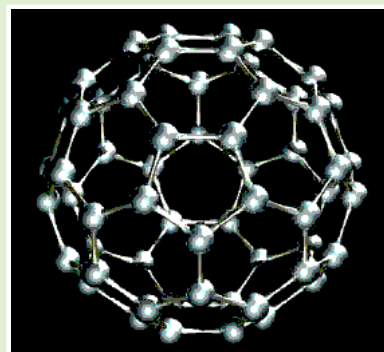


Chapter

14

Carbon and its Compounds



The food you eat, the clothes you wear, the cosmetics you use, the fuels you use to run automobiles are all the compounds of carbon.

Carbon was discovered in prehistory and it was known to the ancients. They used to manufacture charcoal by burning organic material.

Carbon is a non-metal. It belongs to the fourteenth group or IV A group in the modern periodical table. The elements of this group have four electrons in the valence shell.

Let us write the electronic configuration of Carbon (${}_6\text{C}$).

Atomic number of carbon is 6.

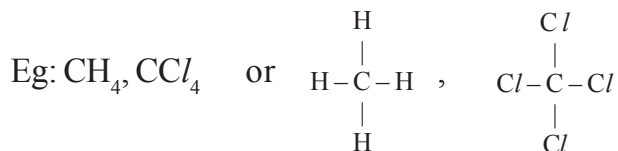
Electronic configuration of carbon (ground state) ${}_6\text{C}$: $1s^2 2s^2 2p^2$. To get the octet in its outer shell it has to gain four more electrons to form C^{4-} . The electronegativity of carbon is only 2.5 and its nucleus has only six protons. Therefore it would be difficult for a nucleus with six protons to hold ten electrons. Hence, carbon cannot form C^{4-} ions so easily.

- Can carbon get helium configuration by losing four electrons from the outer shell?

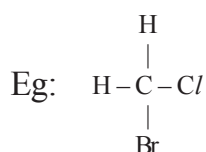
If carbon loses four electrons from the outer shell, it has to form C^{4+} ions. This requires huge amount of energy which is not available normally. Therefore C^{4+} formation also is a remote possibility. Carbon has to satisfy its tetravalency by sharing electrons with other atoms. It has to form four covalent bonds either with its own atoms or atoms of other elements.

The possibility of bonds formation by a carbon atom is as:

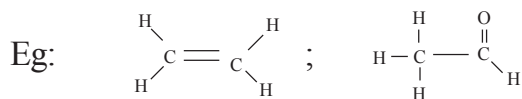
- a) i. Four single covalent bonds, with atoms of same element like hydrogen, Chlorine



- ii. Four single covalent bonds with atoms of different elements ;



- b) Carbon atoms may form one double bond and two single bonds



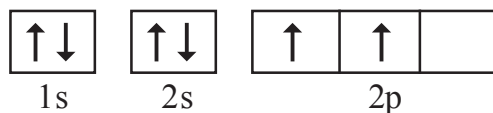
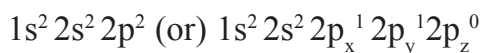
- c) Carbon atom may form one single bond and a triple bond

Eg: $\text{H}-\text{C}\equiv\text{C}-\text{H}$ or $\text{CH}_3-\text{C}\equiv\text{N}$ or carbon atoms may also form two double bonds as in $\text{CH}_2=\text{C}=\text{CH}_2$.

- How do carbon atoms form bonds in so many different ways as mentioned above?
- Explain the four unpaired electrons in carbon atom through excited state.

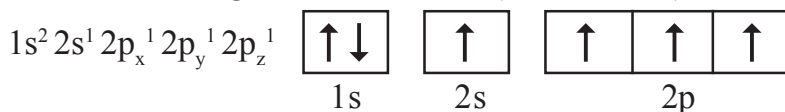
As per valence bond theory (see chapter, chemical bonding), the four unpaired electrons in a carbon atom are shown by suggesting excited state to carbon atom.

Electronic configuration of carbon (ground state):



Carbon (ground state)

Electronic configuration of carbon (excited state):



Carbon (excited state)



Linus Pauling - The world's one of the greatest scientists and a great humanist. He was acknowledged as the most influential chemist.

He is the only person ever to receive two unshared Nobel Prizes — for Chemistry (1954) and for Peace (1962).

In excited state carbon atom gets its one of the '2s' electrons to say $2p_z$.

Each carbon atom has four unpaired electrons when excited and tends to form four covalent bonds.

- Where this energy to excite electron comes from?

We have to understand that free carbon atom would not be in excited state under normal conditions. When the carbon atom is ready to form bonds with other atoms, the energy required for excitation is taken up from bond energies, which are the liberated energies when bonds are formed between carbon atom and other atoms.

- In methane (CH_4) molecule all four carbon – hydrogen bonds are identical and bond angle $\text{H}\hat{\text{C}}\text{H}$ is $109^\circ 28'$. How can we explain this?

In the above discussion, we have found that in excited state, carbon atom has three unpaired electrons in p-orbitals and one electron in s-orbital. These four valence electrons are with different energies.

- How these energetically unequal valence electrons form four equivalent covalent bonds in methane molecule?

Let us see how?

Promotion of an electron

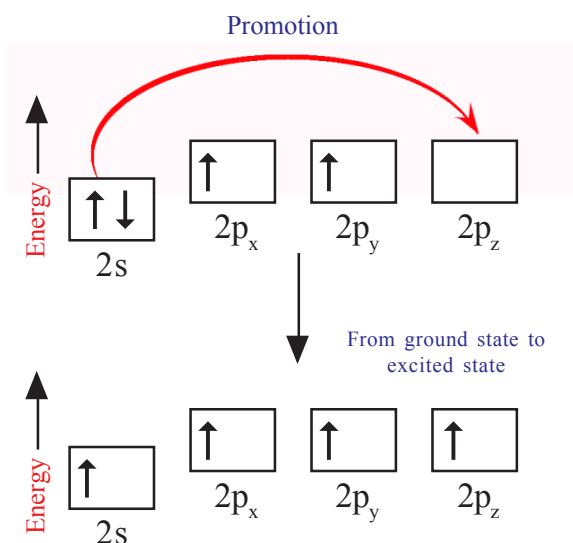
When bonds are formed, energy is released and the system becomes more stable. If carbon forms four bonds rather than two, still more energy is released and so the resulting molecule becomes even more stable.

The energy difference between the 2s and 2p orbitals is very small. When carbon atom is ready to form bonds it gets a small amount of energy from bond energies and gets excited to promote an electron from the 2s to the empty 2p to give four unpaired electrons.

We have got four unpaired electrons ready for bonding, but these electrons are in two different kinds of orbitals and their energies are different. We are not going to get four identical bonds unless these unpaired electrons are in four identical orbitals.

How to explain the four orbitals of carbon containing unpaired electrons as energetically equal?

We can explain it by the phenomenon called *hybridisation*.



(?) Do you know?

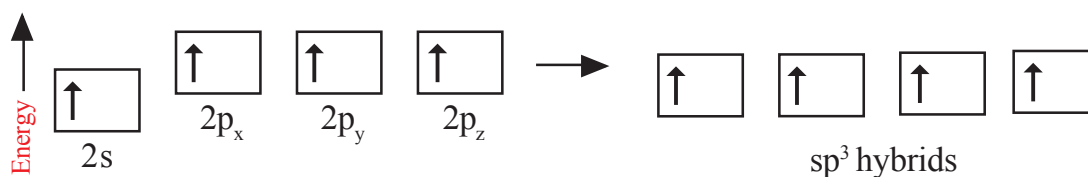
The concept of hybridisation was introduced by Linus Pauling (1931). The redistribution of orbitals of almost equal energy in individual atoms to give equal number of new orbitals with identical properties like energy and shape is called “hybridisation”. The newly formed orbitals are called as ‘hybrid orbitals.’

Hybridisation

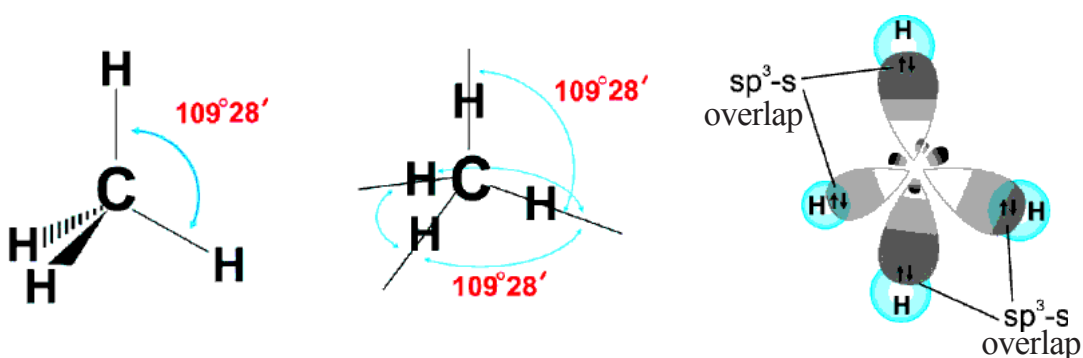
In the excited carbon atom its one s-orbital (2s) and three p-orbitals ($2p_x$, $2p_y$, $2p_z$) intermix and reshuffle into four identical orbitals known as sp^3 orbitals. Thus, carbon atom undergoes sp^3 hybridisation.

The four electrons enter into the new four identical hybrid orbitals known as sp^3 hybrid orbitals one each as per Hund’s rule. (because they are made from one ‘s-orbital’ and three ‘p-orbitals’ they are called sp^3 orbitals).

