_{10}.

Please note that we could have solved this problem in just two lines. But we have given all these details to make you understand the method of solving such problems in a systematic way. However, there is no need for the students to write so many details in their examination.

Sample Problem 2. Which of the following belong to the same homologous series ?

C_3H_8, C_3H_6, C_4H_8, C_4H_6

Solution. All these compounds are hydrocarbons, so all that we have to do is to find out which of them are alkanes, alkenes and alkynes.

(*i*) C_3H_8 corresponds to the general formula for alkanes C_nH_{2n+2} (with $n = 3$), therefore, C_3H_8 is an alkane.

(*ii*) C_3H_6 and C_4H_8 correspond to the general formula for alkenes C_nH_{2n} (with $n = 3$ and $n = 4$ respectively), therefore, C_3H_6 and C_4H_8 are both alkenes.

(*iii*) C_4H_6 corresponds to the general formula for alkynes C_nH_{2n-2} (with $n = 4$), therefore, C_4H_6 is an alkyne.

From the above discussion it is clear that C_3H_6 and C_4H_8 belong to the same homologous series of alkenes.

Before we go further, we should know the meaning of the term 'heteroatom'. In organic chemistry, carbon atoms and hydrogen atoms are considered to be the normal constituents of organic compounds. **In an organic compound, any atom other than carbon and hydrogen, is called a heteroatom** (hetero = other or different). Some of the common heteroatoms are halogen atoms [chlorine (Cl), bromine (Br) and iodine (I) atoms], oxygen atom (O), nitrogen atom (N) and sulphur atom (S). In this class we have to study the functional groups of organic compounds containing only two types of heteroatoms : halogen atoms and oxygen atoms.

FUNCTIONAL GROUPS

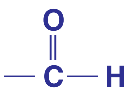
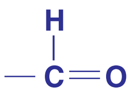
A saturated hydrocarbon is unreactive but if we introduce some other 'atom' or 'group of atoms' into it, the resulting compound becomes very reactive. This other 'atom' or 'group of atoms' present in a carbon compound is known as a functional group. Thus, **an 'atom' or 'a group of atoms' which makes a carbon compound (or organic compound) reactive and decides its properties (or functions) is called a functional group.** The alcohol group, —OH, present in ethanol, C_2H_5OH, is an example of a functional group. Some of the important functional groups present in organic compounds are : Halo group (or Halogeno group), Alcohol group, Aldehyde group, Ketone group, Carboxylic acid group, Alkene group and Alkyne group. These are discussed below.

1. Halo Group : —X (X can be Cl, Br or I)

The halo group can be chloro, —Cl ; bromo, —Br ; or iodo, —I, depending upon whether a chlorine, bromine or iodine atom is linked to a carbon atom of the organic compound. Chloro group is present in chloromethane, CH_3—Cl, bromo group is present is bromomethane, CH_3—Br, and iodo group is present in iodomethane, CH_3—I. Please note that the elements chlorine, bromine and iodine are collectively known as halogens, so the chloro group, bromo group and iodo group are called halo groups and represented by the general symbol —X. So, we can say that the halo group is present in chloromethane (CH_3—Cl), bromomethane (CH_3—Br) and iodomethane (CH_3—I). Please note that **halo group** is also known as **halogeno group.** In fact, halo group is the short form of halogeno group. The haloalkanes can be written as R—X (where R is an alkyl group and X is the halogen atom). The haloalkanes contain halogen atom (Cl, Br or I) as the heteroatom.

2. Alcohol Group : —OH

The alcohol group is made up of one oxygen atom and one hydrogen atom joined together. The alcohol group is also known as alcoholic group or hydroxyl group. The compounds containing alcohol group are known as alcohols. The examples of compounds containing alcohol group are : methanol, CH_3OH, and ethanol, C_2H_5OH. The general formula of an alcohol can be written as R—OH (where R is an alkyl group like CH_3, C_2H_5, etc., and OH is the alcohol group). The alcohols contain oxygen atom (O) as the heteroatom.

3. Aldehyde Group : —CHO or  or 

The aldehyde group consists of one carbon atom, one hydrogen atom and one oxygen atom joined together. Please note that though the oxygen atom of the aldehyde group is attached to the carbon atom but for the sake of convenience in writing, the aldehyde group is written as —CHO (with hydrogen atom in-between the carbon and oxygen atoms). The carbon atom of the aldehyde group is attached to either a hydrogen atom or an alkyl group. The aldehyde group is sometimes called aldehydic group. The compounds containing aldehyde group are known as aldehydes. The examples of compounds containing an aldehyde group are : methanal, HCHO, and ethanal, CH_3CHO. Please note that an aldehyde group always occurs at the end of a carbon chain. The carbon atom of the aldehyde group is attached to only one alkyl group (or only one hydrogen atom as in the case of methanal). The aldehydes can be represented by the general formula R—CHO (where R is an alkyl group).

4. Ketone Group : >C=O or —C(=O)— or —CO—

The ketone group consists of one carbon atom and one oxygen atom. The oxygen atom of the ketone group is joined to the carbon atom by a double bond. The carbon atom of the ketone group is attached to two alkyl groups (which may be same or different). The ketone group is sometimes called a ketonic group. The compounds containing ketone group are known as ketones. The examples of compounds containing ketone group are : propanone, CH_3COCH_3, and butanone, $CH_3COCH_2CH_3$. Please note that a ketone group can occur only in the middle of a carbon chain (in-between two alkyl groups). For example, in propanone (shown above), the ketone group occurs in the middle of the carbon chain, in-between the two CH_3 groups. A ketone group can never occur at the end of a carbon chain (because it has two free valencies which have to be satisfied by two alkyl groups).

5. Carboxylic Acid Group : —COOH or —C(=O)—OH

Carboxylic acid group is present in methanoic acid, H—COOH and ethanoic acid, CH_3—COOH. The carboxylic acid group is also called just carboxylic group or carboxyl group. The organic compounds containing carboxylic acid group (—COOH group) are called carboxylic acids or organic acids.

6. Alkene Group : >C=C<

The alkene group is a carbon-carbon double bond. The alkene group is present in ethene (CH_2=CH_2), and propene (CH_3–CH=CH_2). The compounds containing alkene group are known as alkenes.

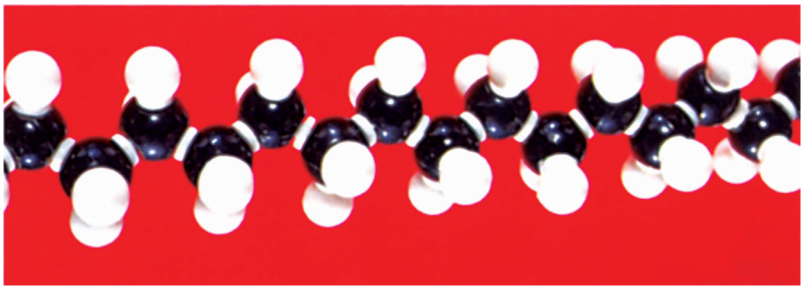


Figure 28. The double bond in ethene enables it to form a polymer called polythene (poly-ethene). This model shows a part of the polythene polymer chain.

Figure 29. This picture shows some of the things which we can make by using polythene.

7. Alkyne Group : —C≡C—

The alkyne group is a carbon-carbon triple bond. The alkyne group is present in ethyne (CH≡CH) and propyne (CH_3—C≡CH). The compounds containing alkyne group are known as alkynes.

The functional group of an organic compound is more reactive than the rest of the molecule. In an organic compound, the functional group determines the chemical properties of the compound. **All the organic compounds having same functional group show similar chemical properties.** For example, all the alcohols have the same functional group (alcohol group, —OH), so all the alcohols show similar chemical properties.

HALOALKANES

When one hydrogen atom of an alkane is replaced by a halogen atom, we get haloalkane (also called halogenoalkane). For example, when one hydrogen atom of methane is replaced by a chlorine atom, we get chloromethane :

$$\underset{\text{Methane}}{CH_4} \xrightarrow{\text{Replace one H by Cl}} \underset{\substack{\text{Chloromethane} \\ \text{(A haloalkane)}}}{CH_3Cl}$$

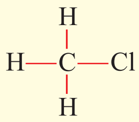
Chloromethane is a haloalkane. The general formula of haloalkanes is C_nH_{2n+1}–X (where X represents Cl, Br or I). The haloalkanes form a homologous series. The first four members of the homologous series of haloalkanes are given in the table on the right side. In this table we have written only four chloroalkanes. We can also write the corresponding bromoalkanes or iodoalkanes.

IUPAC name of haloalkane	*Formula*
1. Chloromethane	CH_3Cl
2. Chloroethane	C_2H_5Cl
3. Chloropropane	C_3H_7Cl
4. Chlorobutane	C_4H_9Cl

Naming of Haloalkanes

In the IUPAC method, all the organic compounds are named after the parent alkane by using certain *prefixes* or *suffixes* to show the presence of the functional group (*prefix* is a word put *before a name* whereas *suffix* is a word put *after a name*.) In the IUPAC method, haloalkanes are named after the parent alkane by using a prefix to show the presence of the halo group such as chloro (—Cl), bromo (—Br) or iodo (—I) group. We will now take some examples to understand the naming of haloalkanes.

1. Let us name CH_3Cl by IUPAC method. This compound contains 1 carbon atom so its parent alkane is methane, CH_4 (because methane also contains 1 carbon atom). This compound contains a chloro group (—Cl group) which is to be indicated by the prefix 'chloro'. So, by combining *chloro* and *methane* we get the name *chloromethane* (chloro + methane = chloromethane). Thus, **the IUPAC name of CH_3Cl is chloromethane**.

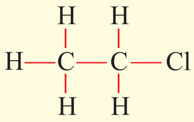
CH_3Cl or CH_3—Cl or 

IUPAC name : Chloromethane

Structure

The common name of chloromethane (CH_3Cl) is **methyl chloride**. Please note that CH_3Br will be bromomethane (or methyl bromide).

2. We will now name C_2H_5Cl by IUPAC method. This compound contains 2 carbon atoms so its parent alkane is ethane. It also contains a chloro group. So, **the IUPAC name of C_2H_5Cl becomes chloroethane**.

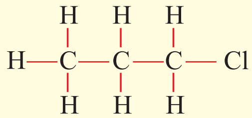
C_2H_5Cl or CH_3—CH_2—Cl or 

IUPAC name : Chloroethane

Structure

The common name of chloroethane is **ethyl chloride**. Please note that C_2H_5Br will be bromoethane (or ethyl bromide).

3. Let us name C_3H_7Cl by IUPAC method. This compound contains 3 carbon atoms so its parent alkane is propane. It also has a chloro group. So, **the IUPAC name of C_3H_7Cl becomes chloropropane**.

C_3H_7Cl or CH_3—CH_2—CH_2—Cl or 

IUPAC name : Chloropropane

Structure

The common name of chloropropane (C_3H_7Cl) is **propyl chloride.**

Note. When we study position isomerism in higher classes, we will learn that the above structure of chloropropane is actually 1-chloropropane. This is because in this structure the chloro group is on the terminal carbon atom which is numbered as carbon 1. We will also find that the common name of the above structure of chloropropane is actually normal-propyl chloride (or *n*-propyl chloride).

ALCOHOLS

Alcohols are the organic compounds containing hydroxyl group (—OH group) attached to a carbon atom. The hydroxyl group (—OH group) is the functional group of alcohols. **The hydroxyl group attached to a carbon atom is known as alcohol group**. The two simple alcohols are methyl alcohol, CH_3OH (which is also known as methanol) and ethyl alcohol, C_2H_5OH (which is also called ethanol). An alcohol is actually a hydroxy derivative of an alkane. So, an alcohol can be supposed to be derived by the replacement of one hydrogen atom (H atom) of an alkane by a hydroxyl group (—OH group). For example, by replacing one hydrogen atom of methane by a hydroxyl group we get an alcohol called methyl alcohol or methanol :

$$\underset{\text{Methane}}{CH_4} \xrightarrow{\text{Replace one H by OH}} \underset{\substack{\text{Methyl alcohol} \\ \text{(or Methanol)}}}{CH_3\text{—}OH}$$

The alcohols form homologous series. The general formula of the homologous series of alcohols is C_nH_{2n+1}—OH, where n is the number of carbon atoms in one molecule of the alcohol. For example, if the number of carbon atoms in an alcohol is one, then $n = 1$, and the formula of this alcohol will be $C_1H_{2\times1+1}$—OH or CH_3—OH. The first four members of the homologous series of alcohols are given in the side table.

IUPAC name of alcohol	*Formula*
1. Methanol	CH_3OH
2. Ethanol	C_2H_5OH
3. Propanol	C_3H_7OH
4. Butanol	C_4H_9OH

(*a*) Methanol (*b*) Ethanol (*c*) Propanol

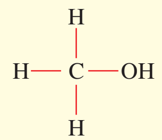
Figure 30. These pictures show the models of the molecules of methanol, ethanol and propanol. The black balls represent carbon atoms, the white balls hydrogen atoms and red ball oxygen atom.

Naming of Alcohols

In the IUPAC method, alcohols are named after the parent alkane by using a suffix to show the presence of functional group. Alcohols are the compounds containing alcohol group —OH. Now, in the word alcohol, the last two letters are *o* and *l*, which taken together make '*ol*'. Thus, '*ol*' is used as a suffix (or ending) to show the presence of alcohol group in an organic compound. In naming the alcohols by IUPAC method, the last '*e*' of the parent 'alkane' is replaced by '*ol*' to indicate the presence of OH group. We will now take some examples to understand the naming of alcohols by the IUPAC method.

1. Let us name the compound CH_3OH by IUPAC method. CH_3OH contains 1 carbon atom, so its parent alkane is methane, CH_4 (which contains 1 carbon atom). It also contains an alcohol group (OH group) which is indicated by using '*ol*' as a suffix or ending. Now, replacing the last '*e*' of methane by '*ol*', we get the name *methanol* (methan + ol = methanol). So, **the IUPAC name of CH_3OH is methanol**.

CH_3OH or



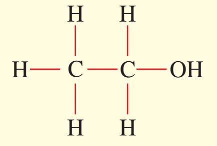
IUPAC name : Methanol

Structure

The common name of methanol is **methyl alcohol.**

2. We will now name C_2H_5OH by IUPAC method. C_2H_5OH contains 2 carbon atoms, so its parent alkane is ethane, C_2H_6 (which contains 2 carbon atoms). It also contains an alcohol group (OH group), which is indicated by using '*ol*' as a suffix or ending. Now, replacing the last '*e*' of ethane by '*ol*' we get the name *ethanol* (ethan + ol = ethanol). Thus, **the IUPAC name of C_2H_5OH is ethanol.**

C_2H_5OH or $CH_3—CH_2—OH$ or



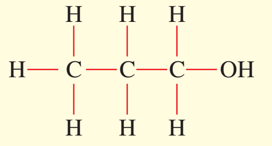
Structure

IUPAC name : Ethanol

The common name of ethanol is **ethyl alcohol**.

3. Let us name C_3H_7OH by IUPAC method. C_3H_7OH contains 3 carbon atoms, so its parent alkane is propane (C_3H_8). It also contains alcohol group (OH group) which is indicated by using '*ol*' as ending. So, replacing the last '*e*' of propane by '*ol*', the name becomes *propanol* (propan + ol = propanol). So, **the IUPAC name of C_3H_7OH becomes propanol**.

C_3H_7OH or $CH_3—CH_2—CH_2—OH$ or



Structure

IUPAC name : Propanol

The common name of propanol is **propyl alcohol**.

Note. When we study position isomerism in higher classes, we will learn that the above structure has the name 1-propanol. This is because in this structure the alcohol group is attached to the terminal carbon atom, which is carbon atom number 1. We will also find that its common name is normal-propyl alcohol or *n*-propyl alcohol.

The parent hydrocarbon of C_4H_9OH is butane (C_4H_{10}), so its IUPAC name is butanol (butan + ol = butanol). We can use this procedure to name any alcohol by the IUPAC method. We will now solve some problems based on alcohols.

Sample Problem 1. Write the molecular formulae of the fourth and fifth members of the homologous series of carbon compounds represented by the general formula $C_nH_{2n+1}—OH$.

Solution. The general formula $C_nH_{2n+1}—OH$ is of alcohol series. Now, to solve such problems, we should know the number of carbon atoms in the first member of the alcohol series. Here, the first member of alcohol series is methanol and it has only 1 carbon atom in its molecule. Knowing this, the above problem can be solved as follows :

(*i*) Since the first member of alcohol series has 1 carbon atom in its molecule, therefore, the fourth member of alcohol series will have 4 carbon atoms in its molecule. So, if we put $n = 4$ in the general formula $C_nH_{2n+1}OH$ then the molecular formula of the fourth member of the homologous series will become $C_4H_{2\times4+1}OH$ or C_4H_9OH.

(*ii*) Since the 1st member of alcohol series has 1 carbon atom in it, therefore, the 5th member will have 5 carbon atoms in it. That is, $n = 5$. So, if we put $n = 5$ in the general formula $C_nH_{2n+1}OH$, then the molecular formula of the fifth member of the alcohol series will become $C_5H_{2\times5+1}OH$ or $C_5H_{11}OH$.

Sample Problem 2. Calculate the difference in the molecular formulae and molecular masses for :

(*a*) CH_3OH and C_2H_5OH

(*b*) C_2H_5OH and C_3H_7OH

(*c*) C_3H_7OH and C_4H_9OH

(*i*) Is there any similarity in these three ?

(*ii*) Arrange these alcohols in the order of increasing carbon atoms to get a family. Can we call this family a homologous series ? **(NCERT Book Question)**

Solution. The atomic mass of C = 12 u, H = 1 u and O = 16 u. So, molecular mass of CH_3OH = 12 + 3 × 1 + 16 + 1 = **32 u.** The molecular mass of C_2H_5OH = 12× 2 + 5 × 1 + 16 + 1 = **46 u**. The molecular mass of C_3H_7OH = 12 × 3 + 7 × 1 + 16 + 1 = **60 u.** And molecular mass of C_4H_9OH = 12 × 4 + 9 × 1 + 16 + 1 = **74 u.**

(*a*) The difference in the molecular formulae of CH_3OH and C_2H_5OH is CH_2. The difference in the molecular masses of CH_3OH and C_2H_5OH is 46 – 32 = 14 u.