NOTE: Read “ sp^3 ” as “s p three”. or “yes pee three”



The hybridisation enables the carbon to have four identical sp^3 hybrid orbitals and these have one electron each. Since carbon has four unpaired electrons, it is capable of forming bonds with four other atoms may be carbon or atoms of some other monovalent element. When carbon reacts with hydrogen, four hydrogen atoms allow their 's' orbitals containing one electron each to overlap the four sp^3 orbitals of carbon atom which are oriented at an angle of $109^\circ 28'$. (Four orbitals of an atom in the outer shell orient along the four corners of a tetrahedron to have minimum repulsion between their electrons). The nucleus of the atom is at the centre of the tetrahedron. See figures below:

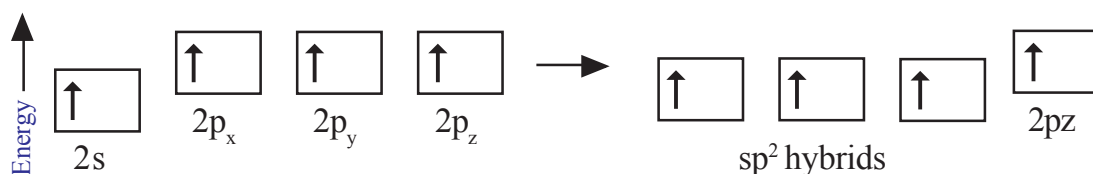


This leads to form four $sp^3 - s$ sigma bonds between carbon atom and four hydrogen atoms. All these bonds are of equal energy.

sp^2 hybridisation

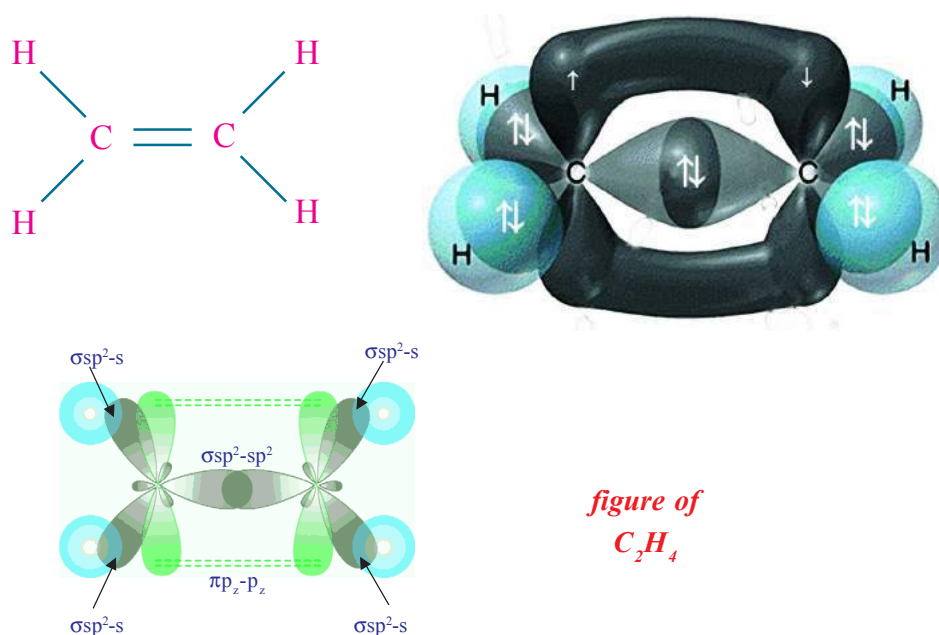
How do you explain the ability of C – atom to form two single covalent bonds and one double bond?

Consider *ethene* (*ethylene*, $CH_2 = CH_2$) molecule as the example.



In the formation of $CH_2=CH_2$ each carbon atom in its excited state *undergoes* sp^2 hybridisation by intermixing one s-orbital (2s) and two p-orbitals (say $2p_x$, $2p_y$) and reshuffling to form three sp^2 orbitals. Now each carbon atom is left with one 'p' orbital (say p_z) unhybridised. The three sp^2 orbitals having one electron each get separated around the nucleus of carbon atoms at an angle of 120° . When carbon is ready to form bonds one sp^2 orbital of one carbon atom overlaps the sp^2 orbital of the other

carbon atom to form $sp^2 - sp^2$ sigma (σ) bond. The remaining two sp^2 orbitals of each carbon atom get overlapped by 's' orbitals of two hydrogen atoms containing unpaired electrons. The unhybridised p_z orbitals on the two carbon atoms overlap laterally as shown in figure to form a π bond. That means there exists a sigma (σ) bond and a pi (π) bond between two carbon atoms in ethene molecule. Hence, the molecule ethene (C_2H_4) is



The common name for Ethene is Ethylene.

sp hybridisation

Each carbon is only joining to two other atoms rather than four (as in methane or ethane) or three (as in ethene). Here the carbon atoms hybridise their outer orbitals before forming bonds, this time they only hybridise two of the orbitals.

They use the 's' orbital (2s) and one of the 2p orbitals, but leave the other 2p orbitals unchanged. The new hybrid orbitals formed are called **sp hybrid orbitals**, because they are made by an s-orbital and a p-orbital reorganizing themselves.

How do you explain the ability of carbon atom to form one single bond and one triple bond?

To know the ability of 'C' to form one single bond and one triple bond, let us consider *ethyne* (acetylene, C_2H_2) molecule as our example.

In acetylene molecule there exists a triple bond between two carbon atoms and the fourth valency of each carbon atom is satisfied by hydrogen atoms ($H-C \equiv C-H$).

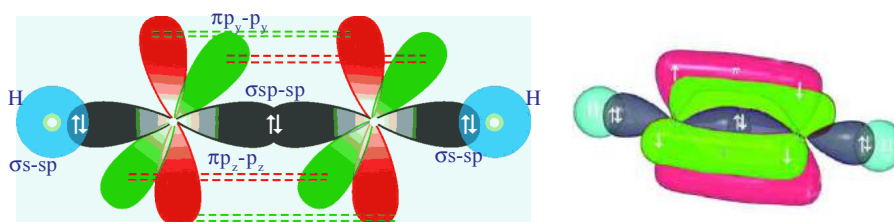
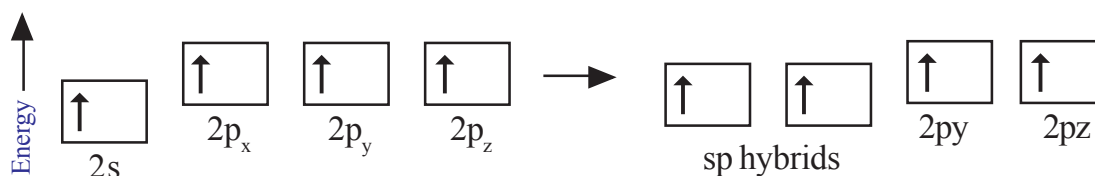


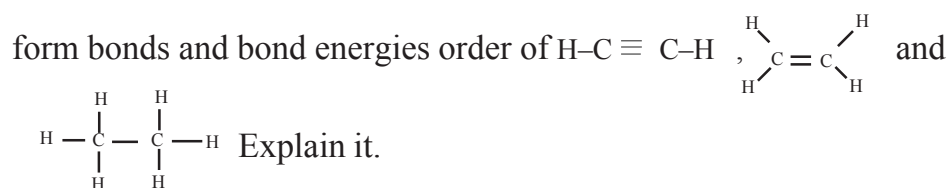
figure of C_2H_2

In C_2H_2 molecule there are two carbon atoms and two hydrogen atoms. In excited state each carbon atom undergoes sp - hybridisation by mixing its one 's' orbital ($2s$) and one 'p' orbital ($2p_x$) and reshuffling to form two identical orbitals known as sp -orbitals. Each carbon atom has two unhybridised p-orbitals (say $2p_y, 2p_z$).



One sp -orbital of a carbon overlaps the sp -orbital of other carbon to give sp - sp sigma bond. The other sp -orbital of each carbon atom overlaps 's' orbital of a hydrogen atom to form a s - sp sigma bond. The unhybridised 'p' orbitals of one carbon atom laterally overlap the unhybridised 'p' orbitals of other carbon atom to give two π bonds between two carbon atoms (say $\pi_{p_y-p_y}, \pi_{p_z-p_z}$, see figure). Thus ethyne molecule $H-C \equiv C-H$ and there exists three σ -bonds and two π -bonds in the molecule.

- Predict the bond distance between the nuclei of carbon atoms that



- What are bond angles \widehat{HCH} in CH_4 , C_2H_4 and C_2H_2 molecules?

Allotropes of Carbon

The property of an element to exist in two or more physical forms having more or less similar chemical properties but different physical properties is called **allotropy**. The different forms of the element are called **allotropes**. Allotropes form due to the difference in the arrangement of atoms in the molecules.

The allotropes of carbon are classified into two types. They are

- **Amorphous forms**
- **Crystalline forms**

Amorphous forms

Different amorphous allotropes of carbon are: Coal; Coke; Wood Charcoal; Animal charcoal; Lamp black; Gas carbon; Petroleum coke; Sugar charcoal.

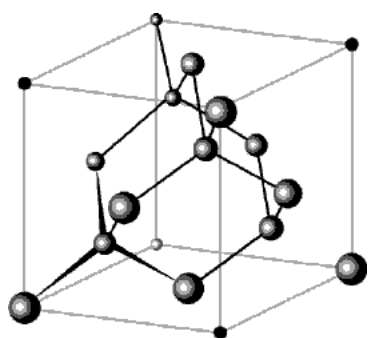
Crystalline forms

Carbon atoms can arrange themselves into different hybridised chemical bonds. Therefore they exhibit different physical and chemical structures such as diamond and graphite. Carbon in solid phase can exist in three crystalline allotropic forms: **diamond, graphite and buckminsterfullerene.**

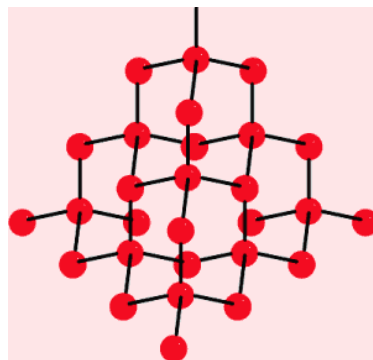
Diamond and graphite form covalent network structures whereas buckminster fullerene has a molecular solid structure with discrete C_{60} molecules. As these crystalline allotropes differ in their structures, they possess different physical properties.

Diamond

In diamond each carbon atom undergoes in its excited state sp^3 hybridisation. Hence, each carbon atom has a tetrahedral environment. The three dimensional structure of diamond is as shown:



Lattice structure of diamond

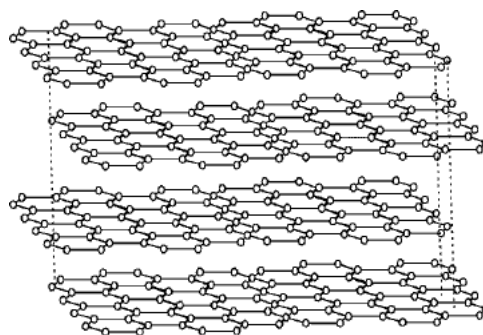
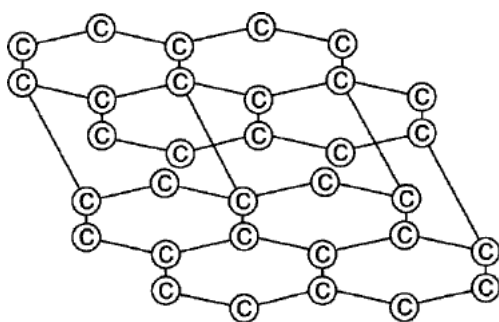


Diamond structure

As C-C bonds are very strong any attempt to distort the diamond structure requires large amount of energy. Hence diamond is one of the hardest materials known.

Graphite

Graphite forms a two dimensional layer structure with C-C bonds within the layers. There are relatively weak interactions between the layers.



The arrangement of carbon atoms in graphite layers

In the layer structure, the carbon atoms are in a trigonal planar environment. This is consistent with each carbon atom in sp^2 hybridisation. Interactions between the sp^2 orbitals (overlaps) lead to the formation of C-C bonds. Each carbon atom is with one unhybridised 'p' orbital. The unhybridised 'p' orbitals interact to form a π system which is delocalised over the whole layer. The interactions known as London dispersion forces between the layers which are separated by a distance of 3.35 \AA are weakened by the presence of water molecules so that it is easy to cleave graphite. For this reason graphite is used as lubricant and as the 'lead' in pencils.

- How do you understand the markings (writings) of a pencil on a paper?

When we write with a pencil, the interlayer attractions breakdown and leave graphite layers on the paper. Pencil marks are easy to remove from paper with an eraser because, the layers do not bind strongly to the paper. Graphite is a good conductor of electricity because of the delocalised π electron system.

Buckminsterfullerene (${}_{60}\text{C}$)

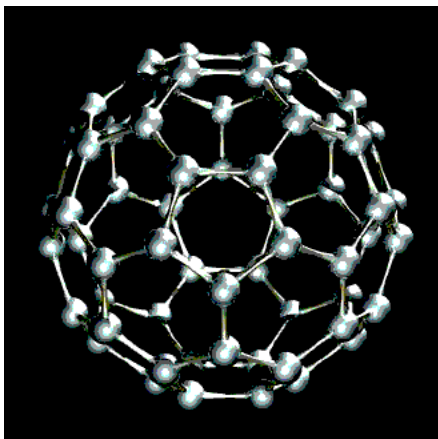
Buckminsterfullerenes are molecules of varying sizes that are composed entirely of carbon. The arrangement of these molecules leads to the form of a hollow sphere, ellipsoid, or tube depending upon their orientations. Fullerenes are formed when vaporized carbon condenses in an atmosphere of an inert gas.

(?) Do you know?

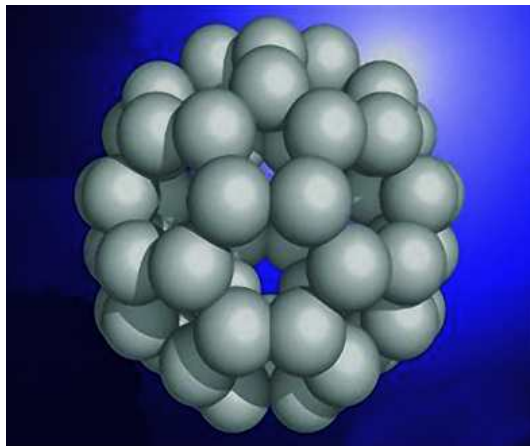
The *buckminsterfullerene*, or usually just *fullerene* for short, was discovered in 1985 by a team of scientists, Robert F. Curl, Harold W. Kroto and Richard E. Smalley from Rice University and the University of Sussex, three of whom were awarded the 1996 Nobel Prize in Chemistry. They are named so for the resemblance of their structure to the geodesic structures devised by the scientist and architect **Richard Buckminster "Bucky" Fuller**.

Buckyballs: Spherical fullerenes are also called *buckyballs*.

Buckminsterfullerene (${}_{60}\text{C}$) contains nearly spherical ${}_{60}\text{C}$ molecules with the shape of a soccer ball.



Buckminsterfullerene (${}_{60}\text{C}$)



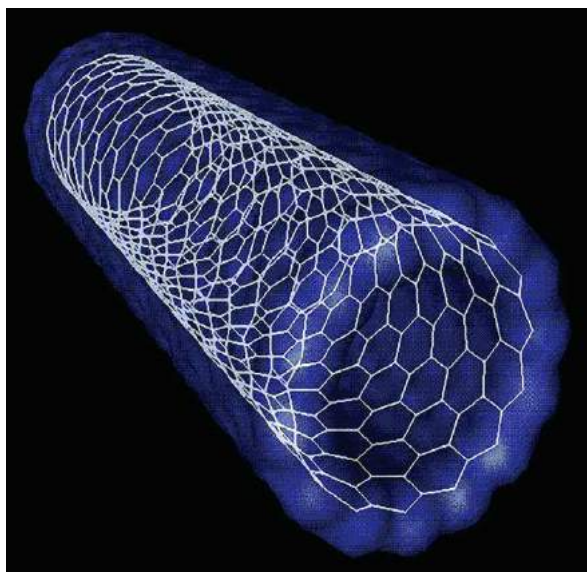
3D structure of Buckminsterfullerene (${}_{60}\text{C}$)

Fullerene, ${}_{60}\text{C}$ molecule contains 12 pentagonal and 20 hexagonal faces on its soccer ball shape, and each carbon atom has sp^2 hybridized orbitals.

Fullerenes are under study for potential medicinal use - such as specific antibiotics to target resistant bacteria and even target certain cancer cells such as melanoma.

Nanotubes

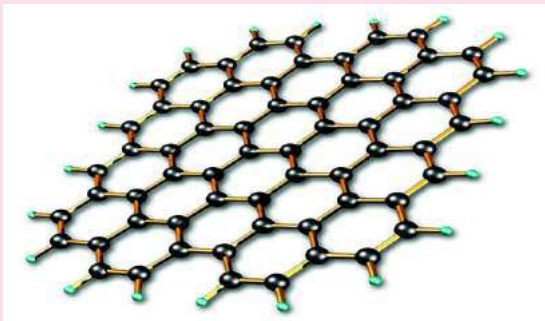
Nanotubes are another allotropic form of carbon discovered in 1991 by *Sumio Iijima*. Nano tubes consist of hexagonal arrays of covalently bonded carbon atoms, similar to the sheets in graphite. Unlike the flat graphite sheets, in nanotubes the sheets are rolled into cylinders. Due to this reason they are called nanotubes. Nanotubes like graphite, are electrical conductors and can be used as molecular wires. In integrated circuits nanotubes are used instead of copper to connect the components together. Scientists inserted biomolecules into nanotubes to inject them into a single cell.



Single-walled carbon nanotube or Buckytube

(?) Do you know?

Graphene - The new wonder material:



3D illustration showing a sheet of graphene



A piece of graphene aerogel - weighing only 0.16 milligrams per cubic centimeter - is placed on a flower.

As its name indicates, graphene is extracted from graphite, the material used in pencils. Like graphite, graphene is entirely composed of carbon atoms. For a thickness of 1mm graphite contains some 3 million layers of graphene. The carbons are perfectly distributed in a hexagonal honeycomb formation only in 0.3 nanometers thickness.

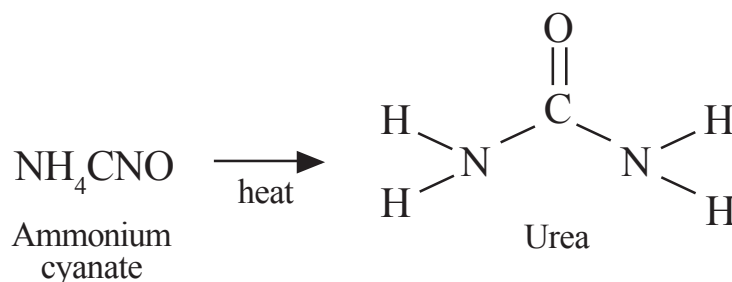
Graphene conducts electricity better than copper. It is 200 times stronger than steel but six times lighter. It is almost perfectly transparent to light.

Versatile nature of carbon

By the eighteenth century scientists tried to explain the difference between the compounds in a broader way.

J. J. Berzelius (1807) named the compounds that derived from living organism as organic compounds and those from non-living materials as inorganic compounds. He thought that organic compounds would be prepared in the living bodies through vital force, the essence of life. As this force is absent outside the living bodies, it was thought that the so called organic compounds could not be synthesized in the laboratories.

Surprisingly *F. Wohler* (1828) produced an organic compound **Urea** in the laboratory by heating an inorganic salt ammonium cyanate.





Wöhler Friedrich (1800 – 1882)

German chemist who was a student of Berzelius. In attempting to prepare ammonium cyanate from silver cyanide and ammonium chloride, he accidentally synthesized urea in 1828. This was the first organic synthesis, and shattered the vitalism theory.

Wöhler pursued the matter further and discovered that urea and ammonium cyanate had the same chemical formula, but very different chemical properties. This was an early discovery of isomerism, since urea has the formula $\text{CO}(\text{NH}_2)_2$ and ammonium cyanate has the formula NH_4CNO .

It inspired many other chemists and they were successful to prepare the so called organic compounds, methane, acetic acid etc., in the laboratory. This gave a death blow to the idea that organic compounds are derived from living organism. Chemists thought about a new definition for organic compounds. After observing the structures and elements of organic compounds, they defined organic compounds as compounds of carbon. Therefore, organic chemistry is totally allotted to carbon compounds.

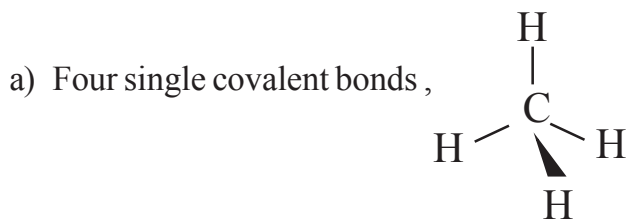
- Allotting completely one special branch in chemistry to compounds of only one element. Is it justified when there are so many elements and their compounds but not with any special branches?

We understand that all molecules that make life possible – carbohydrates, proteins, nucleic acids, lipids, hormones, and vitamins contain carbon. The chemical reactions that take place in living systems are of carbon compounds. Food that we get from nature, various medicines, cotton, silk and fuels like natural gas and petroleum almost all of them are carbon compounds. Synthetic fabrics, plastics, synthetic rubber are also compounds of carbon. Hence, carbon is a special element with the largest number of compounds.