(*b*) The difference in the molecular formulae of C_2H_5OH and C_3H_7OH is CH_2. And the difference in the molecular masses of C_2H_5OH and C_3H_7OH is 60 – 46 = 14 u.

(*c*) The difference in the molecular formulae of C_3H_7OH and C_4H_9OH is CH_2. And the difference in the molecular masses of C_3H_7OH and C_4H_9OH is 74 – 60 = 14 u.

(*i*) Yes, there is a similarity in the difference between their molecular formulae and molecular masses. Their molecular formulae differ by CH_2 (1 carbon atom and 2 hydrogen atoms), and their molecular masses differ by 14 u.

(*ii*) These alcohols can be arranged in the order of the increasing carbon atoms as follows :

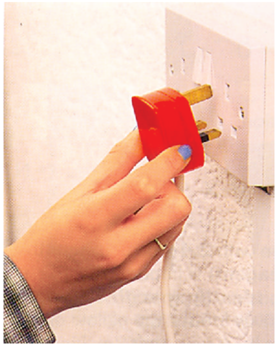
CH_3OH, C_2H_5OH, C_3H_7OH, C_4H_9OH

Yes, we can call it a homologous series.

ALDEHYDES

Aldehydes are the carbon compounds (or organic compounds) containing an aldehyde group (—CHO group) attached to a carbon atom. The two simple aldehydes are formaldehyde, HCHO (which is also called methanal) and acetaldehyde, CH_3CHO (which is also called ethanal). The general molecular formula of aldehydes is $C_nH_{2n}O$ (where *n* is the number of carbon atoms in one molecule of the aldehyde). For example, if the number of carbon atoms in an aldehyde is 1, then *n* = 1, and its molecular formula will be $C_1H_{2\times1}O$ or CH_2O. This aldehyde must contain an aldehyde group, —CHO, so its chemical formula will be HCHO. The aldehydes also form homologous series. The first four members of the homologous series of aldehydes are given in the table above.

IUPAC name of aldehyde	*Formula of aldehyde*
1. Methanal	HCHO
2. Ethanal	CH_3CHO
3. Propanal	CH_3CH_2CHO
4. Butanal	$CH_3CH_2CH_2CHO$



(*a*) Methanal or formaldehyde is used in making plastic for plugs and sockets, etc.

(*b*) A solution of methanal or formaldehyde in water (called formalin) is used to preserve biological specimens.

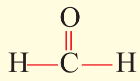
Figure 31. Some uses of aldehydes.

Naming of Aldehydes

Aldehydes are the compounds containing, —CHO group. Now, in the name 'aldehyde', the first two letters make '*al*'. So, the word '*al*' is used as a suffix (or ending) to show the presence of an aldehyde group in an organic compound. In the naming of aldehydes by the IUPAC method, the last '*e*' of the parent alkane is replaced by '*al*' to indicate the presence of an aldehyde group. We will now take some examples to understand the naming of aldehydes by the IUPAC method.

1. Let us name the compound HCHO by IUPAC method. HCHO contains 1 carbon atom, so its parent alkane (or parent hydrocarbon) is methane, CH_4 (because methane also contains 1 carbon atom). HCHO also contains an aldehyde group (–CHO group) which is indicated by using *'al'* as suffix or ending. So, replacing the last *'e'* of methane by *'al'* we get the name *methanal* (methan + al = methanal). Thus, **the IUPAC name of HCHO is methanal.**

HCHO or H—CHO or

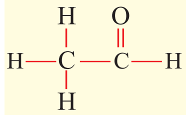


IUPAC name : Methanal — Structure

The common name of methanal (HCHO) is **formaldehyde.**

2. We will now name the compound CH_3CHO by IUPAC method. Now, CH_3CHO contains 2 carbon atoms, so its parent hydrocarbon is ethane (because ethane also contains 2 carbon atoms). CH_3CHO also contains an aldehyde group (–CHO group) which is indicated by using *'al'* as ending. So, by replacing the last *'e'* of ethane by *'al'*, the name becomes *ethanal* (ethan + al = ethanal). Thus, **the IUPAC name of CH_3CHO is ethanal.**

CH_3CHO or CH_3—CHO or

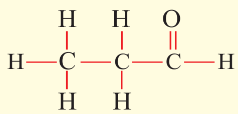


IUPAC name : Ethanal — Structure

The common name of ethanal (CH_3CHO) is **acetaldehyde.**

3. Let us see how the compound CH_3CH_2CHO can be named. CH_3CH_2CHO contains 3 carbon atoms so its parent alkane is propane (because propane also contains 3 carbon atoms). Now, CH_3CH_2CHO also contains an aldehyde group (–CHO group) which is indicated by writing *'al'* as suffix or ending. So, by replacing the last *'e'* of propane by *'al'* we get the name *propanal* (propan + al = propanal). Thus, **the IUPAC name of CH_3CH_2CHO is propanal.**

CH_3CH_2CHO or CH_3—CH_2—CHO or



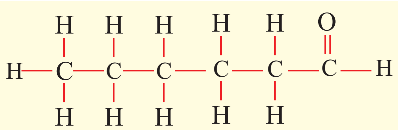
IUPAC name : Propanal — Structure

The common name of propanal (CH_3CH_2CHO) is **propionaldehyde.** Please note that the formula of propanal, CH_3CH_2CHO, can also be written as C_2H_5CHO. The parent hydrocarbon of $CH_3CH_2CH_2CHO$ is butane, so its IUPAC name will be butanal. (The formula of butanal can also be written as C_3H_7CHO). In this way, we can name any aldehyde containing any number of carbon atoms by this method. Let us solve one problem now.

Sample Problem. Draw the structure for the following compound :

Hexanal **(NCERT Book Question)**

Solution. Hexanal is an aldehyde containing 6 carbon atoms (hexanal = hexan + al). The structure of hexanal is given below :



KETONES

Ketones are the carbon compounds (or organic compounds) containing the ketone group, —CO— group. Please note that a ketone group always occurs in the middle of a carbon chain, so a ketone must contain at least three carbon atoms in its molecule, one carbon atom of the ketone group and two carbon atoms on its two sides. There can be no ketone with less than three carbon atoms in it. The simplest ketone is acetone, CH_3COCH_3 (which is also known as propanone). This simplest ketone contains three carbon atoms in it (one carbon atom of the ketone group and two carbon atoms of the two methyl groups). The general molecular formula of ketones is $C_nH_{2n}O$ (where n is the number of carbon atoms in one molecule of the ketone). For example, if the number of carbon atoms in a ketone is 3, then $n = 3$, and its molecular formula will be $C_3H_{2\times3}O$ or C_3H_6O. This ketone having the molecular formula C_3H_6O can be written as CH_3COCH_3. Thus, the chemical formula of a ketone having 3 carbon atoms in its molecule is CH_3COCH_3. It is acetone or propanone. The ketones form a homologous series. The first four members of the homologous series of ketones are given in the above table.

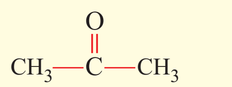
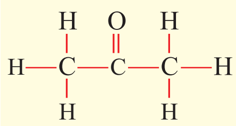
IUPAC name of ketone	*Formula of ketone*
1. Propanone	CH_3COCH_3
2. Butanone	$CH_3COCH_2CH_3$
3. Pentanone	$CH_3COCH_2CH_2CH_3$
4. Hexanone	$CH_3COCH_2CH_2CH_2CH_3$

Figure 32. Propanone (or acetone) is a ketone which is a very good solvent. Nail polish remover is a solvent for nail polish. Propanone (or acetone) is used as nail polish remover by women.

Naming of Ketones

Ketones are the compounds containing the ketone group, —CO— group. In the name ketone, the last three letters make '*one*' (read as 'own'). So, the word '*one*' is used as a suffix (or ending) to show the presence of a ketone group in a carbon compound (or organic compound). In naming the ketones by the IUPAC method, the last '*e*' of the parent alkane is replaced by '*one*' to indicate the presence of a ketone group. We will now take some examples to learn the naming of ketones by the IUPAC method.

1. Let us name the compound CH_3COCH_3 by IUPAC method. CH_3COCH_3 contains 3 carbon atoms, so its parent alkane is propane (because propane also contains 3 carbon atoms). Now, CH_3COCH_3 also contains a ketone group (—CO— group) which is indicated by using '*one*' as ending. So, by replacing the last '*e*' of propane by '*one*', we get the name *propanone* (propan + one = propanone). Thus, **the IUPAC name of CH_3COCH_3 is propanone.**

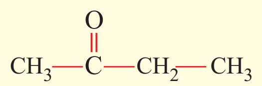
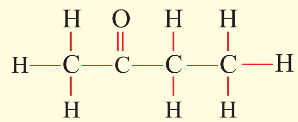
CH_3COCH_3 or  or 

IUPAC name : Propanone

Structure

The common name of propanone is **acetone**. Propanone is the simplest ketone.

2. We will now name the compound $CH_3COCH_2CH_3$ by IUPAC method. This compound contains 4 carbon atoms, so its parent alkane is butane. It also contains a ketone group (—CO— group) which is indicated by using '*one*' as ending. Now, replacing the last '*e*' of butane by '*one*', we get the name *butanone* (butan + one = butanone). Thus, **the IUPAC name of the compound $CH_3COCH_2CH_3$ is butanone.**

$CH_3COCH_2CH_3$ or  or 

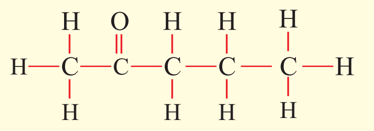
IUPAC name : Butanone

Structure

The common name of butanone is **ethyl methyl ketone.**

3. Let us now name the compound $CH_3COCH_2CH_2CH_3$ by IUPAC method. This compound contains 5 carbon atoms, so its parent alkane is pentane. It also contains a ketone group (—CO— group) which is indicated by using '*one*' as suffix or ending. So by replacing the last '*e*' of pentane by '*one*', the name becomes *pentanone* (pentan + one = pentanone). Thus, the **IUPAC name of the compound $CH_3COCH_2CH_2CH_3$ is pentanone.**

$CH_3COCH_2CH_2CH_3$ or



IUPAC name : Pentanone — Structure

The common name of pentanone is **methyl propyl ketone.**

Note. When we study position isomersim in higher classes, we will learn that the above structure is named as 2-pentanone because the ketone group involves the carbon atom number 2. For the time being, we can call it just pentanone.

CARBOXYLIC ACIDS (OR ORGANIC ACIDS)

The carbon compounds (or organic compounds) containing carboxylic acid group (—COOH group) are called carboxylic acids. Carboxylic acids are commonly known as organic acids. Another name for carboxylic acids is alkanoic acids. The carboxylic acids or organic acids are made up of three elements : carbon, hydrogen and oxygen. The simplest carboxylic acid (or organic acid) is formic acid, HCOOH, which is also known as methanoic acid. The most common carboxylic acid (or organic acid) is, however, acetic acid, CH_3COOH, which is also called ethanoic acid. The carboxylic acids (or organic acids) form a homologous series. This is discussed below.

The general formula of the homologous series of carboxylic acids (organic acids or alkanoic acids) is R—COOH where R is an alkyl group like methyl, CH_3, ethyl, C_2H_5, etc. Only in the case of simplest organic acid, formic acid, H—COOH, R is a hydrogen atom, H. The first four members of the homologous series of organic acids (carboxylic acids or alkanoic acids) are given in the side.

IUPAC name of acid	*Formula of acid*
1. Methanoic acid	HCOOH
2. Ethanoic acid	CH_3COOH
3. Propanoic acid	C_2H_5COOH
4. Butanoic acid	C_3H_7COOH

(*a*) Methanoic acid (*b*) Ethanoic acid (c) Propanoic acid

Figure 33. These pictures show the models of the molecules of methanoic acid, ethanoic acid and propanoic acid. The black balls represent carbon atoms, white balls hydrogen atoms and red balls oxygen atoms.

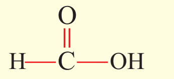
Naming of Carboxylic Acids (or Organic Acids)

In the IUPAC system, the carboxylic acids are named as alkanoic acids. The IUPAC name of an organic acid is obtained by replacing the last '*e*' of the parent alkane by '*oic*' and adding the word '*acid*' to the name thus obtained. In other words, the organic acids are named in IUPAC method by replacing the last '*e*' of parent alkane by '*oic acid*' We will now give some examples to understand the naming of carboxylic acids by IUPAC method.

1. Let us name the compound HCOOH by IUPAC method. This compound contains 1 carbon atom so its parent alkane is methane. It also contains a carboxylic acid group (—COOH group). The name of this compound can be obtained by replacing the last *'e'* of methane by *'oic acid'* so it becomes *methanoic acid* (methan + oic acid = methanoic acid). Thus, **the IUPAC name of HCOOH is methanoic acid.**

HCOOH or

IUPAC name : Methanoic acid



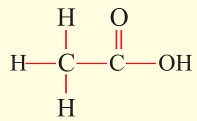
Structure

The common name of methanoic acid (HCOOH) is **formic acid.**

2. We will now name the compound CH_3COOH by IUPAC method. Now, this compound contains 2 carbon atoms so its parent alkane is ethane. It also contains a carboxylic acid group (—COOH group). The name of this compound can be obtained by replacing the last *'e'* of ethane by *'oic acid'* which becomes *ethanoic acid* (ethan + oic acid = ethanoic acid). Thus, **the IUPAC name of CH_3COOH is ethanoic acid.**

CH_3COOH or

IUPAC name : Ethanoic acid



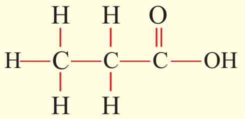
Structure

The common name of ethanoic acid (CH_3COOH) is **acetic acid.**

3. Let us name the compound CH_3CH_2COOH by IUPAC method. This compound contains 3 carbon atoms, so its parent alkane is propane. It also contains a carboxylic acid group (—COOH group). The name of this compound can be obtained by replacing the last *'e'* of propane by *'oic acid'* which gives us *propanoic acid* (propan + oic acid = propanoic acid). So, **the IUPAC name of CH_3CH_2COOH is propanoic acid.**

CH_3CH_2COOH or

IUPAC name : Propanoic acid



Structure

Please note that the formula of propanoic acid can also be written as C_2H_5COOH (which is the same as CH_3CH_2COOH). Another point to be noted is that the common name of propanoic acid is **propionic acid.**

COAL AND PETROLEUM

A fuel is a material that has energy stored inside it. **When a fuel is burned, the energy is released mainly as heat** (and some light). This heat energy can be used for various purposes like cooking food, heating water, and for running generators in thermal power stations, machines in factories and engines of motor cars. Most of the common fuels are either *free carbon* or *carbon compounds.* For example, the fuels such as coal, coke and charcoal contain free carbon whereas the fuels such as kerosene, petrol, LPG and natural gas, are all carbon compounds.

When carbon in any form (coal, coke, charcoal, etc.) is burned in the oxygen (of air), it forms carbon dioxide gas and releases a large amount of heat and some light :

$$\underset{\substack{\text{Carbon}\\\text{(Coal, coke}\\\text{or charcoal)}}}{C} + \underset{\substack{\text{Oxygen}\\\text{(From air)}}}{O_2} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2} + \text{Heat} + \text{Light}$$

Though diamond and graphite are also free carbon, they are not burned as fuels. **Most of the fuels which we use today are obtained from coal, petroleum and natural gas.** Actually, *coal, petroleum and natural gas are known as fossil fuels.* Let us see why they are called fossil fuels. Fossils are the remains of the pre-historic animals or plants buried under the earth, millions of years ago. Coal, petroleum and natural gas are known as fossil fuels because they were formed by the decomposition of the remains of the pre-historic plants and animals (fossils) buried under the earth, long, long, ago.

Coal is a complex mixture of compounds of carbon, hydrogen and oxygen, and some free carbon. Small amounts of nitrogen and sulphur compounds are also present in coal. It is found in deep coal mines under the surface of earth.

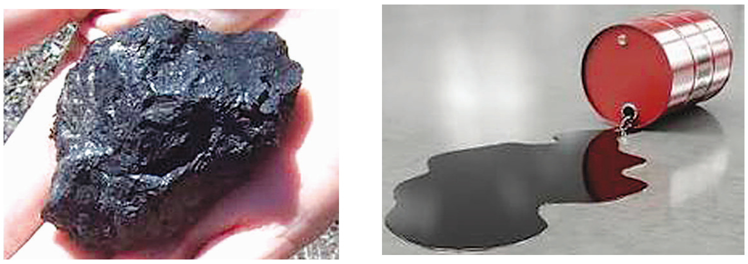
How Coal was Formed

Coal was formed by the decomposition of large land plants and trees buried under the earth millions of years ago. It is believed that millions of years ago, due to earthquakes and volcanoes, etc., the forests were buried under the surface of the earth and got covered with sand, clay and water. Due to high temperature and high pressure inside the earth, and in the absence of air, wood was converted into coal.

Petroleum is dark coloured, viscous, and foul smelling crude oil. The name petroleum means rock oil (petra = rock; oleum = oil). It is called petroleum because it is found under the crust of earth trapped in rocks. **The crude oil petroleum is a complex mixture of several solid, liquid and gaseous hydrocarbons mixed with water, salt and earth particles.** Thus, the crude petroleum oil is not a single chemical compound, it is a mixture of compounds. The fuels such as petrol, kerosene, diesel and LPG are obtained from petroleum.