Catenation

Another peculiar behaviour of carbon is its ability to form longest chains with its own atoms. If any element forms bonds between its own atoms to give big molecules we call that property as catenation property. Carbon has the ability to form longest chains containing millions of carbon atoms in molecules like some proteins. Sulphur, phosphorus and some other non metals have this property but to a very less extent.

You have understood that carbon can form:



b) A double bond and two single covalent bonds ($>\text{C}=\text{C}$)

c) A single covalent bond and a triple bond ($-\text{C}\equiv\text{C}$), or two double bonds ($\text{C}=\text{C}=\text{C}$) with its own atoms or atoms of other elements – to satisfy its tetravalency.

This ability of carbon to form bonds in so many ways made it as versatile element in nature. Hence, carbon's ability 1) to form largest number of compounds 2) to show catenation 3) to form various types of bonds made it the versatile element.

Hydrocarbons

- What are hydrocarbons?

The compounds containing only carbon and hydrogen in their molecules are called **hydrocarbons**.

Hydrocarbons are classified into two categories known as *open chain hydrocarbons* and *closed chain hydrocarbons*. Open chain hydrocarbons are also called *aliphatic hydrocarbons* or *acyclic hydrocarbons*.

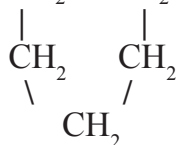
Open and closed chain hydrocarbons

Let us observe the following structural formulae of different hydrocarbons.

1) $\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_3$ n-pentane, a straight chain compound

2) $\text{CH}_3-\text{CH}-\text{CH}_2-\text{CH}_3$ Iso pentane, a branched chain compound

3) $\text{CH}_2 - \text{CH}_2$ cyclo pentane, a cyclic compound *or* a ring compound



- Do all the above compounds have equal number of C and H atoms?

In the first example you will notice that all carbons are linked to one another resulting a linear structure, where as in the second example four carbons are linked in linear way and the fifth carbon is linked to the parent chain resulting a branch. In the third example we find that carbon chain is closed to form a ring. So, it is a closed chain hydrocarbon or ring hydrocarbon.

All hydrocarbons (both Aliphatic and cyclic hydrocarbons) are again classified as Alkanes, Alkenes and Alkynes:

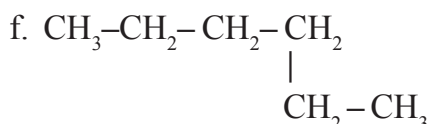
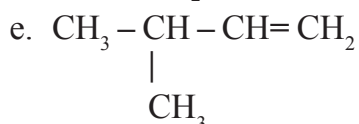
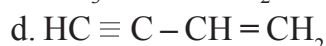
- 1) Hydrocarbons containing only single bonds between carbon atoms are called *Alkanes*.
- 2) Hydrocarbons containing at least one double bond between carbon atoms are called *Alkenes*, and
- 3) Hydrocarbons containing at least one triple bond between carbon atoms are called *Alkynes*.

Saturated and unsaturated hydrocarbons

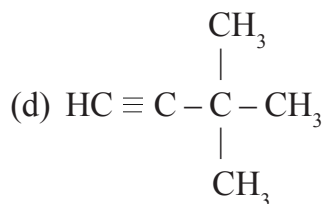
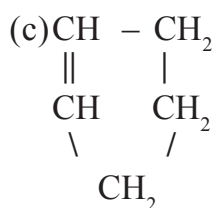
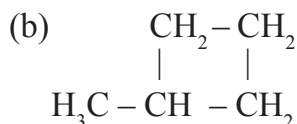
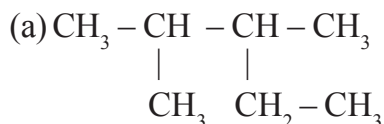
The hydrocarbons containing only C–C single bonds are known as *saturated hydrocarbons*. All alkanes are saturated hydrocarbons. The hydrocarbons that contain at least one double bond (C=C) or contain at least one triple bond (C ≡ C) between the two carbon atoms are called *unsaturated hydrocarbons*. Alkenes and Alkynes are the examples for unsaturated hydrocarbons.

Straight chain, branched chain and closed chain hydro carbon compounds may be saturated or unsaturated. See the following examples.

- 1) Which of the following compounds are unsaturated? Justify your answer.



- 2) Identify the compounds in the following, as branched chain and closed chain compounds.



Binding of carbon with other elements

We have understood that the compounds of carbon and hydrogen are called hydrocarbons.

- Can carbon form bonds with the atoms of other elements?

Practical observations reveal that carbon forms compounds not only with atoms of hydrogen but also with atoms of other elements like oxygen, nitrogen, sulphur, phosphorus, halogens etc.

Let us see the compounds of carbon with other elements.

Carbon compounds with C, H, X.

- Compounds containing C, H, X where 'X' represents halogens (Cl, Br, I atoms).

Eg: CH_3Cl , $\text{CH}_3-\text{CH}_2-\text{Br}$, $\text{CH}_2\text{Cl}-\text{CH}_2\text{I}$, $\text{CH}_3-\text{CHCl}_2$

These are known as *halogen derivatives* of hydrocarbons or halo hydrocarbons.

Carbon compounds with C, H, O.

- Compounds containing C, H, O are of different types:

Alcohols

If a hydrogen atom of H_2O molecule is replaced by 'R' we get alcohols R-OH.

The hydrocarbons that contain -OH group are called alcohols. Observe the following examples:

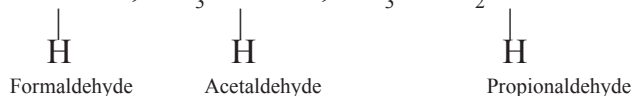
CH_3OH , $\text{CH}_3\text{CH}_2\text{OH}$, $\text{CH}_3-\text{CHOH}-\text{CH}_3$ etc.

General formula of alcohols is **R-OH** where 'R' is *alkyl* group, $\text{C}_n\text{H}_{2n+1}$.

Aldehydes

The hydrocarbons with functional group -CHO are called aldehydes. Observe the following examples:

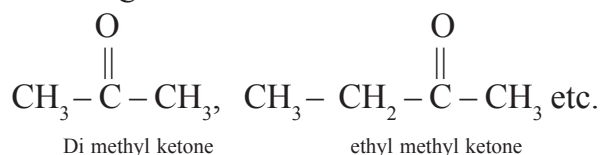
$\text{H}-\text{C}=\text{O}$, $\text{CH}_3-\text{C}=\text{O}$, $\text{CH}_3-\text{CH}_2-\text{C}=\text{O}$ etc.



General formula of aldehydes is **R-CHO**, where **R** = alkyl group or hydrogen and -CHO is functional group.

Ketones

The hydrocarbons with $\begin{array}{c} \text{C} \\ \diagup \\ \text{C} \end{array} > \text{C}=\text{O}$ functional group are called ketones.



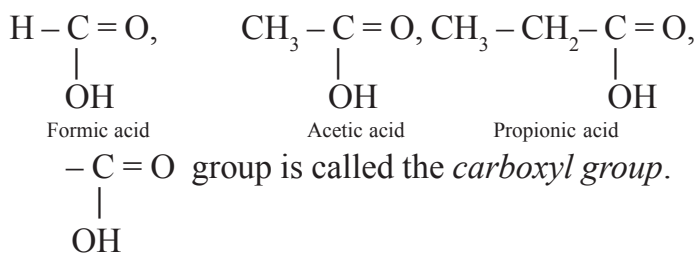
$\begin{array}{c} \text{C} \\ \diagup \\ \text{C} \end{array} > \text{C}=\text{O}$ group is known as *Ketone group* (common system)

General formula of Ketones is $\begin{matrix} \text{R} \\ \text{R}' \end{matrix} > \text{C} = \text{O}$

R and **R'** are alkyl groups which may be same or different.

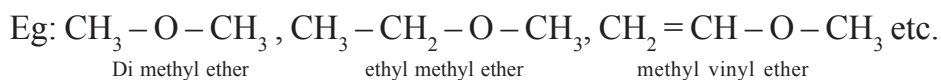
Carboxylic acids

The general molecular formula of carboxylic acid is **R – COOH**, where **R** is an alkyl group or **H** atom.



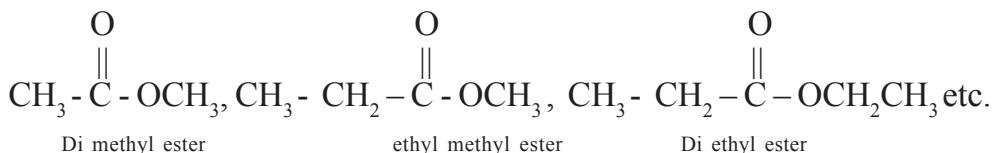
Ethers

Ethers are carbon compounds related to H_2O in such a way that both hydrogen atoms are replaced by two alkyl groups which may be same or different.



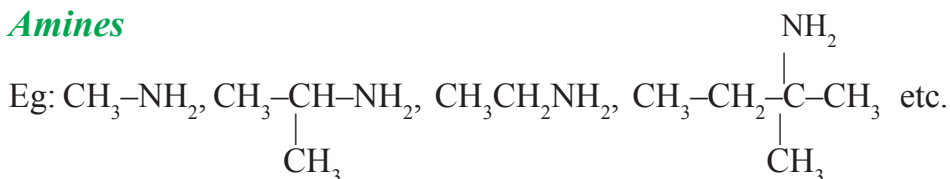
Esters

These compounds are derivatives of carboxylic acids. If the hydrogen atom of **-COOH** gets replaced by 'R', the alkyl group esters are obtained.



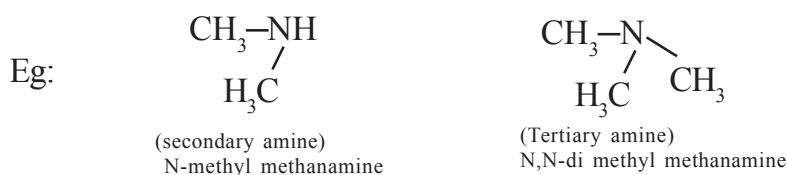
Compounds containing C, H, N

Amines



-NH₂ group is called *amine group*. We may compare amines to NH_3 as we have done ROH and $\text{R} - \text{O} - \text{R}'$ to H_2O .

If one hydrogen atom is replaced from NH_3 by an alkyl group we get the so called *primary amines*. If two hydrogen atoms of NH_3 are replaced by two alkyl groups (same or different) we get *secondary amines* and if all the three hydrogen atoms are replaced by the same or different alkyl groups we get *tertiary amines*.



Functional groups in carbon compounds

The characteristic properties of an organic compound depend mainly on an atom or group of atoms in its molecule known as the **functional group**.

Organic compounds are classified by the type of functional group they contain. Functional groups are responsible for the behavior of the organic compounds. Compounds containing the same functional group undergo similar types of reactions.

Isomerism

Observe the following two structures:



- How about their structures? Are they same?
- How many carbon and hydrogen atoms are there in (a) and (b) structures?
- Write the condensed molecular formulae for (a) and (b). Do they have same molecular formulae?

(Take the help of your teacher and name the compounds mentioned in the above examples).

The first one is called *butane* (or) in the common system it is known as *n-butane*.

The second one is called *2-methyl propane* or *iso-butane* in the common system.

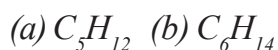
We find both of these compounds in nature. They have different properties due to the difference in their structures. Compounds of this type which have the same molecular formula but different properties are called **isomers**.

The phenomenon of possessing same molecular formula but different properties by the compounds is known as **isomerism**. The compounds that exhibit isomerism are called **isomers**.

(*iso* = same; *meros* = part, i.e., they have same molecular formula)

In the above example isomerism is due to the difference in the structures. Therefore, it is called the **structural isomerism**.

Try to draw different structures for the following carbon compounds and name the isomers of each (Take the help of your teacher)



Homologous series

Till now we have classified Organic compounds on the basis of carbon chains and functional groups. There is another classification based on Homologous series.

The series of carbon compounds in which two successive compounds differ by $-\text{CH}_2$ unit is called *homologous series*.

- Eg:**
- 1) $\text{CH}_4, \text{C}_2\text{H}_6, \text{C}_3\text{H}_8 \dots$
 - 2) $\text{CH}_3\text{OH}, \text{C}_2\text{H}_5\text{OH}, \text{C}_3\text{H}_7\text{OH} \dots$

If you observe above series of compounds, you will notice that each compound in the series differs by $-\text{CH}_2$ unit by its successive compound.

Homologous series of organic compounds have following characteristic features.

- 1) They have one general formula.
Eg: alkanes ($\text{C}_n\text{H}_{2n+2}$); alkynes ($\text{C}_n\text{H}_{2n-2}$); alcohols ($\text{C}_n\text{H}_{2n+1}\text{OH}$) etc.
- 2) Successive compounds in the series possess a difference of ($-\text{CH}_2$) unit.
- 3) They possess similar chemical properties due to the same functional group
Eg: alcohols, aldehydes and carboxylic acids have functional groups $\text{C}-\underline{\text{OH}}$, $\text{C}-\underline{\text{CHO}}$ and $\text{C}-\underline{\text{COOH}}$ respectively.
- 4) They show a regular gradation in their physical properties (see the table-1).

For example: we may take alkanes, alkenes, alkynes, alcohols, aldehydes, and carboxylic acids etc. as homologous series. The individual members of a homologous series are called *homologs*.

Observe the following tables 1, 2 and 3. They represent three different homologous series.

Table-1: Homologous series of Alkanes

Alkane	Molecular formula	Structure	No. of carbons	Boiling Point ($^{\circ}\text{C}$)	Melting Point ($^{\circ}\text{C}$)	Density (gml^{-1} at 20°C)
Methane	CH_4	$\text{H}-\text{CH}_2-\text{H}$	1	-164	-183	0.55
Ethane	C_2H_6	$\text{H}-(\text{CH}_2)_2-\text{H}$	2	-89	-183	0.51
Propane	C_3H_8	$\text{H}-(\text{CH}_2)_3-\text{H}$	3	-42	-189	0.50
Butane	C_4H_{10}	$\text{H}-(\text{CH}_2)_4-\text{H}$	4	0	-138	0.58
Pentane	C_5H_{12}	$\text{H}-(\text{CH}_2)_5-\text{H}$	5	36	-136	0.63

The general formula of this homologous series Alkanes is $\text{C}_n\text{H}_{2n+2}$, where $n = 1, 2, 3, \dots$

Table-2: Homologous series of Alkenes

Alkene	No. of Carbons	Structure	Formula
Ethene	2	$\text{CH}_2=\text{CH}_2$	C_2H_4
Propene	3	$\text{CH}_3-\text{CH}=\text{CH}_2$	C_3H_6
Butene	4	$\text{CH}_3-\text{CH}_2-\text{CH}=\text{CH}_2$	C_4H_8
Pentene	5	$\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}=\text{CH}_2$	C_5H_{10}

Alkenes have general molecular formula C_nH_{2n} , where 'n' is 2, 3, 4, ...

Table-3: Homologous series of Alkynes

Alkyne	No. of Carbons	Structure	Formula
Ethyne	2	$\text{HC}\equiv\text{CH}$	C_2H_2
Propyne	3	$\text{CH}_3-\text{C}\equiv\text{CH}$	C_3H_4
Butyne	4	$\text{CH}_3-\text{H}_2\text{C}-\text{C}\equiv\text{CH}$	C_4H_6
Pentyne	5	$\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{C}\equiv\text{CH}$	C_5H_8

Alkynes have general molecular formula $\text{C}_n\text{H}_{2n-2}$, where 'n' is 2, 3, 4, ...

Nomenclature of organic compounds

We have millions of organic compounds. As number of organic compound is very big it is difficult to remember their names individually. To overcome this problem they have to be properly named. For this, the International Union of Pure and Applied Chemistry (IUPAC) had been formed, and one of its responsibilities is to name the organic and inorganic compounds in a systematic order. The basic idea behind the systematic nomenclature is that there should be only one name for the given structure throughout the world and also there should be only one structure for the given name.

The IUPAC name of an organic compound gives information about:

- a) The number of carbon atoms present in the molecules we call this part of the name as **word root**.

C_1 - Meth;	C_2 - eth;	C_3 - prop;	C_4 - but ;	C_5 -pent; C_6 - hex;
C_7 - hept;	C_8 -oct;	C_9 -non;	C_{10} - dec	and so on.

- b) The substituents in the molecule ; which are shown as the **prefix**
 c) The functional group in the molecule; which is shown as the **suffix**.

Prefix: Prefix again has several parts known as *primary prefix*, *secondary prefix*, *numerical prefix* and *number prefix* etc.

Primary prefix is 'cyclo' and it is useful only for cyclic compounds which have properties similar to aliphatic compounds. If the compounds are not cyclic, this part of the name is absent.

Secondary prefix tells about the second grade functional groups known as substituents. They are ‘halogens’ which are written as *halo*; alkyl groups(R), alkoxy groups(-OR) etc. which are written as alkyl, alkoxy.

Suffix: It also contains several parts known as *primary suffix*, *secondary suffix*, *numerical suffix* and *number suffix* etc.

Primary suffix tells about the saturation of the compound. For saturated (C-C) it is ‘*an*’ and carbon atoms are attached to one another only through single bonds in the compounds.

For unsaturated (C=C) double bonded compounds it is ‘*en*’ and for unsaturated triple bonded (C ≡ C) compounds it is ‘*yn*’.

There is a *Secondary suffix* that tells about the functional groups with the particular term.

For example: For hydrocarbons it is ‘*e*’
 for Alcohols it is ‘*-ol*’
 Aldehydes it is ‘*-al*’
 Ketones it is ‘*-one*’ and
 Carboxylic acid it is ‘*-oic acid*’

Numerical prefixes like *di*, *tri* are written before the secondary prefixes, primary suffixes and secondary suffixes, when the same substituent, multiple bond or functional group is repeated twice, thrice etc., as *di*, *tri* etc respectively.

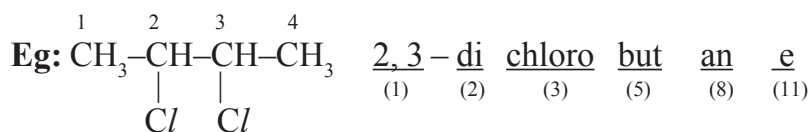
Numbers are written to tell about to which carbon atoms of the compound the substituent(s), multiple bond(s) or functional group(s) are attached.

The following order is to be followed while naming carbon compound.
 The order is as follows:

Numbers	Numerical Prefixes	Secondary Prefix	Primary Prefix	Word Root	Numbers
1	2	3	4	5	6
-Numerical Prefix, Primary Suffix, numbers, numerical Prefixes and Secondary Suffixes.					
7	8	9	10	11	

What differences among (1), (2), (3); (6), (7), (8) and (9), (10) and (11) do you find?

(1), (2) are numbers and numerical designations to be written for secondary prefixes(3) which tell about the position and repetitions of second grade functional groups known as substituents respectively.



- One example is given to guide you in dividing the name as per notation.
- ❖ $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_3$: Butane
 - 4 3 2 1
 - ❖ $\text{CH}_3\text{-CH}_2\text{-CH=CH}_2$: But-1-ene
 - 1 2 3 4
 - ❖ $\text{CH}_3\text{-}\underset{\text{Cl}}{\text{CH}}\text{-CH}_2\text{-CH}_3$: 2-Chloro butane
 - 1 2 3 4
 - ❖ $\text{CH}_3\text{-}\underset{\text{Cl}}{\text{CH}}\text{-}\underset{\text{Cl}}{\text{CH}}\text{-CH}_3$: 2,3 - dichloro butane
 - 4 3 2 1
 - ❖ $\text{CH}_3\text{-CH=CH=CH}_2$: Buta 1, 2- diene
 - 4 3 2 1
 - ❖ $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-OH}$: Butan - 1 - ol
 - 4 3 2 1
 - ❖ $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CHO}$: Butanal
 - ❖ $\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-COOH}$: Butanoic acid.....
 - ❖ $\begin{array}{c} \text{CH}_2\text{-CH}_2 \\ | \quad | \\ \text{CH}_2\text{-CH}_2 \end{array}$: Cyclo butane.....
 - ❖ $\begin{array}{c} \text{Br} \quad \text{Br} \\ | \quad | \\ \text{CH}-\text{CH} \\ | \quad | \\ \text{CH}_2\text{-CH}_2 \end{array}$: 1,2 - di bromo cyclo butane
 - ❖ $\begin{array}{c} \text{CH}_2\text{-CH-CHO} \\ | \quad | \\ \text{Cl} \quad \text{Cl} \end{array}$: 2,3 - di chloro propanal
 - solution: 2,3 - di chloro prop an al
(1) (2) (3) (5) (8) (11)
 - ❖ $\text{CH}_3\text{-}\underset{\text{O}}{\parallel}{\text{C}}\text{-CH}_2\text{-CH}_2\text{-CH}_3$: Penta n - 2 - one

Numbering carbon atoms

1) We can number carbon atoms from left to right or from right to left so that sum of the numbers indicating the positions of substituents and functional groups should be minimum possible.