How Petroleum was Formed

Petroleum oil (and natural gas) were formed by the decomposition of the remains of extremely small plants and animals buried under the sea millions of years ago. It is believed that millions of years ago, the microscopic plants and animals which lived in seas, died. Their bodies sank to the bottom of the sea and were soon covered with mud and sand. The chemical effects of pressure, heat and bacteria, converted the remains of microscopic plants and animals into petroleum oil and natural gas just as they converted forest trees into coal. This conversion took place in the absence of oxygen or air. The petroleum thus formed got trapped between two layers of impervious rocks (non-porous rocks) forming an oil trap. Natural gas is above this petroleum oil.



(*a*) Coal (*b*) Petroleum (Crude oil)

Figure 34. Coal and petroleum are fossil fuels.

The fuels such as coal and petroleum have some nitrogen and sulphur in them. So, when coal, and petroleum fuels (like petrol and diesel) are burnt, they lead to the formation of oxides of nitrogen and sulphur which go into air. These oxides of nitrogen and sulphur are the major *pollutants* in the air (or environment).

Why do Substances Burn with a Flame or without a Flame

We are all familiar with a candle flame. A candle, cooking gas (LPG), and kerosene oil, all burn with a flame. *A flame is the region where combustion (or burning) of gaseous substances takes place*. So, a flame is produced only *when gaseous substances burn.* **All the gaseous fuels burn with a flame but only those solid and liquid fuels which vaporise on heating (to form a gas), burn with a flame.** For example, cooking gas (LPG) is a gaseous fuel which burns with a flame but wax and kerosene oil are solid and liquid fuels respectively, which vaporise (or form gas) on heating and hence burn with a flame. **Flames are of two types : blue flame and yellow flame.** When fuels burn, the type of flame produced depends on the proportion of oxygen (of air) which is available for the burning of fuel or combustion of fuel. This is discussed below.

1. When the oxygen supply (or air supply) is sufficient, then the fuels burn completely producing a blue flame. This blue flame does not produce much light, so it is said to be non luminous (or non light-giving) flame. In a gas stove, cooking gas (LPG) burns with a blue, non-luminous flame (see Figure 35) This can be explained as follows : The gas stove has holes (or inlets) for air to mix properly with cooking gas. The cooking gas gets sufficient oxygen from this air and hence burns completely producing a blue flame. Thus, *complete combustion of cooking gas takes place in a gas stove.*

Figure 35. Cooking gas (LPG) burns in a gas stove with a blue, non-luminous flame.

2. When the oxygen supply (or air supply) is insufficient, then the fuels burn incompletely producing mainly a yellow flame. The yellow colour of flame is caused by the glow of hot, unburnt carbon particles produced due to the incomplete combustion of fuel. This yellow flame produces light, so it is said to be a luminous (light-giving) flame. When wax is burned in the form of a candle, it burns with a yellow, luminous flame (see Figure 36). This can be explained as follows : When a candle is lighted, the wax melts, rises up the wick and gets converted into vapours. In a candle, there is no provision for the proper mixing of oxygen (of air) for burning wax vapours. So, in a candle the wax vapours burn in an insufficient supply of oxygen (of air) which leads to incomplete combustion of wax. The incomplete combustion of wax in a candle produces small unburnt carbon particles. These solid carbon particles rise in the flame, get heated and glow to give out yellowish light. This makes the candle flame yellow and luminous. The unburnt carbon particles then leave the candle flame as soot and smoke. Thus, *incomplete combustion of wax takes place in a candle.* We will now discuss the case of those fuels which burn without producing a flame.

Figure 36. A wax candle burns with a yellow, luminous flame.

Those solid and liquid fuels which do not vaporise on heating, burn without producing a flame. For example, coal and charcoal burn in an *'angithi'* without producing a flame. They just glow red and give out heat. This happens as follows : Coal and charcoal contain some volatile substances. So, when coal or charcoal are ignited, the volatile substances present in them vaporise and they burn with a flame in the beginning. When all the volatile substances present in coal and charcoal get burnt, then the remaining coal or charcoal just glows red and gives heat without producing any flame (see Figure 37). Before we go further and describe the chemical properties of carbon compounds, **please answer the following questions:**

Figure 37. Coal burns without producing a flame. It just glows red.

Very Short Answer Type Questions

1. Write the molecular formula of ethanol.
2. What is the next higher homologue of methanol (CH_3OH) ?
3. Identify the functional group present in the following compound and name it according to IUPAC system :
   CH_3OH
4. Give the common name and IUPAC name of the simplest aldehyde.
5. What is the common name of methanal ?
6. Write the names of the following functional groups :

   (*a*) $—C{\equiv}C—$ (*b*) $>C{=}C<$
7. Name the simplest ketone.
8. What is the common name of propanone ?
9. Write the IUPAC names of the following :
   (*i*) CH_3COCH_3 (*ii*) $CH_3COCH_2CH_3$

10. Write the name and chemical formula of the simplest organic acid.

11. Write the IUPAC names, common names and formulae of the first two members of the homologous series of carboxylic acids.

12. What is the common name of : (*a*) methanoic acid, and (*b*) ethanoic acid ?

13. Draw the structures for the following compounds :
(*a*) Ethanoic acid (*b*) Propanoic acid

14. Give the common names and IUPAC names of the following compounds :
(*a*) HCOOH (*b*) CH_3COOH

15. Give the name and structural formula of one homologue of HCOOH.

16. Write the formulae of : (*a*) methanoic acid, and (*b*) ethanoic acid.

17. Give the common name and IUPAC name of C_2H_5OH.

18. Give the IUPAC name of the following compound :
C_3H_7OH

19. Give the name and structural formula of one member of the following :
Alcohols

20. Give IUPAC names of the following compounds :
(*a*) C_4H_9OH (*b*) $C_5H_{11}OH$

21. What is the common name of methanol ?

22. What is the difference between two consecutive homologues :
(*i*) in terms of molecular mass ?
(*ii*) in terms of number and kind of atoms per molecule ?

23. What type of fuels :
(*a*) burn with a flame ?
(*b*) burn without a flame ?

24. State whether the following statement is true or false :
The minimum number of carbon atoms in a ketone molecule is two.

25. Fill in the following blanks with suitable words :
(*a*) The next higher homologue of ethanol is ....
(*b*) The next homologue of C_2H_5OH is ....
(*c*) The next higher homologue of ethane is ....
(*d*) The functional group present in ethanol is ....
(*e*) Organic compounds having $-\overset{\overset{O}{\|}}{C}-OH$ functional group are known as ....

Short Answer Type Questions

26. (*a*) Give the general name of the class of compounds having the general formula C_nH_{2n-2} . Write name of the first member of this homologous series.
(*b*) The general formula of a homologous series of carbon compounds is C_nH_{2n}. Write the molecular formulae of the second and fourth members of the series.
(*c*) Write the molecular formulae of the third and fifth members of homologous series of carbon compounds represented by the general formula C_nH_{2n+2}

27 (*a*) Give the names and structural formulae of the next two higher homologues of methane.
(*b*) The molecular formula of a hydrocarbon is $C_{10}H_{18}$. Name its homologous series.
(*c*) Select the hydrocarbons which are members of the same homologous series. Give the name of each series.
C_5H_{10} ; C_3H_8 ; C_6H_{10} ; C_4H_{10}; C_7H_{12} ; C_8H_{16}

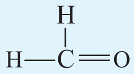
28. (*a*) Give the molecular formula of one homologue of each of the following :
(*i*) C_3H_6 (*ii*) C_2H_6 (*iii*) C_2H_2
(*b*) What is the difference in the molecular mass of any two adjacent homologues ?
(*c*) By how many carbon atoms and hydrogen atoms do any two adjacent homologues differ ?

29. (*a*) Write the formula of the functional group present in carboxylic acids.
(*b*) Name the functional group present in $CH_3-C\equiv CH$.
(*c*) Name the functional groups present in the following compounds :
(*i*) CH_3CHO (*ii*) CH_3CH_2COOH (*iii*) CH_3COCH_3 (*iv*) $CH_3CH_2CH_2OH$

30. (*a*) Write the IUPAC name and common name of CH_3Cl.
(*b*) Draw the structure of chlorobutane.
(*c*) Draw the structure for bromopentane. Are structural isomers possible for bromopentane ?

31. (*a*) Write the name and formula of an organic compound containing a ketone functional group.
(*b*) Write the names and formulae for the first three members of the homologous series of chloroalkanes.
(*c*) How would you name the following compound ?
CH_3-CH_2-Br

32. (*a*) What is the general name of the organic compounds containing the $-\overset{\overset{\displaystyle O}{\|}}{C}-$ group ?
(*b*) Which of the following compounds contains a carboxylic acid group ?
CH_3OH, CH_3COOH, CH_3CHO, CH_3COCH_3
(*c*) How would you name the following compound ?



33. (*a*) Define a homologous series. Give the name and structural formula of one homologue of the following :
CH_3OH
(*b*) Write the molecular formula of the third member of the homologous series of carbon compounds with general formula $C_nH_{2n+1}OH$.
(*c*) Name any two fossil fuels.

34. (*a*) Draw the structures for the following compounds :
(*a*) Propanone (*b*) Butanone
(*b*) Write the IUPAC names of the following :
(*i*) HCHO (*ii*) CH_3CHO (*iii*) CH_3CH_2CHO (*iv*) $CH_3CH_2CH_2CHO$
(*c*) Which functional group is likely to be present in an organic compound having the molecular formula $C_4H_{10}O$? Write the formula of the organic compound.

35. (*a*) Match the formulae in group A with appropriate names from group B :
Group A : CH_3COOH, CH_3CHO, CH_3OH
Group B : Ethanol, Methanol, Ethanal, Ethanoic acid
(*b*) Draw the structure of butanoic acid.
(*c*) What is the IUPAC name of acetic acid ?

36. (*a*) Which functional group do you think can be present in an organic compound having the molecular formula $C_5H_{10}O_2$? Write the formula of the organic compound.
(*b*) Give one example each of the compounds having the following functional groups :
(*i*) Aldehyde group (*ii*) Alcohol group (*iii*) Carboxylic acid group (*iv*) Halo group
(*c*) Give one example each of the compounds having the following functional groups :
(*i*) Alkene group (*ii*) Alkyne group

37. (*a*) What is the molecular formula and structure of the alcohol which can be thought to be derived from pentane ?
(*b*) Write the names of the following functional groups :
(*i*) —CHO (*ii*) —OH (*iii*) —COOH (*iv*) $>C=O$ (*v*) —X
(*c*) What makes the candle flame yellow and luminous ?

Long Answer Type Questions

38. (*a*) What is a homologous series ? Explain with an example.
(*b*) State two characteristics of a homologous series.
(*c*) The molecular formula of an organic compound is $C_{18}H_{36}$. Name its homologous series.

(*d*) Select the hydrocarbons which belong to the same homologous series. Give the name of each series.
CH_4, C_2H_2, C_2H_4, C_2H_6, C_4H_{10}, C_3H_4, C_3H_6

(*e*) What is meant by 'heteroatom'? Give examples. Write the names and formulae of two organic compounds containing different heteroatoms.

39. (*a*) What is meant by a functional group ? Explain with an example.

(*b*) Write three common functional groups present in organic compounds. Give their symbols/formulae.

(*c*) Name the functional groups present in the following compounds :
(*i*) CH_3COOH (*ii*) CH_3CH_2CHO (*iii*) C_2H_5OH (*iv*) $CH_3COCH_2CH_3$

(*d*) Name the functional group which always occurs in the middle of a carbon chain.

(*e*) Draw the structures for the following compounds :
(*i*) Ethanal (*ii*) Propanal (*iii*) Butanal (*iv*) Pentanal

40. (*a*) What happens when carbon burns in air ? Write the chemical equation of the reaction which takes place.

(*b*) Why are coal and petroleum called fossil fuels ?

(*c*) Explain how coal was formed in the earth.

(*d*) Describe how petroleum was formed in the earth.

(*e*) Name a fossil fuel other than coal and petroleum.

Multiple Choice Questions (MCQs)

41. The molecular formula of a homologue of butane is :
(*a*) C_4H_8 (*b*) C_3H_6 (*c*) C_4H_6 (*d*) C_3H_8

42. One of the following molecular formula can represent two organic compounds having different functional groups. This molecular formula is :
(*a*) $C_5H_{12}O$ (*b*) $C_5H_{10}O$ (*c*) $C_5H_{10}O_2$ (*d*) C_5H_{12}

43. The number of carbon atoms present in the molecule of fifth member of the homologous series of alkynes is :
(*a*) four (*b*) five (*c*) six (*d*) seven

44. One of the following burns without producing a flame. This is :
(*a*) wood (*b*) charcoal (*c*) LPG (*d*) candle

45. The functional group which always occurs in the middle of a carbon chain is :
(*a*) alcohol group (*b*) aldehyde group (*c*) carboxyl group (*d*) ketone group

46. The molecular formulae of some organic compounds are given below. Which of these compounds contains an aldehyde group ?
(*a*) C_3H_8O (*b*) $C_3H_6O_2$ (*c*) C_3H_6O (*d*) C_3H_7Cl

47. The organic compounds which are isomeric with one another are :
(*a*) alcohols and aldehydes (*b*) aldehydes and carboxylic acids
(*c*) ketones and aldehydes (*d*) alcohols and ketones

48. The fuel which usually burns with a blue flame is :
(*a*) coal (*b*) LPG (*c*) candle wax (*d*) kerosene (in lamp)

49. Which of the following burns by producing a yellow, luminous flame ?
(*a*) natural gas (*b*) coke (*c*) wax (*d*) charcoal

50. The molecular formula of an organic compound is $C_{48}H_{94}$. This compound belongs to the homologous series of :
` (*a*) alkenes (*b*) aldehydes (*c*) alkynes (*d*) alkanes

51. One of the following molecular formulae represents a ketone. This formula is :
(*a*) $C_5H_{12}O$ (*b*) $C_6H_{12}O_2$ (*c*) $C_6H_{14}O$ (*d*) $C_6H_{12}O$

52. Which one of the following is not a fossil fuel ?
(*a*) petrol (*b*) coke (*c*) charcoal (*d*) coal

53. Butanone is a four-carbon compound having the functional group :
(*a*) —COOH (*b*) —CHO (*c*) —CO— (*d*) —OH

54. The molecular formula of the third member of the homologous series of ketones is :
(*a*) C_4H_8O (*b*) C_3H_6O (*c*) $C_5H_{10}O$ (*d*) $C_6H_{12}O$

55. The functional group present in propanal is :
(*a*) —OH (*b*) —COOH (*c*) —CO— (*d*) —CHO

Questions Based on High Order Thinking Skills (HOTS)

56. An organic compound having the molecular formula C_3H_6O can exist in the form of two isomers A and B having different functional groups. The isomer A is a liquid which is used as a solvent for nail polish. The isomer B is also a liquid. An aqueous solution of one of the lower homologues of B is used for preserving biological specimens in the laboratory

(*a*) What is compound A ?

(*b*) Write the electron-dot structure of A.

(*c*) What is compound B ?

(*d*) Write the electron-dot structure of B.

(*e*) Name the lower homologue of compound B which is used in preserving biological specimens.

57. A hard material X which is mined from the earth is used as a household fuel and also for the generation of electricity at Thermal Power Stations. A soft material Y is also used as a fuel in the form of candles. A gaseous material Z which occurs alongwith petroleum is increasingly being used as a fuel in running vehicles in its compressed form.

(*a*) What are materials, X, Y and Z ?

(*b*) When materials X, Y and Z are burned separately :

(*i*) Which material burns by producing a yellow, luminous flame ?

(*ii*) Which material ultimately burns without producing a flame ?

(*iii*) Which material can burn in a gas stove by producing a blue flame ?

58. Three organic compounds A, B and C have the following molecular formulae :

A $C_4H_8O_2$

B $C_4H_{10}O$

C C_4H_8O

(*a*) Which compound contains an alcohol group ? Write its name and structural formula.

(*b*) Which compound contains a carboxyl group ? Write its name and structural formula.

(*c*) Which molecular formula can represent an aldehyde as well as a ketone ? Write the names and structural formulae of the aldehyde and ketone represented by this molecular formula.

59. A colourless organic liquid X of molecular formula $C_2H_4O_2$ turns blue litmus to red. Another colourless organic liquid Y of molecular formula C_3H_6O has no action on any litmus but it is used as a nail polish remover. A yet another colourless organic liquid Z of molecular formula C_2H_6O has also no action on litmus but it is used in tincture of iodine.

(*a*) Name the liquid X. To which homologous series does it belong ? Give the name of another member of this homologous series.

(*b*) Name the liquid Y. To which homologous series does it belong ? Write the name of another member of this homologous series.

(*c*) Can you name an organic compound having the same molecular formula as liquid Y but which belongs to a different homologous series ? What is this homologous series ?

(*d*) Name the liquid Z. To which homologous series does it belong ? Write the name of another member of this homologous series.

60. You are given an organic compound having the molecular formula C_3H_8. Give the name and formula of the compound formed :

(*a*) when one H atom of C_3H_8 is replaced by a C1 atom.

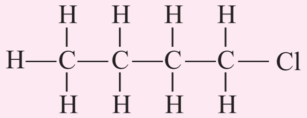
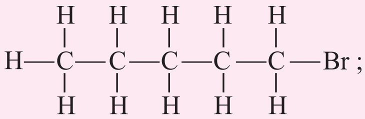
(*b*) when one H atom of C_3H_8 is replaced by OH group.

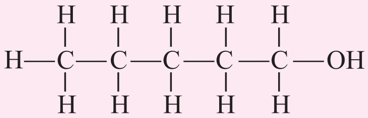
(*c*) when one H atom of C_3H_8 is replaced by a CHO group.

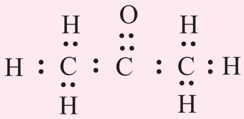
(*d*) when one H atom of C_3H_8 is replaced by a COOH group.

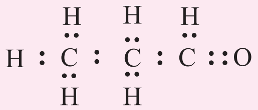
(*e*) when two H atoms joined to the middle carbon atom of C_3H_8 are replaced by one O atom.

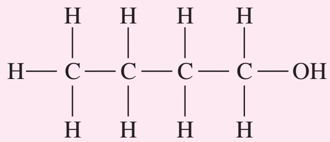
ANSWERS

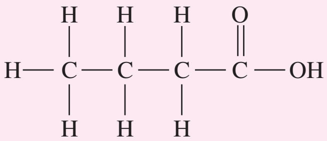
2. Ethanol (C_2H_5OH) **3.** Alcohol group ; Methanol **5.** Formaldehyde **6.** (*a*) Alkyne (*b*) Alkene **24.** False **25.** (*a*) propanol (*b*) C_3H_7OH (*c*) propane (*d*) –OH (alcohol) (*e*) carboxylic acids **26.** (*a*) Alkynes ; Ethyne (*b*) C_3H_6 ; C_5H_{10} (*c*) C_3H_8 ; C_5H_{12} **27.** (*b*) Alkyne (*c*) Alkanes : C_3H_8, C_4H_{10} ; Alkenes : C_5H_{10} , C_8H_{16} ; Alkynes : C_6H_{10} , C_7H_{12} **30.** (*a*) Chloromethane ; Methyl chloride (*b*)  (c)  ; Yes **32.** (*a*) Ketones (*b*) CH_3COOH **33.** (*b*) C_3H_7OH **34.** (*c*) Alcohol group, –OH ; C_4H_9OH **35.** (*a*)CH_3COOH : Ethanoic acid ; CH_3CHO : Ethanal ; CH_3OH : Methanol **36.** (*a*) Carboxyl group, –COOH ; C_4H_9COOH

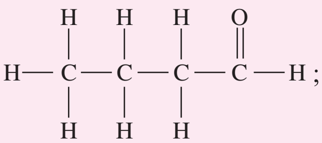
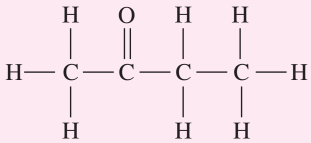
37. (*a*) $C_5H_{12}O$ or $C_5H_{11}OH$;  **38.** (*c*) Alkene (*d*) Alkanes : CH_4, C_2H_6, C_4H_{10} ; Alkenes : C_2H_4, C_3H_6 ; Alkynes : C_2H_2, C_3H_4 **39.** (*d*) Ketone group, –CO– **40.** (*e*) Natural gas **41.** (*d*) **42.** (*b*) **43.** (*c*) **44.** (*b*) **45.** (*d*) **46.** (*c*) **47.** (*c*) **48.** (*b*) **49.** (*c*) **50.** (*c*) **51.** (*d*) **52.** (*c*) **53.** (*c*)

54. (*c*) **55.** (*d*) **56.** (*a*) Propanone (or Acetone) (*b*)  (*c*) Propanal

(*d*)  (*e*) Methanal (or Formaldehyde) **57.** (*a*) X is coal ; Y is wax ; Z is natural gas

(*b*) (*i*) Y (wax) (*ii*) X (coal) (*iii*) Z (natural gas) **58.** (*a*) B ; Butanol, C_4H_9OH, 

(*b*) A ; Butanoic acid, C_3H_7COOH,  (*c*) C_4H_8O ; Aldehyde : Butanal,

C_3H_7CHO,  ; Ketone : Butanone , $CH_3COCH_2CH_3$, 

59. (*a*) Ethanoic acid ; Carboxylic acids ; Methanoic acid (*b*) Propanone ; Ketones ; Butanone (*c*) Propanal ; Aldehydes (*d*) Ethanol ; Alcohols ; Methanol **60.** (*a*) Chloropropane, $CH_3–CH_2–CH_2–Cl$ (*b*) Propanol, $CH_3–CH_2–CH_2–OH$ (*c*) Butanal, $CH_3–CH_2–CH_2–CHO$ (*d*) Butanoic acid, $CH_3–CH_2–CH_2–COOH$ (*e*) Propanone, $CH_3–CO–CH_3$

CHEMICAL PROPERTIES OF CARBON COMPOUNDS

The most common carbon compounds are hydrocarbons (alkanes, alkenes and alkynes). We will now study some of the chemical properties of carbon compounds called hydrocarbons. The chemical properties which we are going to study here are : combustion reactions, substitution reactions and addition reactions. Combustion reactions occur in all types of hydrocarbons (saturated as well as unsaturated), substitution reactions are given by only saturated hydrocarbons (or alkanes) whereas addition reactions are given by only unsaturated hydrocarbons (alkenes and alkynes). Let us start with combustion.

1. Combustion (or Burning)

The process of burning of a carbon compound in air to give carbon dioxide, water, heat and light, is known as combustion. Combustion is also called *burning.* Most of the carbon compounds burn in air to produce a lot of heat. For example, **alkanes burn in air to produce a lot of heat due to which alkanes are excellent fuels.** Let us take an example of the combustion of an alkane called *methane* (which is the major constituent of natural gas).

When methane (natural gas) burns in a sufficient supply of air, then carbon dioxide and water vapour are formed, and a lot of heat is also produced :

$$\underset{\substack{\text{Methane} \\ \text{(Natural gas)}}}{CH_4} + \underset{\substack{\text{Oxygen} \\ \text{(From air)}}}{2O_2} \xrightarrow{\text{Combustion}} \underset{\substack{\text{Carbon} \\ \text{dioxide}}}{CO_2} + \underset{\text{Water}}{2H_2O} + \text{Heat} + \text{Light}$$

Since natural gas (methane) produces a lot of heat on burning, so it is used as a fuel in homes, transport and in industry (see Figure 38). The cooking gas (LPG) which we use in our homes is mainly an alkane called *butane* (C_4H_{10}). When butane (or LPG) burns in air in the burner of a gas stove, then it forms carbon dioxide and water vapour, with the evolution of a lot of heat (and some light). Due to this, butane (or LPG) is an excellent fuel. Please note that **carbon and its compounds are used as fuels because they burn in air releasing a lot of heat energy.**

Figure 38. Natural gas is an excellent fuel which does not cause much air pollution. Many cars, buses and autos in Delhi run on compressed natural gas (CNG). This picture shows a CNG cylinder fitted in the boot of a car.

The saturated hydrocarbons (alkanes) generally burn in air with a blue, non-sooty flame. This is because the percentage of carbon in the saturated hydrocarbons is *comparatively low* which gets oxidised completely by the oxygen present in air. **If, however, the supply of air (and hence oxygen) for burning is reduced (or limited), then incomplete combustion of even saturated hydrocarbons will take place and they will burn producing a sooty flame** (giving a lot of black smoke). This point will become clear from the following activity.

We all use a Bunsen burner (which is a gas burner) in the laboratory. This Bunsen burner has an air hole near its base which can be opened or closed with the help of a sliding valve.

1. Let us first keep the air hole fully open and light the burner. We will find that with fully open air hole, the gas in the burner burns with a blue flame or non-sooty flame (without giving any smoke at all). In this case, complete combustion of the saturated hydrocarbon butane takes place (due to the sufficient supply of air for burning because of fully open air hole of the burner).

2. Let us now make the air hole smaller and smaller to reduce the amount of air going into burner. As we go on reducing the amount of air going into burner, the gas in burner starts burning with a sooty flame. And when the air hole is closed completely, the gas burns with a highly sooty flame producing a thick black smoke. In this case, incomplete combustion of the saturated hydrocarbon butane takes place (due to insufficient supply of air for burning because of closed air hole of the burner).

The gas stove (and kerosene stove) used in our homes have tiny holes (or inlets) for air so that sufficient oxygen of air is available for the complete burning of fuel to produce a smokeless blue flame. Thus, when the flame in a gas stove is blue, then the fuel is burning completely (or that complete combustion takes place). When the fuel in a gas stove (or kerosene stove) burns completely giving a blue flame, then the bottom of the cooking utensils (or vessels) remains clean from outside. It does not get blackened. If, however, the fuel in a gas stove (or kerosene stove) does not burn completely, then a sooty flame is produced which blackens the bottom of the cooking utensils from the outside. So, **if the bottom of the cooking utensils in our homes are getting blackened, it shows that the air holes of the gas stove (or kerosene stove) are getting blocked and the fuel is not burning completely** (the fuel gets wasted in this case). We will now discuss the case of combustion of unsaturated hydrocarbons.

The unsaturated hydrocarbons (alkenes and alkynes) burn in air with a yellow, sooty flame (producing black smoke). For example, ethene and ethyne burn in air with a sooty flame. The unsaturated hydrocarbons (alkenes and alkynes) burn with a sooty flame because the percentage of carbon in unsaturated hydrocarbons is *comparatively higher* (than that of alkanes), which does not get oxidised completely in the oxygen of air. Now, air contains only about 21 per cent of oxygen in it which is insufficient for the complete combustion of unsaturated hydrocarbons (having higher carbon percentage). But **if unsaturated hydrocarbons are burned in pure oxygen, then they will burn completely producing a blue flame (without**

any smoke at all). This point will become more clear from the following example.

Acetylene (ethyne) is an unsaturated hydrocarbon. When acetylene is burned in air, it burns with a very sooty flame due to incomplete combustion. The temperature of flame produced is also not high. Now, if a mixture of acetylene (ethyne) and pure oxygen is burned, then acetylene burns completely producing a blue flame. The oxygen - acetylene flame (called oxy-acetylene flame) is extremely hot and produces a very high temperature which is used for welding metals (see Figure 39). It is clear that **a mixture of acetylene (ethyne) and air is not used for welding because burning of acetylene (ethyne) in air produces a sooty flame (due to incomplete combustion), which is not hot enough to melt metals for welding.**

Figure 39. Oxy-acetylene torch being used for welding metals.

The most common fuels contain a high percentage of carbon, so it is obviously very important to burn them completely. **The incomplete combustion of fuels has the following disadvantges :** Incomplete combustion in insufficient supply of air, leads to unburnt carbon in the form of soot which pollutes the atmosphere, blackens cooking utensils, and blocks chimneys in factories. The incomplete combustion also leads to the formation of an extremely poisonous gas called carbon monoxide. A yet another disadvantage is that the incomplete combustion of a fuel produces less heat than that produced by complete combustion.

2. Substitution Reactions

Saturated hydrocarbons (alkanes) are quite unreactive (because they contain only carbon-carbon single bonds) Being unreactive, saturated hydrocarbons do not react with many substances. **Saturated hydrocarbons, however, undergo substitution reactions with chlorine in the presence of sunlight.** Before we describe the substitution reaction of a saturated hydrocarbon 'methane' with chlorine, we should know the meaning of substitution reactions. This is described below.

The reaction in which one (or more) hydrogen atoms of a hydrocarbon are replaced by some other atoms (like chlorine), is called a substitution reaction. If the substitution of hydrogen atoms takes place by chlorine, it is also called chlorination. Please note that **substitution reactions (like chlorination) are a characteristic property of saturated hydrocarbons or alkanes** (Unsaturated hydrocarbons do not give substitution reactions with halogens, they give addition reactions). The substitution reactions of saturated hydrocarbons (alkanes) with chlorine take place in the presence of sunlight. We will now give the substitution reaction of methane with chlorine.

Substitution Reaction of Methane with Chlorine. Methane reacts with chlorine in the presence of sunlight to form chloromethane and hydrogen chloride :

$$\underset{\text{Methane}}{CH_4} + \underset{\text{Chlorine}}{Cl_2} \xrightarrow{\text{Sunlight}} \underset{\substack{\text{Chloromethane}\\\text{(or Methyl chloride)}}}{CH_3Cl} + \underset{\substack{\text{Hydrogen}\\\text{chloride}}}{HCl}$$

In this reaction, one H atom of methane has been substituted (replaced) by a Cl atom, converting CH_4 into CH_3Cl.

In the above reaction between methane and chlorine, only one hydrogen atom of methane has been replaced by chlorine atom and we get chloromethane, CH_3Cl. By supplying more chlorine, it is possible to replace all the hydrogen atoms of methane by chlorine, one by one. In this way we can obtain three more compounds : Dichloromethane or Methylene dichloride, CH_2Cl_2; Trichloromethane

Figure 40. Trichloromethane (commonly known as chloroform) is used as an anaesthetic during surgical operations in hospitals (Anaesthetic is a substance which induces insensitivity to pain).

or Chloroform, $CHCl_3$ and Tetrachloromethane or Carbon tetrachloride, CCl_4. Methane (CH_4), Ethane (C_2H_6), Propane (C_3H_8), Butane (C_4H_{10}), Pentane (C_5H_{12}), and Hexane (C_6H_{14}), etc., are all saturated hydrocarbons (or alkanes). So, all these compounds will give substitution reactions (with chlorine).

3. Addition Reactions

We will first understand the meaning of an addition reaction. The reaction in which an unsaturated hydrocarbon combines with another substance to give a single product is called an addition reaction. **Addition reactions (like the addition of hydrogen, chlorine or bromine) are a characteristic property of unsaturated hydrocarbons.** Addition reactions are given by all unsaturated hydrocarbons containing a double bond or a triple bond. That is, **addition reactions are given by all the alkenes and alkynes** (like ethene and ethyne). We will now describe an addition reaction in which hydrogen is added to unsaturated hydrocarbons containing carbon-carbon double bonds (which are called alkenes). The simplest alkene is ethene, $CH_2{=}CH_2$.

Addition Reaction of Ethene with Hydrogen. Ethene reacts with hydrogen when heated in the presence of nickel catalyst to form ethane :

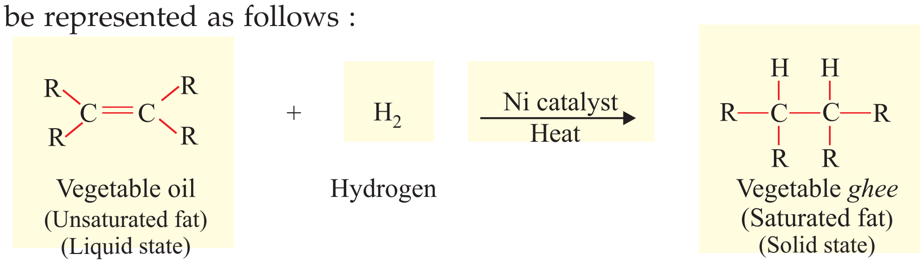
$$\underset{\substack{\text{Ethene}\\\text{(Unsaturated)}}}{CH_2{=}CH_2} + \underset{\text{Hydrogen}}{H_2} \xrightarrow[\text{Heat}]{\text{Ni catalyst}} \underset{\substack{\text{Ethane}\\\text{(Saturated)}}}{CH_3{-}CH_3}$$

Please note that in this reaction, one H atom adds to each C atom of ethene due to which the double bond opens up to form a single bond in ethane. We can also say that one molecule of hydrogen is added to an unsaturated hydrocarbon 'ethene' having a double bond to form a saturated hydrocarbon 'ethane' having a single bond.

In general, unsaturated hydrocarbons add on hydrogen in the presence of catalysts such as nickel (Ni) or palladium (Pd) to form saturated hydrocarbons. **The addition of hydrogen to an unsaturated hydrocarbon to obtain a saturated hydrocarbon is called hydrogenation.** The process of hydrogenation takes place in the presence of nickel or palladium metals as catalyst. **The process of hydrogenation has an important industrial application : It is used to prepare vegetable *ghee* (or *vanaspati ghee*) from vegetable oils.** This is discussed below.

Hydrogenation of Oils. The vegetable oils (like groundnut oil, cotton seed oil and mustard oil) are unsaturated compounds containing double bonds. They are in the *liquid* state at room temperature. Due to the presence of double bonds, vegetable oils undergo addition of hydrogen just like alkenes to form saturated products called vegetable *ghee* or *vanaspati ghee* which are *solid* (or *semi-solid*) at the room temperature. Thus, the addition of hydrogen (or hydrogenation) to the vegetable oils leads to the formation of vegetable *ghee* or *vanaspati ghee*. An example of the hydrogenation of oils is given below.

Vegetable oils are unsaturated fats having double bonds between some of their carbon atoms. When a vegetable oil (like groundnut oil) is heated with hydrogen in the presence of finely divided nickel as catalyst, then a saturated fat called vegetable *ghee* (or *vanaspati ghee*) is formed. This reaction is called hydrogenation of oils and it can be represented as follows :



Please note that vegetable oil is a liquid whereas vegetable *ghee* is a solid (or a semi-solid).

Vegetable oils containing unsaturated fatty acids are good for our health. We should, therefore, use oils for cooking. Some of the common cooking oils are sunflower oil, *kardi* oil, soyabean oil and groundnut oil. These are available in the market under the brand names such as Sundrop, Saffola, Fortune and Dalda refined oil, etc. **The saturated fats like vegetable *ghee*, obtained by the hydrogenation of oils, are not good for health.** They are available in the market under the brand names such as *Dalda, Rath* and *Panghat*, etc. **The animal fats (like butter and *desi ghee*) are also saturated fats containing saturated fatty acids which are said to be harmful for health** (if taken in *large amounts).*

(*a*) This is vegetable oil (like groundnut oil). It is a liquid

(*b*) This is the solid fat (like *vanaspati ghee*) obtained from vegetable oil.

Figure 41. Hydrogenation converts liquid vegetable oils into solid fats.

We have discussed only the addition reaction of hydrogen with unsaturated hydrocarbons. Other substances such as chlorine (Cl_2) and bromine (Br_2) also give addition reactions with unsaturated compounds (like alkenes and alkynes). The addition of bromine is particularly important because it is used as a test for unsaturated compounds. For this purpose, bromine is used in the form of bromine water. A solution of bromine in water is called bromine water. **Bromine water has a red-brown colour due to the presence of bromine in it.** When bromine water is added to an unsaturated compound, then bromine gets added to the unsaturated compound and the red-brown colour of bromine water is discharged (it becomes colourless). So, **if an organic compound decolourises bromine water, then it will be an unsaturated compound (containing a double bond or a triple bond).**

All the unsaturated compounds (alkenes and alkynes, etc.) decolourise bromine water but saturated compounds (alkanes) *do not* decolourise bromine water. For example, ethene and ethyne decolourise bromine water (because they are unsaturated compounds) but methane and ethane *do not* decolourise bromine water (because they are saturated compounds). **We can distinguish chemically between a cooking oil and butter by the bromine water test.** Add bromine water to a little of cooking oil and butter taken in separate test-tubes.