2) The functional group carbon should be given the lowest number even if it does not obey Rule (1).

3) The carbon atoms of the chain terminating functional group say $-\text{CHO}$, or $-\text{COOH}$ groups should be given always number '1' even if it does not obey Rules (1) & (2).

Table -4:

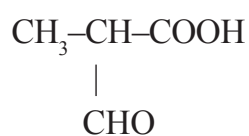
Suffixes and prefixes for some important characteristic functional groups:

Class	Formula	Prefix	Suffix
Acid halides	$-\text{COX}$ (Where X is halogen atom)	halocarbonyl	carbonyl halide
	$-(\text{C})\text{O-X}$		oyl halide
Alcohols	$-\text{OH}$	hydroxy	ol
Aldehydes	$-\text{CHO}$	formyl	carbaldehyde
	$-(\text{C})\text{HO}$	oxo	-al
Amides	$-\text{CONH}_2$	carbamoyl	carboxamide
	$-(\text{C})\text{ONH}_2$	oxo	-al
Amines	$-\text{NH}_2$	amino	amine
Carboxylic acids	$-\text{COOH}$	carboxy	carboxylic acid
	$-(\text{C})\text{OOH}$		oic acid
Ethers	$-\text{OR}$	(R)oxy	
Esters	$-\text{COOR}$	oxycarbonyl	(R)...carboxylate
	$(\text{C})\text{OOR}$	R - oxycarbonyl	(R)...oate
Ketones	$-\text{C} = \text{O}$	oxo	-one
Nitriles	$-\text{CN}$	cyano	-carbonytrile
	$-(\text{C})\text{N}$		Nitrile

NOTE: (C) designates a carbon atom included in the name of the parent hydride and does not belong to a group designated by a suffix or a prefix.

Example: $\text{CH}_3-\text{CH}_2-\text{CHO}$

propanal - (C) of CHO included in the name of the main chain.



2- formyl propanoic acid - 'C' of CHO not included in the name of main (parent) chain.

Example-1: CH₃CH₂OH

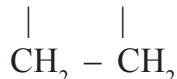
Principal functional group : -OH (-ol)

Parent hydride : CH₃-CH₃

Parent hydride + one Principal functional group → CH₃CH₂OH

Name of the compound → Eth an ol
(5) (8) (11)

Example-2: OH OH



Parent hydride + two Principal functional groups → OH OH

Name of the compound → eth ane - 1,2 - di ol $\begin{array}{c} | \quad | \\ \text{CH}_2 - \text{CH}_2 \end{array}$
(5) (8) (9) (10) (11)

Example-3: CH₃-C(=O)-CH₂-CH₂-CH₂-CH₂-CH₂-OH

Principal functional group >(C)=O -one

Parent hydride CH₃-CH₂-CH₂-CH₂-CH₂-CH₂-CH₃ Heptane

Parent hydride + Principal functional group

$\begin{array}{c} \text{O} \\ || \\ \text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{C} - \text{CH}_3 \\ | \\ \text{OH} \end{array}$ Heptan-2-one
Substituent -OH → hydroxy

$\text{OH} - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{C}(=\text{O}) - \text{CH}_3$
Name of the compound 7 - hydroxy hept ane - 2 - one
(1) (3) (5) (8) (9) (11)

Note: In the solution the principal functional group >C=O (Keto) group is given more priority than to -OH (alcohol).

Example-4: CH₂=CH-CH₂-CH(OH)-CH₃

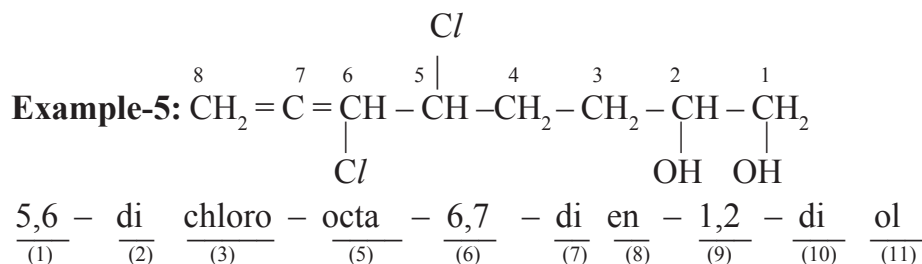
Parent hydride CH₃-CH₂-CH₂-CH₂-CH₃ Pentane

Principal functional group -OH -ol

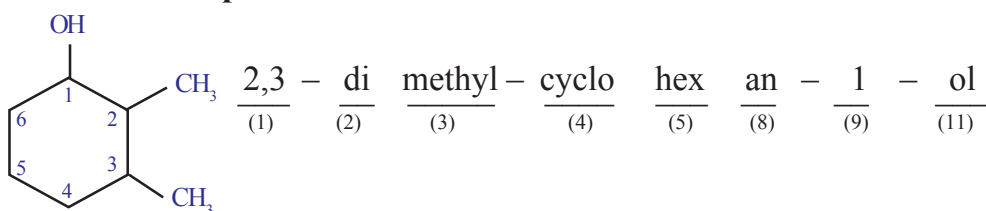
Principal hydride + Principal functions Pentan-2-ol

Subtractive modification (-2H) -en

Name of the compound: Pent - 4 - en - 2 - ol
(5) (6) (8) (9) (11)



Example-6:



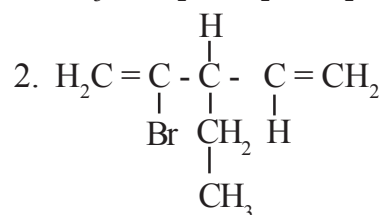
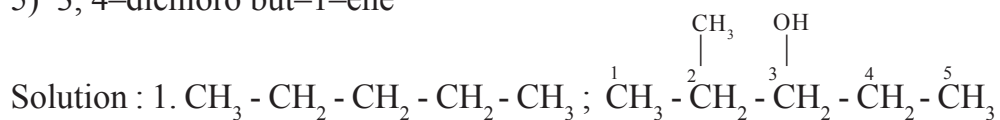
- Can we write the structure of a compound if the name of the compound is given?

Yes, we can write the structures from the name of the compound as follows:

- 1) From the word root in the name write the carbon atoms in the main chain
- 2) Select counting of carbon atoms in the appropriate manner from left to right or right to left as for the name given.
- 3) Attach the substituent at respective numbers of carbon atoms as per their numbers and numerical designations.
- 4) Write the functional groups formulae as per the name at the respective carbon atom.
- 5) Keeping in view that the tetravalency of each carbon atom has to be satisfied use hydrogen atoms in the required number.

Examples:

- 1) 2-methyl pentan-3-ol
- 2) 2-bromo-3-ethyl penta-1,4-diene
- 3) 3-bromo-2-chloro-5-oxohexanoic acid
- 4) 3-amino-2-bromo hexan-1-ol
- 5) 3, 4-dichloro but-1-ene



Chemical properties of carbon compounds

Though we have millions of organic compounds, the reactions they undergo are limited. Some important reactions among them are discussed here.

They are:

- 1) Combustion
- 2) Oxidation reactions
- 3) Addition reactions
- 4) Substitution reactions

1. Combustion reactions

Carbon, and its compounds burn in presence of oxygen or air to give CO_2 , heat and light.

The process of burning of carbon or carbon compound in excess of oxygen to give heat and light is called the *combustion reaction*. In the reactions carbon is in its maximum oxidation state of 4^+ in the product.

Eg: 1) $\text{C} + \text{O}_2 \rightarrow \text{CO}_2 + \text{Energy}$

2) $2\text{C}_2\text{H}_6 + 7\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O} + \text{Energy}$

3) $\text{CH}_3\text{CH}_2\text{OH} + 3\text{O}_2 \rightarrow \text{CO}_2 + 3\text{H}_2\text{O} + \text{Energy}$

Generally, saturated hydrocarbons burn with a clear light blue flame, whereas unsaturated hydrocarbons burn with yellow flame with soot (carbon). If air is not sufficiently available during combustion, even saturated hydrocarbons give sooty flame. When Coal, Petroleum etc., burn in air they give oxides of sulphur and nitrogen in addition to CO_2 and H_2O which pollute the environment. When Coal or Charcoal is burnt sometimes they just glow red without flame. This is because to get a flame gaseous fuels should burn.

Most of the aromatic compounds burn with sooty flame.

- Why do sometimes cooking vessels get blackened on a gas or kerosene stove?

Because of the inlets of air getting closed, the fuel gases do not completely undergo combustion. Hence, it forms a sooty carbon form which gets coated over the vessels.

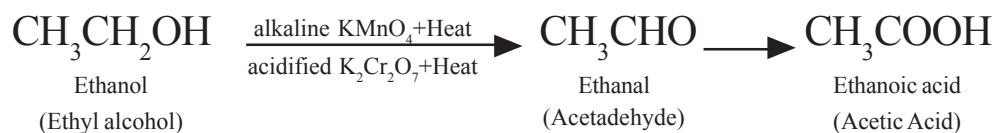
A combustion reaction is generally defined as any reaction that sustains a flame. It usually involves burning with oxygen, though some exceptions are there, combustion reaction is always exothermic, that is energy is liberated during combustion reaction.

2. Oxidation reactions

Though combustion is generally oxidation reaction, all oxidation reactions are not combustion reactions. Oxidation reactions may be carried out using oxidizing agents. *Oxidizing agents* or *Oxidants* are substances that oxidize other substances. They themselves undergo *reduction*.

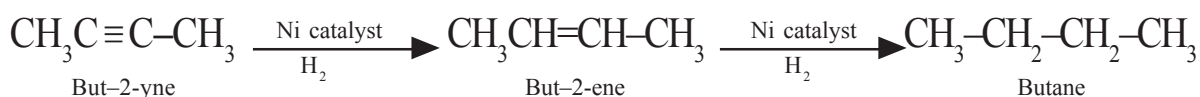
Eg: Alkaline Potassium permanganate *or* Acidified Potassium dichromate in solutions act as oxidizing agents and supplies oxygen to convert alcohols into carboxylic acids.