(*i*) Cooking oil decolourises bromine water (showing that it is an unsaturated compound).

(*ii*) Butter *does not* decolourise bromine water (showing that it is a saturated compound).

Let us solve one problem now.

Sample Problem. Which of the following hydrocarbons undergo addition reactions ?

C_2H_6, C_3H_8, C_3H_6, C_2H_2 and CH_4 (**NCERT Book Question)**

Solution. The unsaturated hydrocarbons (alkenes and alkynes) undergo addition reactions. Out of the above hydrocarbons C_3H_6 is an alkene whereas C_2H_2 is an alkyne. So, C_3H_6 and C_2H_2 will undergo addition reactions.

SOME IMPORTANT CARBON COMPOUNDS

A large number of carbon compounds (or organic compounds) are extremely useful to us. In this class we will study the properties and uses of only two commercially important carbon compounds (or organic compounds) : Ethanol and Ethanoic acid.

ETHANOL (OR ETHYL ALCOHOL)

Ethanol is the second member of the homologous series of alcohols (the first member being methanol). The formula of ethanol is C_2H_5OH (which can also be written as : $CH_3—CH_2OH$ or $CH_3—CH_2—OH$). **The**

common name of ethanol is ethyl alcohol. Ethanol is the most common and most widely used alcohol and sometimes ehanol is also called just alcohol. Please note that whether we use the name ethanol or ethyl alcohol, it is just the same thing.

Physical Properties of Ethanol

Ethanol is a colourless liquid having a pleasant smell and a burning taste. Ethanol is a volatile liquid having a low boiling point of 78°C (351 K). It is lighter than water. Ethanol mixes with water in any proportion. The solubility of ethanol in water is due to the presence of hydroxyl group in it. Ethanol containing 5 per cent water is called *rectified spirit*. Rectified spirit is the commercial alcohol. 100% pure ethanol is called *absolute alcohol.* Ethanol is a covalent compound. Ethanol does not contain any hydrogen ions, so **it is a neutral compound.** Thus, **ethanol has no effect on any litmus solution.** In fact, all the alcohols are neutral compounds and hence do not affect litmus.

Figure 42. Ethanol (or ethyl alcohol) is a colourless liquid. The conical flask shown in this picture contains ethanol.

Chemical Properties of Ethanol

The chemical properties of ethanol which we will discuss here are combustion, oxidation, reaction with sodium metal, dehydration, and reaction with carboxylic acids. Before we describe these properties, we should know the difference between *combustion* and *oxidation* of an organic compound. Combustion is the burning of an organic compound in the oxygen (of air). **During combustion, the organic compound reacts rapidly with oxygen and breaks up completely to form carbon dioxide and water vapour, and a lot of heat and light are also produced .** Oxidation is a kind of controlled combustion. **During oxidation, the organic compound combines with oxygen (provided by an oxidising agent) to form a new compound.** The organic compound *does not* break down completely during oxidation. Much less heat and light (if any) are produced during oxidation. Keeping these points in mind, we will now describe the combustion and oxidation reactions of ethanol.

1. Combustion. Ethanol is a highly inflammable liquid. It catches fire easily and starts burning. Ethanol burns readily in air to form carbon dioxide and water vapour, and releasing a lot of heat and light :

$$\underset{\substack{\text{Ethanol}\\\text{(Ethyl alcohol)}}}{C_2H_5OH} + \underset{\substack{\text{Oxygen}\\\text{(From air)}}}{3O_2} \xrightarrow[\text{(Burning)}]{\text{Combustion}} \underset{\substack{\text{Carbon}\\\text{dioxide}}}{2CO_2} + \underset{\substack{\text{Water}\\\text{vapour}}}{3H_2O} + \text{Heat} + \text{Light}$$

In fact, all the alcohols burn in air to form carbon dioxide and water, and produce heat and light.

Ethanol as a Fuel. A material which is burnt to obtain heat is called a fuel. **Since ethanol burns with a clear flame giving a lot of heat, therefore, it is used as a fuel.** Some countries add ethanol to petrol to be used as a fuel in cars. Thus, **ethanol is used as an additive in petrol.** For example, in Brazil, a mixture of

Figure 43. Ethanol burns with a 'clear' flame. It is a clean fuel.

Figure 44. The picture on left shows sugar cane crop in the fields. The picture on right side shows sugar cane. Ethanol is produced on a large scale from sugar cane.

Figure 45. This is molasses (which is a by-product of sugar industry). Ethanol is obtained by the fermentation of cane sugar present in molasses.

ethanol and petrol is used as a fuel for cars. *Ethanol is a clean fuel because it gives only harmless products carbon dioxide and water vapour on burning.* It does not produce any poisonous gas like carbon monoxide. So, the addition of ethanol to petrol has the advantage of reducing the emission of carbon monoxide from cars.

Ethanol is produced on a large scale from sugar cane crop. Sugar cane juice is used to obtain sugar by the process of crystallisation. **After the crystallisation of sugar from concentrated sugar cane juice, a thick, dark brown liquid called molasses is left behind.** Molasses still contains about 30% of sugar which could not be separated by crystallisation. **Ethanol is produced by the fermentation (breakdown by enzymes) of the cane sugar present in molasses.** Ethanol produced by the fermentation of sugar (from sugar cane) is mixed with petrol and used as fuel for running cars. Ethanol alone can also be used as a fuel for cars.

Before we describe the next reaction of ethanol, we should know the meaning of 'alkaline potassium permanganate solution' and 'acidified potassium dichromate solution'. **An aqueous solution of potassium permanganate containing sodium hydroxide is called alkaline potassium permanganate solution.** Thus, alkaline potassium permanganate solution is $KMnO_4$ + NaOH. **The potassium dichromate solution containing sulphuric acid is called acidified potassium dichromate solution.** In other words, acidified potassium dichromate solution is $K_2Cr_2O_7 + H_2SO_4$. A substance which gives oxygen (for oxidation) is called an oxidising agent. **Alkaline potassium permanganate and acidified potassium dichromate are strong oxidising agents** (because they provide oxygen for oxidising other substances). Please note that nascent oxygen is freshly generated atomic oxygen which is very, very reactive. Keeping these points in mind, we will now describe the oxidation of ethanol.

2. Oxidation. 'Oxidation' means 'controlled combustion'. When ethanol is heated with alkaline potassium permanganate solution (or acidified potassium dichromate solution), it gets oxidised to ethanoic acid :

$$\underset{\substack{\text{Ethanol}\\\text{(Ethyl alcohol)}}}{CH_3CH_2OH} + \underset{\substack{\text{Nascent oxygen}\\\text{(From oxidising agent)}}}{2[O]} \xrightarrow[\text{(or Acidified } K_2Cr_2O_7)]{\text{Alkaline } KMnO_4\text{; Heat}} \underset{\substack{\text{Ethanoic acid}\\\text{(Acetic acid)}}}{CH_3COOH} + \underset{\text{Water}}{H_2O}$$

This reaction can be carried out by adding a 5 per cent aqueous solution of potassium permanganate in sodium hydroxide solution to ethanol dropwise till the purple colour of potassium permanganate solution no longer disappears. On warming the test-tube containing ethanol and alkaline potassium permanganate solution gently in a hot water bath, ethanol is oxidised to ethanoic acid. Thus, ethanoic acid is formed by the oxidation of ethanol by using a strong oxidising agent. This ethanoic acid (or acetic acid) formed by the oxidation of ethanol can turn blue litmus to red.

We can also carry out the above reaction of the oxidation of *ethanol* to *ethanoic acid* by using acidified potassium dichromate as the oxidising agent (in place of alkaline potassium permanganate). Please note that the conversion of ethanol into ethanoic acid is called an oxidation reaction because oxygen is added to it during this conversion (see the equation given above). In fact, all the alcohols can be oxidised to the corresponding carboxylic acids by strong oxidising agents.

3. Reaction with Sodium Metal. Ethanol reacts with sodium to form sodium ethoxide and hydrogen gas :

$$\underset{\substack{\text{Ethanol}\\\text{(Ethyl alcohol)}}}{2C_2H_5OH} + \underset{\text{Sodium}}{2Na} \longrightarrow \underset{\text{Sodium ethoxide}}{2C_2H_5O^-Na^+} + \underset{\text{Hydrogen}}{H_2}$$

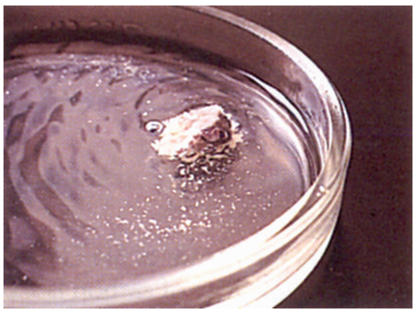


Figure 46. Sodium metal reacts with ethanol giving off hydrogen gas.

This reaction is used as a test for ethanol. When a small piece of sodium metal is put into ethanol in a dry test-tube, rapid effervescence due to the evolution of hydrogen gas is produced. The hydrogen gas produced can be tested by burning. When a burning splinter is brought near the mouth of the test-tube, the gas burns with a 'pop' sound, which is a characteristic of hydrogen gas. This shows that the gas produced by the action of sodium metal on ethanol is hydrogen. In fact, all the alcohols react with sodium metal to evolve hydrogen gas.

4. Dehydration. Dehydration of an alcohol means removal of water molecule from it. When ethanol is heated with excess of concentrated sulphuric acid at 170°C (443 K), it gets dehydrated to form ethene (which is an unsaturated hydrocarbon) :

$$\underset{\substack{\text{Ethanol} \\ \text{(Ethyl alcohol)}}}{CH_3–CH_2OH} \xrightarrow[\text{(Dehydration)}]{\text{Conc. } H_2SO_4\text{; 170°C}} \underset{\text{Ethene}}{CH_2{=}CH_2} + \underset{\text{Water}}{H_2O}$$

During dehydration of ethanol molecule ($CH_3–CH_2OH$), H from the CH_3 group and OH from CH_2OH group are removed in the form of a water molecule (H_2O) resulting in the formation of ethene molecule ($CH_2{=}CH_2$). In this reaction, **concentrated sulphuric acid acts as a dehydrating agent** (which removes water molecule from the ethanol molecule).

5. Reaction with Ethanoic Acid (Formation of Ester). Ethanol reacts with ethanoic acid on warming in the presence of a few drops of concentrated sulphuric acid to form a sweet smelling ester, ethyl ethanoate :

$$\underset{\substack{\text{Ethanoic acid} \\ \text{(Acetic acid)}}}{CH_3COOH} + \underset{\substack{\text{Ethanol} \\ \text{(Ethyl alcohol)}}}{C_2H_5OH} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\substack{\text{Ethyl ethanoate} \\ \text{(Ethyl acetate)} \\ \textit{(Sweet smelling ester)}}}{CH_3COOC_2H_5} + \underset{\text{Water}}{H_2O}$$

The reaction in which a carboxylic acid combines with an alcohol to form an ester is called esterification. Esterification takes place in the presence of a catalyst like concentrated sulphuric acid. The above reaction is an example of esterification. The formation of sweet smelling esters is used as a test for alcohols as well as carboxylic acids.

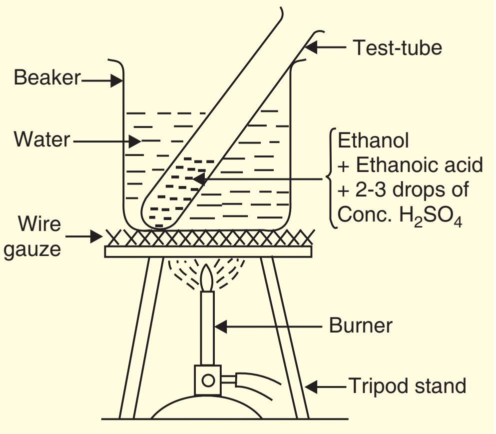


Figure 47. Formation of ester.

We can carry out the reaction between ethanol and ethanoic acid to form an ester as follows :

(*i*) Take 1 mL of pure ethanol (absolute alcohol) in a test-tube and add 1 mL of glacial ethanoic acid to it. Then add 2 or 3 drops of concentrated sulphuric acid to the mixture.

(*ii*) Warm the test-tube containing above reaction mixture in hot water bath (a beaker containing hot water) for about 5 minutes (see Figure 47).

(*iii*) Pour the contents of the test-tube in about 50 mL of water taken in another beaker and smell it.

(*iv*) A sweet smell is obtained indicating the formation of an ester.

Please note that all the alcohols react with carboxylic acids in the presence of a little of concentrated sulphuric acid to form sweet-smelling esters.

Tests for an Alcohol

An alcohol can be tested by any one of the following tests :

1. Sodium Metal Test. Add a small piece of sodium metal to the organic liquid (to be tested), taken in a dry test-tube. If bubbles (or effervescence) of hydrogen gas are produced, it indicates that the given organic liquid is an alcohol.

2. Ester Test for Alcohols. The organic compound (to be tested) is warmed with some glacial ethanoic acid and a few drops of concentrated sulphuric acid. A sweet smell (due to the formation of ester) indicates that the organic compound is an alcohol.

Uses of Ethanol (Ethyl Alcohol)

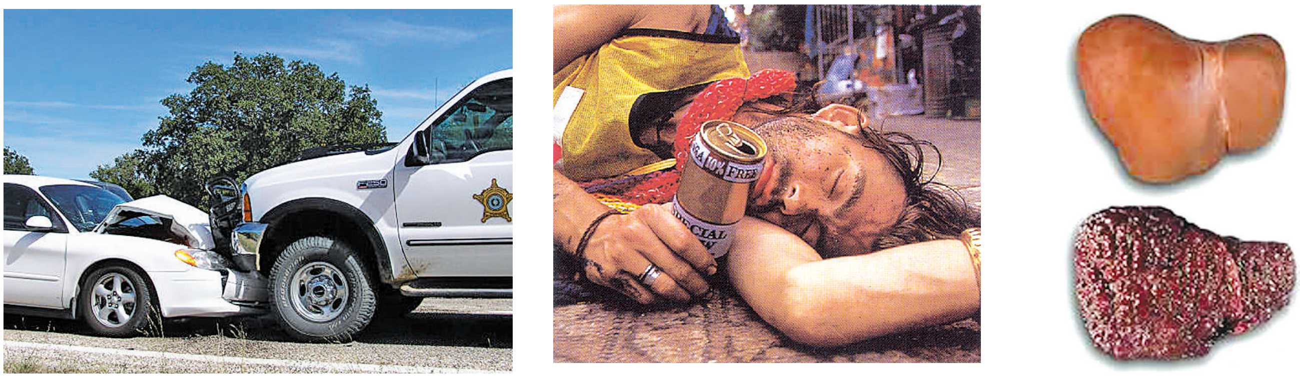
1. Ethyl alcohol (ethanol) is used in the manufacture of paints, varnishes, lacquers, medicines, perfumes, dyes, soaps and synthetic rubber.
2. Ethyl alcohol (ethanol) is used as a solvent. Many organic compounds which are insoluble in water, are soluble in ethyl alcohol.
3. Being a good solvent, ethyl alcohol (ethanol) is used in medicines such as tincture iodine, cough syrups and many tonics.
4. Ethyl alcohol (ethanol) is used as a fuel in cars alongwith petrol. It is also used as a fuel in spirit lamps.
5. Ethyl alcohol (ethanol) is used in alcoholic drinks (beverages) like whisky, wine, beer and other liquors. Whisky contains about 35% of ethyl alcohol, wine contains 10% to 20% of ethyl alcohol, and beer contains about 6% of ethyl alcohol.
6. Ethyl alcohol (ethanol) is used as an antiseptic to sterilize wounds and syringes in hospitals and dispensaries.

Figure 48. Iodine tincture is an antiseptic solution. It is a solution of iodine in ethanol. Iodine is the real germ killer. Ethanol acts as a solvent to dissolve iodine. This is because iodine is not much soluble in water.

Harmful Effects of Drinking Alcohol

We should not use any alcoholic drinks because of the following harmful effects which they produce :

1. Alcohol slows down the activity of the nervous system and the brain due to which the judgement of a person is impaired and his 'reaction' becomes slow. So, a person driving a car under the influence of alcohol cannot judge a situation properly and act quickly in case of an emergency. In this way, drunken driving leads to increased road accidents [see Figure 49(*a*)].
2. Alcohol drinking lowers inhibitions (mental restrain) due to which a drunken man becomes quarrelsome. This leads to quarrels and fights which increases violence and crime in society.



(*a*) Drunken driving is a major cause of road accidents all over the world.

(*b*) Alcohol drinking causes misery to the person himself as well as to the family.

(*c*) The liver shown at the top is healthy. The liver shown at the bottom is suffering from disease called cirrhosis which has been caused by heavy alcohol drinking

Figure 49. Some of the harmful effects of drinking alcohol (such as whisky, beer, etc.).

3. Drinking alcohol heavily on a particular occasion leads to staggered movement, slurred speech (unclear speech), blurred vision, dizziness, and vomiting. Drinking of large quantities of alcohol makes a man unconscious [see Figure 49(*b*)]. He may even die.
4. Heavy drinking of alcohol makes a person alcoholic (addicted to alcohol). This makes the person financially bankrupt (*diwaliya*).
5. Heavy drinking of alcohol over a long period of time can damage the stomach, liver, heart and even brain. The liver disease known as 'cirrhosis' caused by alcohol can lead to death [see Figure 49(*c*)].

6. The drinking of adulterated alcohol containing methyl alcohol (methanol), causes severe poisoning leading to blindness and even death.

The Case of Methanol. When taken internally, methanol is a poison. So, unlike ethanol, drinking methanol even in very small quantity can cause severe poisoning leading to blindness and even death. This happens as follows. **Methanol damages the optic nerve causing permanent blindness in a person.** Methanol is oxidised to methanal in the liver of a person. This methanal reacts rapidly with the components of the cells causing coagulation of their protoplasm. Due to this the cells stop functioning normally. This leads to the death of the person who drinks methanol.

Denatured Alcohol (or Denatured Ethanol)

A lot of ethyl alcohol (ethanol) is used in industry for manufacturing various products. For industrial purposes, ethyl alcohol is supplied 'duty free' (without charging production tax) by the Government. This makes the industrial alcohol much cheaper than its market rate. To prevent the misuse of industrial alcohol for drinking purposes (or black marketing), ethyl alcohol meant for industrial purposes is denatured by adding small amounts of poisonous substances like methanol, pyridine or copper sulphate, etc. The addition of these poisonous substances makes the ethyl alcohol unfit for drinking. We can now say that : **Denatured alcohol is ethyl alcohol which has been made unfit for drinking purposes by adding small amounts of poisonous substances like methanol, pyridine, copper sulphate, etc.** Please note that the addition of small amount of copper sulphate imparts a blue colour to industrial ethyl alcohol so that it can be identified easily.

Figure 50. A can containing denatured alcohol.

ETHANOIC ACID (OR ACETIC ACID)

Ethanoic acid is the second member of the homologous series of carboxylic acids (the first member being methanoic acid). The formula of ethanoic acid is CH_3COOH. **The common name of ethanoic acid is acetic acid.** A dilute solution of ethanoic acid in water is called *vinegar.* Vinegar contains about 5 to 8 per cent ethanoic acid. In other words, vinegar contains about 5 to 8 per cent acetic acid. Vinegar is used widely as a preservative in pickles.

Figure 51. Vinegar is a solution containing 5 to 8 per cent ethanoic acid.

Physical Properties of Ethanoic Acid

1. Ethanoic acid is a colourless liquid having a sour taste and a smell of vinegar.
2. The boiling point of ethanoic acid is 118°C (391 K).
3. When pure ethanoic acid is cooled, it freezes to form a colourless, ice-like solid (which looks like a glacier). Due to this, pure ethanoic acid is called glacial ethanoic acid (or glacial acetic acid).
4. Ethanoic acid is miscible with water in all proportions.

Chemical Properties of Ethanoic Acid

1. Action on Litmus. Ethanoic acid is acidic in nature. Being acidic in nature, ethanoic acid turns blue litmus solution red. In fact, all the carboxylic acids turn blue litmus to red.

We will now compare the strength of carboxylic acids (like ethanoic acid) and mineral acids (like hydrochloric acid). Let us test both, ethanoic acid and hydrochloric acid with blue litmus paper and universal indicator paper, one by one.

(*i*) Dilute ethanoic acid turns blue litmus paper to red, showing that it is acidic in nature. Dilute hydrochloric acid also turns blue litmus paper to red, showing that it is also acidic in nature. Thus, litmus test shows that both, ethanoic acid and hydrochloric acid, are acidic in nature but the litmus test does not show which one is a strong acid and which one is a weak acid.

(*ii*) **Dilute ethanoic acid turns universal indicator paper to orange, showing that its pH is about 4.** This tells us that **ethanoic acid is a weak acid.** On the other hand, **dilute hydrochloric acid turns universal indicator paper to red, showing that its pH is about 1.** This shows that **hydrochloric acid is a strong acid.**

From this discussion we conclude that **the comparison of pH with universal indicator tells us that ethanoic acid and hydrochloric acid are not equally strong.** It shows that ethanoic acid is a weak acid whereas hydrochloric acid is a strong acid. Actually, carboxylic acids (like ethanoic acid) are only partially ionised in solution (to give a small number of hydrogen ions), so they are weak acids. On the other hand, mineral acids (like hydrochloric acid) are completely ionised in solution (and give a large number of hydrogen ions), due to which they are strong acids.

Due to its acidic nature, ethanoic acid reacts with carbonates, hydrogencarbonates, and bases (or alkalis) to form salts. These reactions of ethanoic acid are described below.

Figure 52. Ethanoic acid reacts with sodium hydrogen-carbonate to produce brisk effervescence of carbon dioxide gas.

2. Reaction with Carbonates and Hydrogencarbonates. Ethanoic acid reacts with carbonates and hydrogencarbonates to evolve carbon dioxide gas alongwith the formation of salt and water. The reactions of ethanoic acid with sodium carbonate and sodium hydrogencarbonate are as follows.

(*i*) Reaction with Sodium Carbonate. Ethanoic acid reacts with sodium carbonate to form sodium ethanoate and carbon dioxide gas :

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

Ethanoic acid (Acetic acid) + Sodium carbonate → Sodium ethanoate (Sodium acetate) + Carbon dioxide + Water

When sodium carbonate is added to a solution of ethanoic acid, brisk effervescence of carbon dioxide is given off. The salt formed in this reaction is sodium ethanoate. The common name of sodium ethanoate is sodium acetate. All other carboxylic acids react with sodium carbonate in a similar way.

(*ii*) Reaction with Sodium Hydrogencarbonate. Ethanoic acid reacts with sodium hydrogencarbonate to evolve brisk effervescence of carbon dioxide gas :

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

Ethanoic acid + Sodium hydrogencarbonate (Sodium bicarbonate) → Sodium ethanoate + Carbon dioxide + Water

This reaction is used as a test for ethanoic acid (or acetic acid) (see Figure 52). In fact, all the carboxylic acids decompose sodium hydrogencarbonate giving brisk effervescence of carbon dioxide gas.

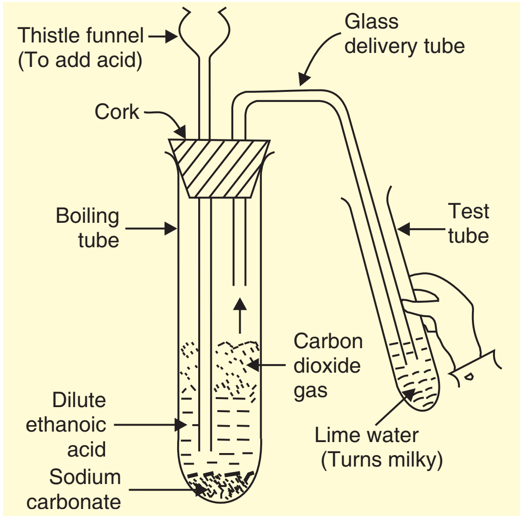


Figure 53. Ethanoic acid reacts with sodium carbonate to produce carbon dioxide gas (which turns lime water milky).

The reaction between ethanoic acid and sodium carbonate can be performed as follows : Take a boiling tube and put about 0.5 g of sodium carbonate in it. Add 2 mL of dilute ethanoic acid to the boiling tube (through a thistle funnel as shown in Figure 53). We will observe that brisk effervescence of carbon dioxide gas is produced. Let us pass this gas through lime water taken in a test-tube (as shown in Figure 53). We will find that lime water turns milky. *Only carbon dioxide gas can turn lime water milky.* So, this experiment proves that when ethanoic acid reacts with sodium carbonate, then carbon dioxide gas is evolved. We can repeat this experiment by using sodium hydrogencarbonate in place of sodium carbonate. Again we will get carbon dioxide gas (which will turn lime water milky).

3. Reaction with Sodium Hydroxide. Ethanoic acid reacts with bases (or alkalis) to form salts and water. For example, ethanoic acid reacts with sodium hydroxide to form a salt called sodium ethanoate and water :

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

In its reaction with bases, ethanoic acid behaves just like mineral acids (HCl, etc.). In fact, all the carboxylic acids react with bases (or alkalis) like sodium hydroxide to form the corresponding salts and water.

4. Reaction with Alcohols : Formation of Esters. Ethanoic acid reacts with alcohols in the presence of a little of concentrated sulphuric acid to form esters. For example, when ethanoic acid is warmed with ethanol in the presence of a few drops of concentrated sulphuric acid, a sweet smelling ester called ethyl ethanoate is formed :

$$\underset{\substack{\text{Ethanoic acid} \\ \text{(Acetic acid)}}}{CH_3COOH} + \underset{\substack{\text{Ethanol} \\ \text{(Ethyl alcohol)}}}{C_2H_5OH} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\substack{\text{Ethyl ethanoate} \\ \text{(Ethyl acetate)} \\ (\textit{Sweet smell})}}{CH_3COOC_2H_5} + \underset{\text{Water}}{H_2O}$$

This reaction in which a sweet smelling ester is formed, is used as a test for ethanoic acid. In fact, all the carboxylic acids react with alcohols in the presence of a little of concentrated sulphuric acid to form pleasant smelling esters. The reaction of a carboxylic acid with an alcohol to form an ester is called esterification.

Figure 54. Perfumes contain esters.

Esters are usually volatile liquids having sweet smell or pleasant smell. They are also said to have *fruity smell.* Esters are used in making artificial perfumes (artificial scents). This is because of the fact that most of the esters have a pleasant smell. Esters are also used as flavouring agents. This means that esters are used in making artificial flavours and essences used in ice-cream, sweets and cold drinks. **One of the most important reactions of esters is that they can be hydrolysed back to the alcohol and carboxylic acid (from which they are originally formed).** This is discussed below.

Hydrolysis of Esters. When an ester is heated with sodium hydroxide solution then the ester gets hydrolysed (breaks down) to form the parent alcohol and sodium salt of the carboxylic acid. For example, when ethyl ethanoate ester is boiled with sodium hydroxide solution, then sodium ethanoate and ethanol are produced :

$$\underset{\substack{\text{Ethyl ethanoate} \\ \text{(Ethyl acetate)}}}{CH_3COOC_2H_5} + \underset{\text{Sodium hydroxide}}{NaOH} \xrightarrow{\text{Heat}} \underset{\substack{\text{Sodium ethanoate} \\ \text{(Sodium acetate)}}}{CH_3COONa} + \underset{\substack{\text{Ethanol} \\ \text{(Ethyl alcohol)}}}{C_2H_5OH}$$

The alkaline hydrolysis of esters (using alkali like sodium hydroxide) is known as saponification (soap making). This is because of the fact that this reaction is used for the preparation of soaps. When the esters of higher fatty acids with glycerol (oils and fats) are hydrolysed with sodium hydroxide solution, we get sodium salts of higher fatty acids which are called soaps.

Tests for Carboxylic Acids

A carboxylic acid can be tested by any one of the following tests :

1. Sodium Hydrogencarbonate Test. The organic compound (to be tested) is taken in a test-tube and a pinch of sodium hydrogencarbonate is added to it. Evolution of carbon dioxide gas with brisk effervescence shows that the given organic compound is a carboxylic acid.

2. Ester Test for Acids. The organic compound (to be tested) is warmed with some ethanol and 2 or 3 drops of concentrated sulphuric acid. A sweet smell (due to the formation of ester) shows that the organic compound is a carboxylic acid.

3. Litmus Test. Some blue litmus solution is added to the organic compound (to be tested). If the blue litmus solution turns red, it shows that the organic compound is acidic in nature and hence it is a carboxylic acid.

Uses of Ethanoic Acid (or Acetic Acid)

1. Dilute ethanoic acid (in the form of vinegar) is used as a food preservative in the preparation of pickles and sauces (like tomato sauce). As vinegar, it is also used as an appetiser for dressing food dishes.
2. Ethanoic acid is used for making cellulose acetate which is an important artificial fibre.
3. Ethanoic acid is used in the manufacture of acetone (propanone) and esters used in perfumes.
4. Ethanoic acid is used in the preparation of dyes, plastics and pharmaceuticals.
5. Ethanoic acid is used to coagulate rubber from latex.

Figure 55. Ethanoic (acid) anhydride is used in the manufacture of aspirin. Aspirin is an analgesic and antipyretic (Analgesic is a drug which relieves pain and antipyretic is a drug which reduces fever).

Objective-Type Questions

We should remember the following points to answer the objective-type questions based on alcohols, carboxylic acids (organic acids) and esters :

1. The two common alcohols are methanol (methyl alcohol), CH_3OH, and ethanol (ethyl alcohol), C_2H_5OH or CH_3CH_2OH. The molecular formula of methanol is CH_4O and the molecular formula of ethanol is C_2H_6O.

2. The two common carboxylic acids or organic acids are methanoic acid (formic acid), HCOOH, and ethanoic acid (acetic acid), CH_3COOH. The molecular formula of methanoic acid is CH_2O_2 and the molecular formula of ethanoic acid is $C_2H_4O_2$.

3. The two common esters are methyl ethanoate (methyl acetate) CH_3COOCH_3 and ethyl ethanoate (ethyl acetate), $CH_3COOC_2H_5$. The molecular formula of methyl ethanoate is $C_3H_6O_2$ and the molecular formula of ethyl ethanoate is $C_4H_8O_2$.

Keeping these points in mind, let us solve some problems now.

Sample Problem 1. An organic compound 'A' is a constituent of wine and beer. This compound, on heating with alkaline potassium permanganate forms another organic compound 'B' which turns blue litmus to red. Identify the compound 'A'. Write the chemical equation of the reaction that takes place to form the compound 'B'. Name the compound 'B'.

Solution. The organic compound which is a constituent of wine and beer is ethyl alcohol (or ethanol). Thus, the compound 'A' is ethanol. Now, ethanol on oxidation with alkaline potassium permanganate produces an acid known as ethanoic acid. This ethanoic acid turns blue litmus to red. Thus, the compound 'B' is ethanoic acid. Please write the chemical equation for the oxidation of ethanol yourself.

Sample Problem 2. An organic compound A has the molecular formula $C_2H_4O_2$ and is acidic in nature. On heating with ethanol and conc. H_2SO_4, vapours with pleasant and fruity smell are given out. What is the compound A and what is the chemical equation involved in this reaction ?

Solution. The molecular formula of A is $C_2H_4O_2$. Since this compound is acidic in nature it should contain carboxylic acid group, —COOH. If we subtract COOH group (1 carbon, 2 oxygen and 1 hydrogen atom) from $C_2H_4O_2$, we are left with 1 carbon atom and 3 hydrogen atoms which is a methyl group, CH_3. Combining CH_3 and COOH we get CH_3COOH. Thus, compound A is ethanoic acid CH_3COOH. When ethanoic acid is warmed with ethanol in the presence of conc. H_2SO_4 a pleasant and fruity smelling ester, ethyl ethanoate is formed. (Write the equation yourself).

Sample Problem 3. The molecular formula of an ester is $C_3H_7COOC_2H_5$. Write the molecular formula of the alcohol and the acid from which it might be prepared.

Solution. The left side part of the formula of an ester (containing the CO part) is derived from the acid and the right side part of an ester is derived from the alcohol. So, in the ester $C_3H_7COOC_2H_5$, the acid will be C_3H_7COOH and the alcohol will be HOC_2H_5 which is written more conveniently as C_2H_5OH. Thus,

(*i*) The acid present in the ester $C_3H_7COOC_2H_5$ is C_3H_7COOH which is butanoic acid.

(*ii*) The alcohol present in the ester $C_3H_7COOC_2H_5$ is C_2H_5OH which is ethanol.

The reaction of butanoic acid and ethanol to form this ester can be represented as :

$$\underset{\text{Butanoic acid}}{C_3H_7.CO\boxed{OH \; + \; H}} \underset{\text{Ethanol}}{O.C_2H_5} \xrightarrow{\text{Conc. } H_2SO_4} \underset{\text{Ethyl butanoate}}{C_3H_7.COO.C_2H_5} + \underset{\text{Water}}{H_2O}$$

Sample Probem 4. How can ethanol and ethanoic acid be differentiated on the basis of their physical and chemical properties ? **(NCERT Book Question)**

Solution. (*i*) Ethanol has a pleasant smell whereas ethanoic acid has the smell of vinegar

(*ii*) Ethanol has a burning taste whereas ethanoic acid has a sour taste.

(*iii*) Ethanol has no action on litmus paper whereas ethanoic acid turns blue litmus paper to red.

(*iv*) Ethanol has no reaction with sodium hydrogencarbonate but ethanoic acid gives brisk effervescence with sodium hydrogencarbonate.

SOAPS AND DETERGENTS

If we wash our dirty hands with water alone, they do not get cleaned. But if we use some soap or detergent powder, the cleaning becomes very easy. **Any substance which has cleansing action in water is called a detergent.** In other words, any substance which removes dirt is called a detergent. There are two types of detergents : soapy and non-soapy. In everyday language, soapy detergents are called soaps and non-soapy detergents are called 'synthetic detergents' or just 'detergents'. So, in everyday language, when we talk of a detergent, it means synthetic detergent, though in the real sense of the word soap is also a detergent (or cleansing agent). Soaps and detergents are used for washing clothes (laundry), cleaning our body (sanitation), shaving soaps, hair shampoos, cleaning utensils and in textile manufacture. We will now discuss soaps and detergents in detail, one by one.

SOAPS

A soap is the sodium salt (or potassium salt) of a long chain carboxylic acid (fatty acid) which has cleansing properties in water. A soap has a large non-ionic hydrocarbon group and an ionic group, COO^-Na^+ . Examples of the soaps are : Sodium stearate and Sodium palmitate.

Figure 56. Soap.

(*i*) Sodium Stearate, $C_{17}H_{35}COO^-Na^+$. Sodium stearate 'soap' is the sodium salt of a long chain saturated fatty acid called stearic acid, $C_{17}H_{35}COOH$. Sodium stearate soap has a long alkyl group $C_{17}H_{35}$ and an ionic carboxylate group COO^-Na^+.

(*ii*) Sodium Palmitate, $C_{15}H_{31}COO^-Na^+$. Sodium palmitate 'soap' is the sodium salt of a long chain saturated fatty acid called palmitic acid, $C_{15}H_{31}COOH$.

A soap is the salt of a strong base (sodium hydroxide) and a weak acid (carboxylic acid), so a solution of soap in water is basic in nature. Being basic, **a soap solution turns red litmus paper to blue**.