Ethyl alcohol undergoes oxidation to form the product *Acetaldehyde* and finally *Acetic acid*. (see following equation)



3. Addition reactions

Unsaturated organic compounds that contain multiple bonds (=, ≡ bonds) like alkenes and alkynes undergo addition reactions to become saturated. During the reactions addition of the reagent takes place at the double bonded or triple bonded carbon atoms.



In the above reactions 'Ni' acts as 'catalyst.'

- **Do you know what is a 'catalyst'?**

A catalyst is a substance which regulates (increase/decrease) the rate of a given reaction without itself finally undergoing any chemical change.

These reactions are commonly used in the hydrogenation of vegetable oils using nickel as catalyst. Vegetable oils generally have long unsaturated carbon chains, while animal fats have saturated carbon chains.



Think and discuss

- Why we are advised not to use animal fats for cooking?
- Which oil is recommended for cooking? Why?

Fats and oils are both of fatty acids. Oils are generally liquids at room temperature due to unsaturated fatty acids but fats are solids due to saturated fatty acids.

4. Substitution reactions

A reaction in which an atom or a group of atoms in a given compound is replaced by other atom or group of atoms is called a substitution reaction.

Alkanes, the saturated hydrocarbons are chemically least reactive. Therefore they are also called *paraffins* (*parum* = little; *affins* = affinity,

i.e., no affinity towards chemical changes). However they undergo some chemical changes under suitable conditions which are substitution reactions.

For example, methane (CH_4) reacts with chlorine in the presence of sunlight. Hydrogen atoms of CH_4 are replaced by chlorine atoms.

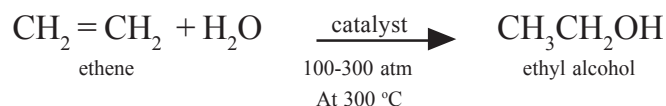


Some important carbon compounds

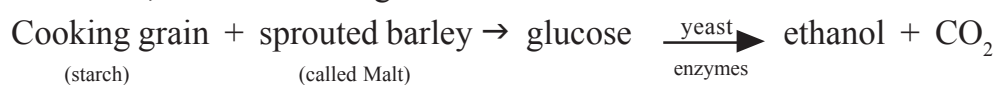
Many carbon compounds are invaluable to us. But here we study, the properties of Ethanol (Ethyl alcohol) and Ethanoic acid (Acetic acid) which are two very important carbon compounds.

Ethanol (Ethyl alcohol)

Preparation: Ethanol is prepared on large scale from ethene by the addition of water vapour to it in the presence of catalysts like P_2O_5 , Tungsten oxide at high pressure and temperature.



Grains such as corn, wheat, barley are common sources for ethanol. Therefore, it is also called grain alcohol.



The process of conversion of starches and sugars to $\text{C}_2\text{H}_5\text{OH}$ is called *fermentation process*.

Properties

Ethanol is a colourless liquid with characteristic sweet odour. Pure ethanol boils at 78.3°C . Pure ethanol is called *absolute (100%) alcohol*. Denatured alcohol is ethanol that contains impurities that make it undrinkable. The impurities are methanol, methyl isobutyl ketone, aviation gasoline etc. It is toxic and 200 ml of it is a fatal dose to an adult. Solution of about 10% ethanol in gasoline (gasohol) is a good motor fuel.

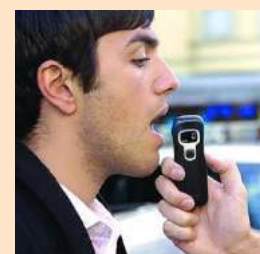
Ethanol is commonly called alcohol and is active ingredient of all alcoholic drinks. Consumption of small quantity of dilute ethanol causes drunkenness. In addition, as it is a good solvent it is also used in medicines such as tincture iodine, cough syrups and many tonics

- Do you know how the police detect whether suspected drivers have consumed alcohol or not?

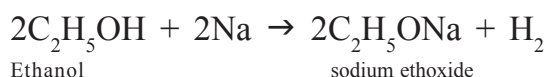
The police officer asks the suspect to blow air into a plastic bag through a mouth piece of the detecting instrument which contains crystals of potassium-di-chromate ($K_2Cr_2O_7$). As $K_2Cr_2O_7$ is a good oxidizing agent, it oxidizes any ethanol in the driver's breath to ethanal and ethanoic acid.

Orange $Cr_2O_7^{2-}$ changes to bluish green Cr^{3+} during the process of the oxidation of alcohol. The length of the tube that turned into green is the measure of the quantity of alcohol that had been drunk. Now a days police are using even an electronic instrument containing small fuel cell that measures the electrical signal produced when ethanol in the breath is oxidized.

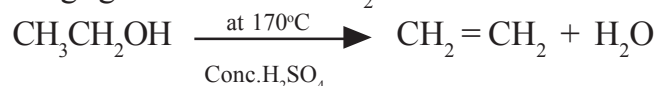
The police even use the IR Spectra to detect the bonds C – OH and C – H of $CH_3 - CH_2OH$.



As ethanol is similar to water molecule (H_2O) with C_2H_5 group in place of hydrogen, it reacts with metallic sodium to liberate hydrogen and form *sodium ethoxide*.



Action of conc. H_2SO_4 : Ethanol reacts with conc. H_2SO_4 at about $170^\circ C$ (443 K) to give ethene. It is a dehydration reaction. H_2SO_4 is a dehydrating agent and removes H_2O .



Ethanoic acid (Acetic acid, CH_3COOH)

Ethanoic acid is a colourless liquid with characteristic unpleasant odour. It is soluble in water and more acidic than H_2O or ethanol, but less acidic than mineral acids.

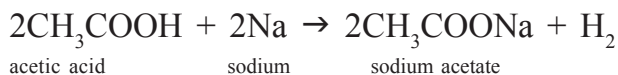
Ethanoic acid is commonly called as acetic acid. 5-8% solution of acetic acid in water is called vinegar and is used widely as a preservative in pickles.

Chemical properties

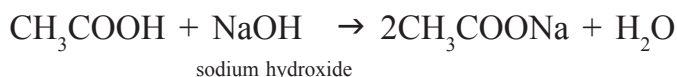
Acidity: (Reaction with metals and alkalis)

1) Ethanoic acid reacts with active metals like Na to liberate hydrogen.

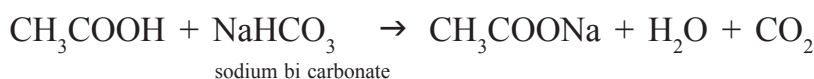
This reaction is similar to that of ethanol.



2) Ethanoic acid reacts with NaOH to form salt and water.



3) Ethanoic acid reacts with sodium carbonate and sodium hydrogen carbonate which are weaker bases and liberates CO_2 .



The strength of acids may be expressed in terms of their *pKa* values. These values are related to their dissociation in aqueous solutions.

What is pK_a ?

pK_a is the negative value of logarithm of dissociation constant of an acid.

pK_a is a measure of how much an acid dissociates in a solution.

$$pK_a = -\log_{10} K_a$$

The lower the pK_a value, the stronger is the acid.

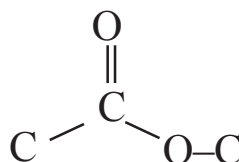
Note that *pKa* of 1.0M HCl is zero but *pKa* of CH_3COOH is 4.76. *pKa* values are useful to tell about acid strength. Strong acids have *pKa* < 1, acids with *pKa* between 1 and 5 are moderately strong and weak acids have *pKa* between 5 and 15. The weakest acids have *pKa* > 15.

Note that *pKa* values less than zero are not generally given as they are of no use to give in terms of *pKa*. They may be directly given in terms of K_a .

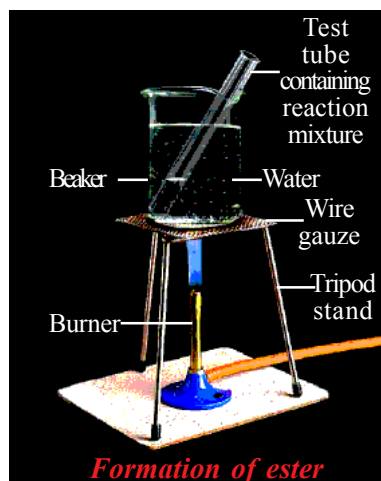
4) Esterification Reactions

- What are esters?

Esters contain the functional group



and the general formula is $\text{R}-\text{COO}-\text{R}'$. R and R' are *alkyl groups* or *phenyl groups*.



Activity 2

Take 1 ml of ethanol (absolute alcohol) and 1 ml of glacial acetic acid along with a few drops of concentrated sulphuric acid in a test tube.

Warm it in a water-bath or a beaker containing water for at least five minutes as shown in Fig.

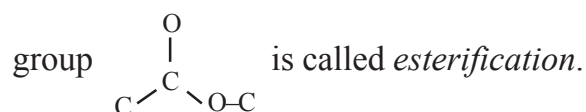
Pour the warm contents into a beaker containing 20-50 ml of water and observe the odour of the resulting mixture.

- What do you notice?

You will notice that the resulting mixture is a sweet odoured substance. This substance is nothing but ethyl acetate, an ester. The reaction in activity – 2 is called *esterification reaction*.

Esterification

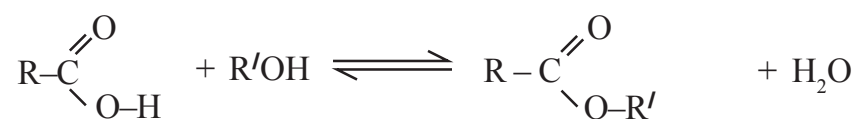
The reaction between carboxylic acid and an alcohol in the presence of conc. H_2SO_4 to form a sweet odoured substance, **ester** with the functional



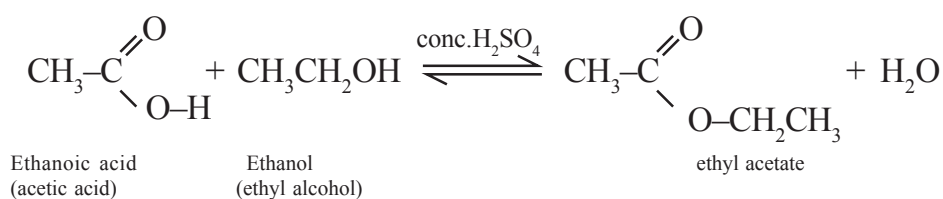
The esterification reaction is slow and reversible.