Manufacture of Soap

Soap is made from animal fat or vegetable oils. Fats and vegetable oils are naturally occurring esters of higher fatty acids (long chain carboxylic acids) and an alcohol called glycerol. When fats and oils (obtained from animals and plants) are heated with sodium hydroxide solution, they split to form sodium salt of higher fatty acid (called soap) and glycerol. This is described below.

Soap is made by heating animal fat or vegetable oil with concentrated sodium hydroxide solution (caustic soda solution). The fats or oils react with sodium hydroxide to form soap and glycerol :

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

The process of making soap by the hydrolysis of fats and oils with alkalis is called saponification. In other words, the process of splitting the fat or oil to form soap is called saponification. The above reaction is an example of saponification. Please note that it is not necessary to use animal fats for preparing soaps. Vegetable oils like castor oil, cotton seed oil, soyabean oil, linseed oil, coconut oil, palm oil and olive oil are also used for preparing soaps. We can also prepare soap ourselves in the school laboratory or at home.

Preparation of Soap in the Laboratory (or at Home)

The main raw materials required for preparing soap in a school laboratory or at home are :

(*i*) Vegetable oil (like Castor oil, Cottonseed oil, Linseed oil or Soyabean oil)

(*ii*) Sodium hydroxide (Caustic soda)

(*iii*) Sodium chloride (Common salt)

Figure 57. Castor oil is a vegetable oil. It is used for making soap.

Procedure. Soap can be prepared in the laboratory (or at home) as follows :

1. Take about 20 mL of castor oil (cottonseed oil, linseed oil or soyabean oil) in a beaker.
2. Add 30 mL of 20% sodium hydroxide solution to it.
3. Heat the mixture with constant stirring till a paste of soap is formed.
4. Then add 5 to 10 grams of common salt (sodium chloride).
5. Stir the mixture well and allow it to cool. On cooling the solution, solid soap separates out.
6. When the soap sets, it can be cut into pieces called 'soap bars'. (We can also add perfumes before the soap sets).

Why Common Salt (Sodium Chloride) is Added in Soap Making. Common salt is added to the mixture to make the soap come out of solution. Though most of the soap separates out on its own but some of it remains in solution. **Common salt is added to precipitate out all the soap from the aqueous solution.** Actually, when we add common salt to the solution, then the solubility of soap present in it decreases, due to which all the soap separates out from the solution in the form of a solid.

The dirty clothes and dirty body have usually oil or grease particles which hold dirt on clothes and skin, respectively. **The soap which is used for washing clothes (or bathing) works by making the oil and grease particles dissolve in water (because normally the oil and grease are insoluble in water)**. In order to understand the cleansing action of soap, we should first know the structure of a soap molecule. This is described below.

Structure of a Soap Molecule

A soap molecule is made up of two parts : a long hydrocarbon part and a short ionic part containing —COO^-Na^+ group. The soap molecule is said to have a tadpole structure (see Figure 58).

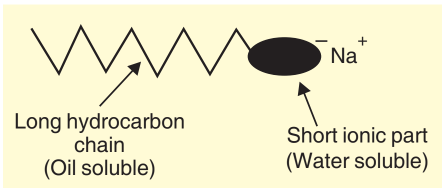
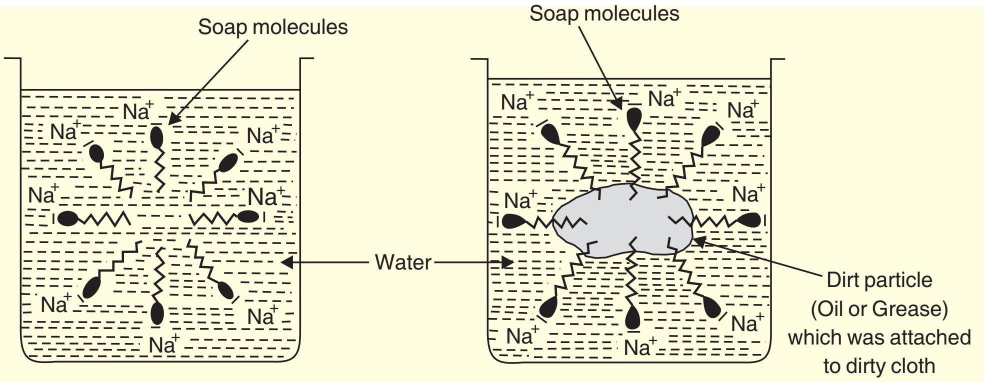


Figure 58. Structure of a soap molecule.

The long hydrocarbon chain is hydrophobic (water-repelling), so the hydrocarbon part of soap molecule is insoluble in water but soluble in oil and grease. The ionic portion of the soap molecule is hydrophilic (water-attracting) due to the polar nature of water molecules. So, the ionic portion of soap molecule is soluble in water but insoluble in oil and grease. From this discussion we conclude that **the hydrocarbon part of the soap molecule is soluble in oil or grease, so it can attach to the oil and grease particles present on dirty clothes**. On the other hand, **the short ionic part of the soap molecule (having negative charge) is soluble in water, so it can attach to the water particles (in which the soap is dissolved and dirty cloth is dipped)**. Keeping these two unique properties of the soap molecules in mind, we will now explain how soap actually cleans the dirty clothes. We will be using a term 'micelle' here. **A 'spherical aggregate of soap molecules' in the soap solution in water is called a 'micelle'**. Please note that a soap solution is a colloidal solution. A soap solution appears cloudy because the soap micelles are large enough to scatter light.

Cleansing Action of Soap

When soap is dissolved in water, it forms a colloidal suspension in water in which the soap molecules cluster together to form spherical micelles [see Figure 59(*a*)]. In a soap micelle, the soap molecules are arranged radially with hydrocarbon ends directed towards the centre and ionic ends directed outwards (The ionic ends are directed outwards because negative charges at the ends repel one another) [see Figure 59(*a*)]. Please note that *micelle formation takes place when soap is added to water because the hydrocarbon chains of soap molecules are hydrophobic (water repelling) which are insoluble in water, but the ionic ends of soap molecules are hydrophilic (water attracting) and hence soluble in water*. Another point to be noted is that *micelle formation will not take place when soap is added to organic solvents like ethanol because the hydrocarbon chains of soap molecules are soluble in organic solvents like ethanol*.



(*a*) Soap micelle (*b*) Soap micelle entraps the dirt particle

Figure 59. Cleansing action of soap.

When a dirty cloth is put in water containing dissolved soap, then the hydrocarbon ends of the soap molecules in the micelle attach to the oil or grease particles present on the surface of dirty cloth. In this way the soap micelle entraps the oily or greasy particle by using its hydrocarbon ends [as shown in Figure 59(*b*)]. The ionic ends of the soap molecules in the micelles, however, remain attached to water [see Figure 59(*b*)]. When the dirty cloth is agitated in soap solution, the oily and greasy particles present on its surface and entrapped by soap micelles get dispersed in water due to which the soap water becomes dirty but the cloth gets cleaned. The cloth is cleaned thoroughly by rinsing in clean water a number of times.

Please note that the whole purpose of using soap for washing is to make the oily and greasy dirt particles soluble in water so that they can be washed away with water during agitating and rinsing. **The fact that soap acts by making oily and greasy particles mix with water can be demonstrated as follows** :

1. Take about 10 mL of water in a test-tube and add a little cooking oil to it. The oil does not mix with water. It floats on water.
2. Put a cork on the test-tube and shake it well for a few minutes. Even then oil floats on water and does not mix in it.
3. Now add a little of soap and shake it again.

4. This time the oil and water mix and form a milky emulsion.
5. From this we conclude that soap has made the oil mix in water.

Limitations of Soap

Hard water contains calcium and magnesium salts. **Soap is not suitable for washing clothes with hard water** because of two reasons :

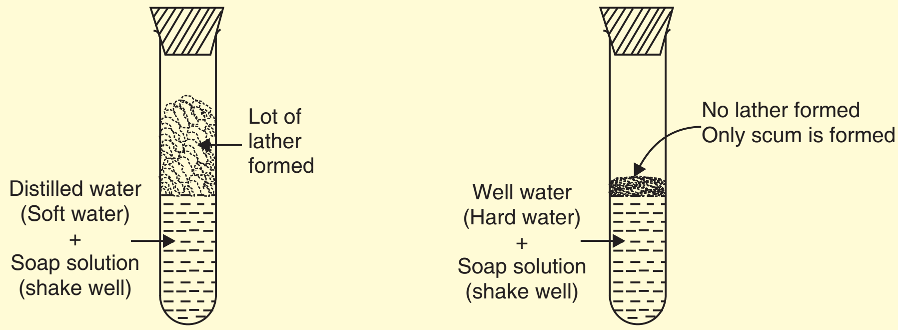
1. When soap is used for washing clothes with hard water, a large amount of soap is wasted in reacting with the calcium and magnesium ions of hard water to form an insoluble precipitate called scum, before it can be used for the real purpose of washing. So, a larger amount of soap is needed for washing clothes when the water is hard.

2. The scum (or curdy precipitate) formed by the action of hard water on soap, sticks to the clothes being washed and interferes with the cleaning ability of the additional soap. This makes the cleaning of clothes difficult.

Figure 60. Soap forms 'scum' with hard water.

The formation of lather or foam (*jhaag*) is necessary for removing dirt from clothes during the washing of clothes. Soap does not give lather easily with hard water because it first reacts with the calcium ions and magnesium ions present in hard water to form insoluble precipitates of calcium and magnesium salts of fatty acids. Soft water, however, does not contain any calcium ions or magnesium ions and, therefore, lathers easily when soap is added. This will become clear from the following experiment. Please note that distilled water is the softest water we can have. On the other hand, well water and hand-pump water are hard water.

(*i*) Take about 10 mL soft water (distilled water or rain water) in a test-tube and add five drops of soap solution to it. Shake the test-tube vigorously. We will see that a lot of lather (*jhaag*) is formed quickly [see Figure 61(*a*)]. From this we conclude that *soap forms lather easily with soft water*.



(*a*) Soap forms lather easily with soft water

(*b*) Soap does not give lather easily with hard water

Figure 61. Behaviour of soap with soft and hard water.

(*ii*) Take about 10 mL hard water (well water or hand-pump water) in another test-tube and add five drops of soap solution to it. Shake the test-tube vigorously. We will see that no lather (*jhaag*) is formed at first. Only a dirty white curd-like scum is formed on the surface of water [see Figure 61(*b*)]. From this we conclude that *soap does not form lather easily with hard water*. We will have to add much more soap to obtain lather with hard water.

Note. If hard water (well water or hand-pump water) is not available for performing the above experiment, **we can prepare a sample of hard water ourselves**. Hard water can be made by dissolving a little of calcium salt or magnesium salt in a beaker of water. The calcium and magnesium salts which can be dissolved to obtain hard water are : calcium hydrogencarbonate, calcium sulphate, calcium chloride, magnesium hydrogencarbonate, magnesium sulphate or magnesium chloride. Please note that tap water is usually soft water.

DETERGENTS

We have just seen that it is quite difficult to wash clothes with soap when the water is hard. This difficulty has been overcome by using another kind of cleansing agents called detergents. **Detergents are also called 'soap-less soaps' because though they act like a soap in having the cleansing properties, they do not contain the usual 'soaps' like sodium stearate, etc.** Detergents are better cleansing agents than soaps because they do not form insoluble calcium and magnesium salts with hard water, and hence can be used for washing even with hard water. Unlike soap, a detergent can lather well even with hard water. This can be shown as follows.

Figure 62. These are some common detergent powders.

Take about 10 mL hard water (well water or hand-pump water) in a test-tube and add 5 drops of a detergent solution to it. Shake the test-tube vigorously. We will see that a lot of lather (or foam) is formed quickly (see Figure 63). From this we conclude that *a detergent forms lather easily even in hard water*. Please note that **we would not be able to check whether a sample of water is hard by using a detergent (because a detergent forms lather easily even with hard water)**. We will have to use a soap for this purpose.

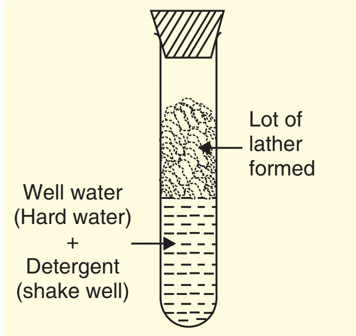


Figure 63. A detergent forms lather easily even with hard water.

A detergent is the sodium salt of a long chain benzene sulphonic acid (or the sodium salt of a long chain alkyl hydrogensulphate) which has cleansing properties in water. A detergent has a large non-ionic hydrocarbon group and an ionic group like sulphonate group, $SO_3^-Na^+$, or sulphate group $SO_4^-Na^+$. Examples of detergents are : Sodium *n*-dodecyl benzene sulphonate and Sodium *n*-dodecyl sulphate. These are shown below :

$CH_3—(CH_2)_{11}—C_6H_4—SO_3^-Na^+$
Sodium *n*-dodecyl benzene sulphonate
(A common detergent)

$CH_3—(CH_2)_{10}—CH_2—SO_4^-Na^+$
Sodium *n*-dodecyl sulphate
(Another detergent)

It is clear from the above discussion that the structure of a detergent is similar to that of soaps. A detergent molecule also consists of two parts : a long hydrocarbon chain which is water repelling (hydrophobic), and a short ionic part which is water attracting (hydrophilic). Detergents can lather well even in hard water because they do not form insoluble calcium or magnesium salts on reacting with the calcium ions and magnesium ions present in hard water. Detergents are made from long chain hydrocarbons obtained from petroleum.**The cleansing action of a detergent is similar to that of a soap**. That is, a detergent works by making the oil and grease particles of dirty clothes dissolve in water through the formation of micelles. Detergents are usually used to make washing powders and shampoos. We will now give the main differences between soaps and detergents.

Differences between Soaps and Detergents

Soaps	*Detergents*
1. Soaps are the sodium salts (or potassium salts) of the long chain carboxylic acids (fatty acids). The ionic group in soaps is $—COO^-Na^+$	1. Detergents are the sodium salts of long chain benzene sulphonic acids or long chain alkyl hydrogensulphates. The ionic group in a detergent is $—SO_3^-Na^+$ or $—SO_4^-Na^+$
2. Soaps are not suitable for washing purposes when the water is hard.	2. Detergents can be used for washing even when the water is hard.
3. Soaps are biodegradable.	3. Some of the detergents are not biodegradable.
4. Soaps have relatively weak cleansing action.	4. Detergents have a strong cleansing action.

Detergents have a number of advantages over soaps due to which they are replacing soaps as washing agents. Detergents are better than soaps because of the following reasons :

1. Detergents can be used even with hard water whereas soaps are not suitable for use with hard water.
2. Detergents have a stronger cleansing action than soaps.
3. Detergents are more soluble in water than soaps.

Figure 64. Water pollution caused by detergents.

An important disadvantage of detergents over soaps is that some of the detergents are not biodegradable, that is, they cannot be decomposed by micro-organisms like bacteria and hence cause water pollution in lakes and rivers. All the soaps are, however, biodegradable (which can be decomposed by micro-organisms like bacteria), and hence do not cause water pollution. Let us answer one question now.

Sample Problem. People use a variety of methods to wash clothes. Usually after adding the soap, they beat the clothes on a stone slab, 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 ? **(NCERT Book Question)**

Answer. It is necessary to agitate (or shake) to get clean clothes because the soap micelles which entrap oily or greasy particles on the surface of dirty cloth have to be removed from its surface. When the cloth wetted in soap solution is agitated (or beaten), the micelles containing oily or greasy dirt particles get removed from the surface of dirty cloth and go into water. And the dirty cloth gets cleaned.

We are now a position to **answer the following questions :**

Very Short Answer Type Questions

1. Name the gas evolved when ethanoic acid is added to sodium carbonate. How would you prove the presence of this gas ?

2. Which of the following will give brisk effervescence with sodium hydrogencarbonate and why ?

CH_3COOH, CH_3CH_2OH

3. Name the functional group present in an organic compound which gives brisk effervescence with $NaHCO_3$.

4. Name the hydrocarbon formed when ethanol is heated with conc. H_2SO_4 at 170°C ? What is this reaction known as ?

5. Why does ethyne (acetylene) burn with a sooty flame ?

6. Name the product formed when hydrogen is added to ethene.

7. Explain why, ethene decolourises bromine water whereas ethane does not.

8. Name two catalysts which can be used in the hydrogenation of unsaturated compounds.

9. State two disadvantages of incomplete combustion.

10. What happens when (give chemical equation) :

Sodium reacts with ethanol (ethyl alcohol)

11. Describe one reaction of ethanol.

12. Name one liquid carbon compound which is being used as an additive in petrol in some countries.

13. What are the raw materials required for making soap in a laboratory (or at home) ?

14. Would you be able to check whether water is hard by using a detergent ? Why ?

15. Describe a test for carboxylic acids.

16. Why is the conversion of ethanol into ethanoic acid an oxidation reaction ?

17. Explain why, alkanes are excellent fuels.

18. Name one chemical compound which can be used to distinguish between ethanol and ethanoic acid.

19. Complete the following equations :

(*a*) $CH_3CH_2OH \xrightarrow[170°C]{Conc.\ H_2SO_4}$

(*b*) $CH_3COOH + C_2H_5OH \xrightarrow{Conc.\ H_2SO_4}$

20. Complete and balance the following equations :

(*a*) $CH_4 + O_2 \longrightarrow$

(*b*) $CH_4 + Cl_2 \xrightarrow{\text{Sunlight}}$

21. Fill in the following blanks with suitable words :

(*a*) The process of burning of a hydrocarbon in the presence of air to give CO_2, H_2O, heat and light is known as ....

(*b*) The sodium salt of a long chain fatty acid is called ....

(*c*) .... is better than soap for washing clothes when the water is hard.

(*d*) The organic acid present in vinegar is............

Short Answer Type Questions

22. Which of the following hydrocarbons will give substitution reactions and why ?

CH_4, C_3H_6, C_3H_8, C_4H_6, C_5H_{12}, C_5H_{10}

23. Which of the following will give addition reactions and why ?

C_4H_{10}, C_2H_6, C_2H_4, CH_4, C_3H_8, C_3H_4

24. (*a*) Write the chemical equation of the reaction which takes place during the burning of ethanol in air.

(*b*) Why is ethanol used as a fuel ?

(*c*) State two uses of ethanol (other than as a fuel).

25. (*a*) What happens when propanoic acid is warmed with methanol in the presence of a few drops of concentrated sulphuric acid ? Write equation of the reaction involved.

(*b*) What change will you observe if you test soap solution with a litmus paper (red and blue) ? Give reason for your observation.

(*c*) What is meant by denatured alcohol ? What is the need to denature alcohol ?

26. (*a*) How would you test for an alcohol ?

(*b*) Give the harmful effects of drinking alcohol.

(*c*) Explain why, methanol is much more dangerous to drink than ethanol.

27. How would you convert :

(*a*) ethanol into ethene ?

(*b*) propanol into propanoic acid ?

Name the process in each case and write the equations of the reactions involved.

28. Give reasons for the following observations :

(*a*) Air holes of a gas burner have to be adjusted when the vessels being heated get blackened by the flame.

(*b*) Use of synthetic detergents causes pollution of water.

29. (*a*) What would be observed on adding a 5% alkaline potassium permanganate solution drop by drop to some warm ethanol in a test-tube ? Write the name of the compound formed during the chemical reaction. Also write chemical equation of the reaction which takes place.

(*b*) How would you distinguish experimentally between an alcohol and a carboxylic acid on the basis of a chemical property ?

30. Name the functional group of organic compounds that can be hydrogenated. With the help of a suitable example, explain the process of hydrogenation, mentioning the conditions of the reaction and any one change in physical property with the formation of the product. Name any one natural source of organic compounds that are hydrogenated.

31. (*a*) Name the gas evolved when ethanol reacts with sodium.

(*b*) What type of compound is formed when a carboxylic acid reacts with an alcohol in the presence of conc. H_2SO_4 ?

(*c*) What will you observe when dilute ethanoic acid and dilute hydrochloric acid are put on universal indicator paper, one by one ? What does it show ?

32. (*a*) What type of compound is CH_3COOH ?

(*b*) What substance should be oxidised to prepare CH_3COOH ?

(*c*) What is the physical state of CH_3COOH ?

(*d*) State one advantage of soaps over detergents.

33. (*a*) What happens when ethanol reacts with ethanoic acid in the presence of a little of concentrated sulphuric acid ? Write equation of the reaction involved.

(*b*) What happens when ethanol is heated with concentrated sulphuric acid at 170°C ? Write the equation of the reaction which takes place.

34. (*a*) What happens when ethanol is oxidised with alkaline potassium permanganate (or acidified potassium dichromate) ? Write the equation of the reaction involved.

(*b*) Choose those compounds from the following which can turn blue litmus solution red :

$HCHO$, CH_3COOH, CH_3OH, C_2H_5OH, $HCOOH$, CH_3CHO

Give reasons for your choice.

35. (*a*) Explain the process of preparation of soap in laboratory.

(*b*) Why is common salt (sodium chloride) added during the preparation of soap ?

(*c*) Why is soap not suitable for washing clothes when the water is hard ?

36. (*a*) What happens when methane (natural gas) burns in air ? Write the chemical equation of the reaction involved.

(*b*) What happens when ethanoic acid reacts with sodium carbonate ? Write chemical equation of the reaction involved.

(*c*) Give a test that can be used to differentiate chemically between butter and cooking oil.

37. (*a*) Describe, giving equation, a chemical reaction which is characteristic of saturated hydrocarbons (or alkanes).

(*b*) What is an oxidising agent ? Name two oxidising agents which can oxidise ethanol to ethanoic acid.

(*c*) Describe one reaction of a carboxylic acid.

38. (*a*) Write names and formulae of hydrocarbons containing a single and a double bond (one example for each). Give one characteristic chemical property of each.

(*b*) What is a detergent ? Name one detergent.

(*c*) Why have detergents replaced soap as a washing agent ?

39. (*a*) How does ethanoic acid react with sodium hydrogencarbonate ? Give equation of the reaction which takes place.

(*b*) Why are carbon and its compounds used as fuels for most applications ?

(*c*) Which of the two is better for washing clothes when the water is hard : soap or detergent ? Give reason for your answer.

40. (*a*) What is meant by a substitution reaction ? Give an example (with equation) of the substitution reaction of an alkane.

(*b*) How is soap made ? Write a word equation involved in soap making.

41. (*a*) How is ethanoic acid obtained from ethanol ? Write down the chemical equation of the reaction involved.

(*b*) How would you distinguish between ethanol and ethanoic acid by chemical test ?

(*c*) Explain the formation of scum when hard water is treated with soap.

42. (*a*) What happens when methane reacts with chlorine ? Give equation of the reaction which takes place.

(*b*) What is hydrogenation ? What is its industrial application ?

(*c*) Give any two differences between soaps and detergents.

43. (*a*) What happens when ethanoic acid reacts with sodium hydroxide ? Write equation of the reaction involved.

(*b*) What happens when vegetable oils are hydrogenated ? Name the catalyst used.

(*c*) What is the advantage of detergents over soaps for washing clothes ? Also state one disadvantage.

44. (*a*) An organic compound *X* of molecular formula $C_2H_4O_2$ gives brisk effervescence with sodium hydrogencarbonate. Give the name and formula of *X*.

(*b*) A mixture of ethyne (acetylene) and oxygen is burnt for welding. Can you tell why a mixture of ethyne and air is not used ?

(*c*) Name a chemical reaction which is characteristic of unsaturated hydrocarbons (like alkenes and alkynes).

45. (*a*) What is meant by an addition reaction ? Give an example (with equation) of an addition reaction of an alkene.

(*b*) What is added to groundnut oil when it is to be converted to *vanaspati ghee* ?

(*c*) Which of the two is better for our health : butter or vegetable oil ? Why ?

Long Answer Type Questions

46. (*a*) When ethanoic acid reacts with sodium hydrogencarbonate, then a salt X is formed and a gas Y is evolved. Name the salt X and gas Y. Describe an activity with the help of a labelled diagram of the apparatus used to prove that the evolved gas is the one which you have named. Also write the chemical equation of the reaction involved.

(*b*) Give any two uses of ethanoic acid.

47. (*a*) Esters are sweet-smelling substances and are used in making perfumes. Describe an activity for the preparation of an ester with the help of a well labelled diagram. Write an equation for the chemical reaction involved in the formation of the ester. Also write the names of all the substances involved in the process of esterification.

(*b*) State any two uses of esters.

48. (*a*) Name the reaction which is usually used in the conversion of vegetable oils to fats. Explain the reaction involved in detail. Write a chemical equation to illustrate your answer.

(*b*) What is saponification ? Write the chemical equation of the reaction involved in this process. Name all the substances which take part in this process and also those which are formed.

(*c*) Why does micelle formation take place when soap is added to water ? Will a micelle be formed in other solvents like ethanol also ?

49. (*a*) What is a soap ? Name one soap.

(*b*) Describe the structure of a soap molecule with the help of a diagram.

(*c*) Explain the cleansing action of soap. Draw diagrams to illustrate your answer.

Multiple Choice Questions (MCQs)

50. While cooking, if the bottom of the utensil 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.

51. When ethanol is heated with alkaline potassium permanganate solution, it gets converted into ethanoic acid. In this reaction, alkaline potassium permanganate acts as :

(*a*) reducing agent (*b*) oxidising agent (*c*) catalyst (*d*) dehydrating agent

52. When ethanol is heated with concentrated sulphuric acid at 170°C, it gets converted into ethene. In this reaction, concentrated sulphuric acid acts as :

(*a*) oxidising agent (*b*) catalyst (*c*) dehydrating agent (*d*) reducing agent

53. When a vegetable oil is treated with hydrogen in the presence of nickel (or palladium) catalyst , it forms a fat. This is an example of :

(*a*) anodising reaction (*b*) substitution reaction (*c*) displacement reaction (*d*) addition reaction

54. The soap molecule has a :

(*a*) hydrophilic head and a hydrophobic tail (*b*) hydrophobic head and a hydrophilic tail
(*c*) hydrophobic head and a hydrophobic tail (*d*) hydrophilic head and a hydrophilic tail

55. Chlorine reacts with saturated hydrocarbons at room temperature in the :

(*a*) absence of sunlight (*b*) presence of sunlight
(*c*) absence of moisture (*d*) presence of H_2SO_4

56. In a soap micelle, the soap molecules are arranged radially with :

(*a*) ionic ends directed towards the centre and hydrocarbon ends directed outwards
(*b*) hydrocarbon ends directed towards the centre and ionic ends directed outwards
(*c*) both ionic ends and hydrocarbon ends directed towards the centre
(*d*) both hydrocarbon ends and ionic ends directed outwards

57. When ethanol reacts with sodium metal, it forms two products. These products are :

(*a*) sodium ethanaoate and oxygen (*b*) sodium ethanaoate and hydrogen
(*c*) sodium ethoxide and oxygen (*d*) sodium ethoxide and hydrogen

58. Vinegar is a solution of about :

(*a*) 5 to 8 per cent ethanoic acid in alcohol (*b*) 5 to 8 per cent ethanoic acid in water
(*c*) 50 to 80 per cent ethanoic acid in water (*d*) 50 to 80 per cent ethanoic acid in alcohol

59. One of the following substances is not added to make denatured alcohol. This is :
(*a*) methyl alcohol (*b*) copper sulphate (*c*) chloroform (*d*) pyridine

60. One of the following organic compounds cannot decolourise the red-brown colour of bromine water. This compound is :
(*a*) $C_{14}H_{28}$ (*b*) C_7H_{12} (*c*) C_6H_{14} (*d*) C_9H_{16}

61. The substance which can produce brisk effervescence with baking soda solution is :
(*a*) ethanol (*b*) vegetable oil (*c*) vinegar (*d*) soap solution

62. The chemical which is not required for the preparation of soap in the laboratory is :
(*a*) vegetable oil (*b*) baking soda (*c*) caustic soda (*d*) common salt

63. Which of the following can damage optic nerve leading to blindness, if taken internally ?
(*a*) CH_3COOH (*b*) C_2H_5OH (*c*) $NaHCO_3$ (*d*) CH_3OH

64. The usual disease caused by the excessive drinking of alcohol over a long period of time is :
(*a*) diabetes (*b*) cataract (*c*) cirrhosis (*d*) arthritis

65. Which of the following molecular formula corresponds to ethyl butanoate ester ?
(*a*) $C_5H_{10}O_2$ (*b*) $C_6H_{12}O_2$ (*c*) $C_7H_{14}O_2$ (*d*) $C_8H_{16}O_2$

Questions Based on High Order Thinking Skills (HOTS)

66. A neutral organic compound X of molecular formula C_2H_6O on oxidation with acidified potassium dichromate gives an acidic compound Y. Compound X reacts with Y on warming in the presence of conc. H_2SO_4 to give a sweet smelling substance Z. What are X, Y and Z ?

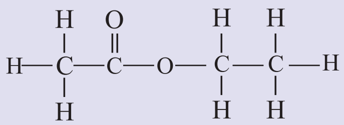
67. Consider the following organic compounds :

$HCHO$, C_2H_5OH, C_2H_6, CH_3COOH, C_2H_5Cl

Choose two compounds which can react in the presence of conc. H_2SO_4 to form an ester. Give the name and formula of the ester formed.

68. A neutral organic compound is warmed with some ethanoic acid and a little of conc. H_2SO_4. Vapours having sweet smell (fruity smell) are evolved. What type of functional group is present in this organic compound ?

69. The structural formula of an ester is :



Write the formula of the acid and the alcohol from which it is formed.

70. Consider the following organic compounds :

CH_3OH, C_2H_5OH, CH_3COCH_3, CH_3COOH, C_2H_5COOH, $C_4H_9COOC_2H_5$, CH_4, C_2H_6, CH_3CHO, $HCHO$

Out of these compounds :
(*a*) Which compound is most likely to be sweet-smelling ?
(*b*) Which compound on treatment with conc. H_2SO_4 at 170°C forms an alkene ?
(*c*) Which compound on repeated chlorination forms chloroform ?
(*d*) Which compound is added to alcohol to denature it ?
(*e*) Which compound is a constituent of vinegar ?
(*f*) Which compound is used to sterilise wounds and syringes ?

71. An organic acid X is a liquid, which often freezes during winter time in cold countries, having the molecular formula $C_2H_4O_2$. On warming it with methanol in the presence of a few drops of concentrated sulphuric acid, a compound Y with a sweet smell is formed.
(*a*) Identify X and Y. Also write their formulae showing the functional group present in them.
(*b*) Write a chemical equation for the reaction involved.

72. An organic compound A having the molecular formula C_3H_8O is a liquid at room temperature. The organic liquid A reacts with sodium metal to evolve a gas which burns causing a little explosion. When the organic liquid A is heated with concentrated sulphuric acid at 170°C, it forms a compound B which decolourises bromine water. The compound B adds on one molecule of hydrogen in the presence of Ni as catalyst to form compound C which gives substitution reactions with chlorine.

(*a*) What is compound A ?

(*b*) What is compound B ?

(*c*) What type of reaction occurs when A is converted into B ?

(*d*) What is compound C ?

(*e*) What type of reaction takes place when B is converted into C ?

73. An organic compound A (molecular formula $C_2H_4O_2$) reacts with Na metal to form a compound B and evolves a gas which burns with a pop sound. Compound A on treatment with an alcohol C in the presence of a little of concentrated sulphuric acid forms a sweet-smelling compound D (molecular formula $C_3H_6O_2$). Compound D on treatment with NaOH solution gives back B and C. Identify A, B, C and D.

74. Which of the following hydrocarbons can decolourise bromine water and which cannot ? Why ?

C_6H_{12}, C_6H_{14}, C_6H_{10}

75. A four carbon atoms containing neutral organic compound X reacts with sodium metal to evolve a gas which burns with a 'pop' sound. Another four carbon atoms containing carbon compound reacts with sodium hydrogencarbonate to evolve a gas which turns lime water milky. When compounds X and Y are heated together in the presence of a little of concentrated sulphuric acid, then a new compound Z is formed.

(*a*) What is compound X ? Also write its formula.

(*b*) What is compound Y ? Also write its formula,.

(*c*) What is compound Z ? Also write its formula.

(*d*) What type of smell is given by compound Z ?

(*e*) What is the general name of compounds like Z ?

(*f*) What is the general name of the reaction which takes place between X and Y to form Z ?

ANSWERS

2. CH_3COOH ; Being acid, it reacts with sodium hydrogencarbonate to produce carbon dioxide gas **3.** Carboxylic acid group, –COOH **4.** Ethene ; Dehydration **6.** Ethane **12.** Ethanol **18.** Sodium hydrogencarbonate **21.** (*a*) combustion (*b*) soap (*c*) Detergent (*d*) ethanoic acid **22.** CH_4, C_3H_8 and C_5H_{12} ; All these are saturated hydrocarbons (Alkanes) **23.** C_2H_4 and C_3H_4 ; These are unsaturated hydrocarbons (Alkene and Alkyne) **29.** (*b*) A carboxylic acid reacts with sodium hydrogencarbonate to give brisk effervescence of carbon dioxide gas but an alcohol does not react with sodium hydrogencarbonate **30.** Alkenes ; Vegetable oils are hydrogenated ; The liquid vegetable oils change into solid fat **32.** (*a*) Carboxylic acid (*b*) Ethanol, CH_3CH_2OH (*c*) Liquid state **34.** (*b*) CH_3COOH and HCOOH ; These are organic acids **44.** (*a*) Ethanoic acid, CH_3COOH **45.** (*b*) Hydrogen **46.** Salt X is sodium ethanoate, CH_3COONa ; Gas Y is carbon dioxide, CO_2 ; Gas Y turns lime water milky **48.** (*a*) Catalytic hydrogenation **50.** (*b*) **51.** (*b*) **52.** (c) **53.** (*d*) **54.** (*a*) **55.** (*b*) **56.**(*b*) **57.** (*d*) **58.** (*b*) **59.** (*c*) **60** (*c*) **61.** (*c*) **62.** (*b*) **63.** (*d*) **64.** (*c*) **65.** (*b*) **66.** X is ethanol ; Y is ethanoic acid ; Z is ethyl ethanoate **67.** C_2H_5OH and CH_3COOH; Ethyl ethanoate, $CH_3COOC_2H_5$ **68.** Alcohol group, –OH **69.** Acid : $CH_3-\overset{\overset{O}{||}}{C}-OH$; Alcohol : $CH_3–CH_2–OH$ **70.** (*a*) $C_4H_9COOC_2H_5$; Ester (*b*) C_2H_5OH; Ethene, C_2H_4 (*c*) CH_4 (*d*) CH_3OH (*e*) CH_3COOH (*f*) C_2H_5OH **71.** (*a*) X is ethanoic acid, $CH_3-\overset{\overset{O}{||}}{C}-OH$; Y is methyl ethanoate , $CH_3-\overset{\overset{O}{||}}{C}-O-CH_3$ **72.** (*a*) A is propanol, $CH_3–CH_2–CH_2OH$ (*b*) B is propene, $CH_3–CH=CH_2$ (*c*) Dehydration reaction (*d*) C is propane, $CH_3–CH_2–CH_3$ (*e*) Addition reaction **73.** A is ethanoic acid, CH_3COOH; B is sodium ethanoate, CH_3COONa ; C is methanol, CH_3OH; D is methyl ethanoate, CH_3COOCH_3 **74.** Can decolourise bromine water : C_6H_{12} and C_6H_{10}, These are unsaturated hydrocabons ; Cannot decolourise bromine water : C_6H_{14}, It is a saturated hydrocarbon **75.** (*a*) X is butanol, C_4H_9OH (*b*) Y is butanoic acid, C_3H_7COOH (*c*) Z is butyl butanoate , $C_3H_7COOC_4H_9$ (*d*) Sweet smell (*e*) Esters (*f*) Esterification