The equation for the reaction between an acid RCOOH and an alcohol $\text{R}'\text{OH}$

(where R and R' can be the same or different) is:



So, for example, if you want to prepare ethyl ethanoate or ethyl acetate from ethanoic acid and ethanol, the equation would be:

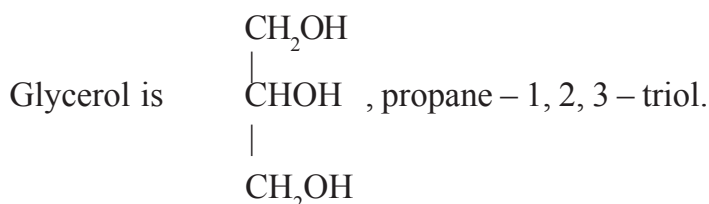


Soaps – Saponification and Micelles

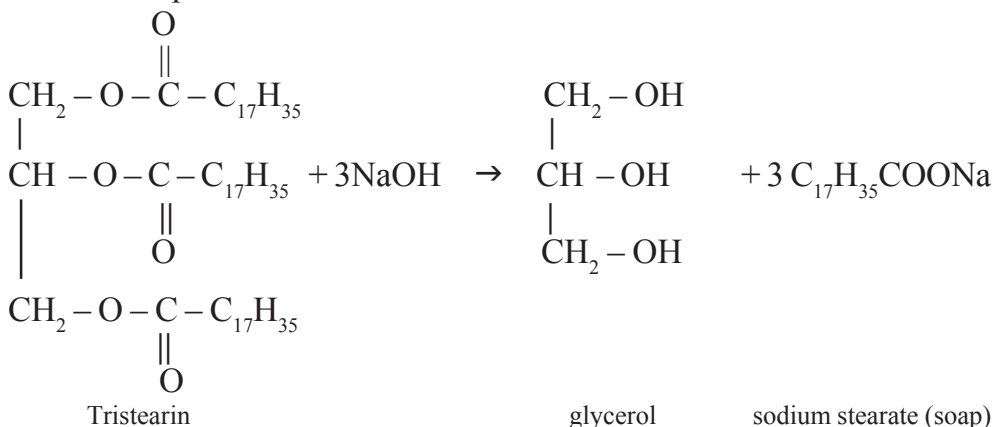
Do you know what ‘soap’ is?

Soap is a sodium or potassium salt of a higher fatty acid like palmitic acid ($C_{15}H_{31}COOH$), stearic acid ($C_{17}H_{35}COOH$), oleic acid ($C_{17}H_{33}COOH$) etc. The formula of a soap in general is $RCOONa$ or $RCOOK$, where $R = C_{15}H_{31}$; $C_{17}H_{35}$ etc.

Fats are esters of higher fatty acids and the trihydroxy alcohol known as **glycerol**.



When fats are treated with sodium hydroxide, sodium salts the fatty acids and glycerol is formed. The sodium salts of these higher fatty acids being soaps the reaction is the soap formation reaction which is generally called as ‘saponification reaction’.



Saponification reaction

Alkaline hydrolysis of tristers of higher fatty acids producing soaps is called *saponification*.

Soaps are good cleansing agents. Do you know how they do this?

For understanding this you should know about a ‘*true solution*’ and a *colloidal solution*.

- What is a true solution?

A true solution is that in which the solute particles dispersed in the solvent are less than 1nm in diameter. A colloidal solution contains the solute known as ‘dispersed phase’ with its particles with diameters greater than 1nm but lesser than 1000nm in the solvent known as ‘*dispersion medium*’.

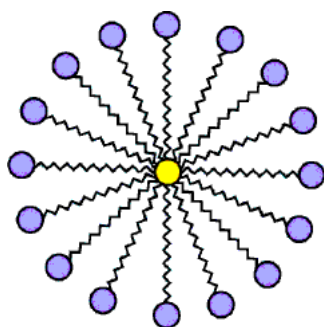
Soap is an electrolyte. When soap is put in water in very small amount it gives low concentrated solutions. It gives true solution but, above a particular concentration known as *critical micelle concentration* (CMC), the soap particles get aggregated and these aggregated particles are of colloidal size known as *micelles* or *associated colloids*.

Micelle

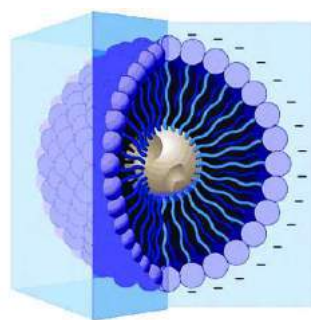
A spherical aggregate of soap molecules in water is called *micelle*. When soap is dissolved in water, it forms a colloidal suspension in which the soap molecules cluster together to form spherical micelles.

Formation of micelle

Activity 3



Micelle



3D structure of a micelle

Take about 10 ml of water each in two test tubes.

Add a drop of oil (cooking oil) to both the test tubes and label them as A and B.

Add a few drops of soap solution to test tube B.

Now shake both the test tubes vigorously for the same period of time.

What is that you find in them?

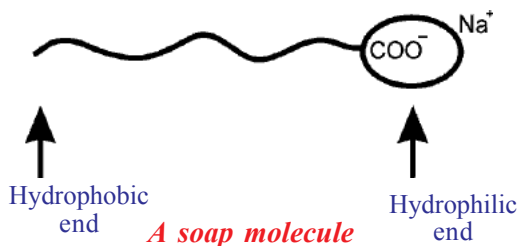
Can you see the oil and water layers separately in both the test tubes immediately after

- You stop shaking them?
- Leave the test tubes undisturbed for sometime and observe. Does the oil layer separate out?
- In which test tube does this happen first? Give your observations.

Cleansing action of soap

Suppose that we put dirty cloth in the soap solution. Dirt is mainly greasy matter. The soap molecules are arranged radially with hydrocarbon ends directed inwards into the greasy matter and ionic part directed outwards into water.

When a dirty cloth is inserted in the solution then the hydrocarbon part sticks to the dirt or oil. With a little agitation the dirt particles get entrapped by the soap micelles and get dispersed in water due to which the soap water gets dirty and the cloth gets cleaned.



- What is the action of soap particles on the greasy cloth?

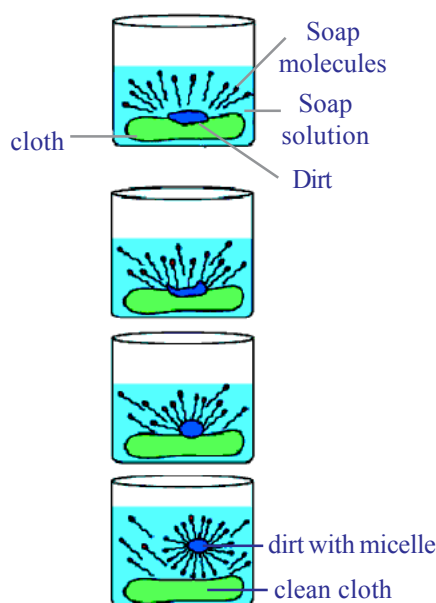
We know that soaps and detergents make oil and dirt present on the cloth come out into water, thereby making the cloth clean.

Soap has one polar end (the end with $\text{—}\overset{\text{O}}{\parallel}{\text{C}}\text{—}\text{O}$ carboxy) and one non-polar end (the end with hydrocarbon chain) as shown in the figure.

The polar end is hydrophilic in nature and this end is attracted towards water.

The non-polar end is hydrophobic, in nature and it is attracted towards grease or oil on the cloth, but not attracted towards water.

When soap is dissolved in water, its hydrophobic ends attach themselves to dirt and remove it from the cloth, as shown sequentially in the figure that follows.



Representing the cleansing action of soap

- The hydrophobic end of the soap molecules move towards the dirt or grease particle.
- The hydrophobic ends attached to the dirt particle and try to pull out.
- The molecules of soap surround the dirt particle at the centre of the cluster and form a spherical structure called micelle.

These micelles remain suspended in water like particles in a colloidal solution.

The various micelles present in water do not come together to form a precipitate as each micelle repels the other because of the ion-ion repulsion.

Thus, the dust particles remain trapped in micelles (which remain suspended) and are easily rinsed away with water. Hence, soap micelles remove dirt by dissolving it in water.



Key words

Hybridisation, allotropy, diamond, graphite, buckminsterfullerene, nanotubes, catenation, tetravalency, hydrocarbons, alkanes, alkenes, alkynes, saturated hydrocarbons, unsaturated hydrocarbons, functional group, isomerism, homologous series, nomenclature, combustion, oxidation, addition reaction, substitution reaction, ethanol, ethanoic acid, ester, esterification, saponification, micelle.



What we have learnt

- Carbon forms a large variety of compounds. Its tetravalency and the property of catenation and ability to form four single bonds, a double bond and two single bonds, a triple bond and a single bond or two double bonds makes carbon versatile and brings one special branch in chemistry for carbon compounds.
- Hydrocarbons are the compounds of carbon and hydrogen.
- Hydrocarbons are of two types – saturated hydrocarbons (alkanes) and unsaturated hydrocarbons (alkenes and alkynes).
- Carbon forms covalent bonds with its own atoms and atoms of other elements such as hydrogen, oxygen, sulphur, nitrogen and chlorine.
- The functional groups such as alcohols, aldehydes, ketones and carboxylic acids bestow characteristic properties to the carbon compounds that contain them. Even $C=C$, $C\equiv C$, give characteristic properties.
- A group / series of hydrocarbons having same general formula, with two successive compounds possessing difference of $-CH_2$ and with similar structures and similar properties (i.e., same functional group) are called a homologous series.
- Carbon chains may be in the form of straight chains, branched chains or rings.
- Carbon compounds with identical molecular formula but different structures are called structural isomers.
- Saturated hydrocarbons on combustion give carbon dioxide and water with the liberation of heat.
- Unsaturated hydrocarbons undergo addition reactions while saturated hydrocarbons undergo substitution reactions.
- Ethanol and Ethanoic acid (glacial acetic acid) are carbon compounds of importance in our daily life.

- The molecules of soap are sodium or potassium salts of long chain carboxylic acids.
- Detergents are ammonium or sulphonate salts of long chain carboxylic acids.
- The action of soaps and detergents is based on the presence of both hydrophobic and hydrophilic groups in the molecule and this helps to emulsify the oily dirt and hence its removal.

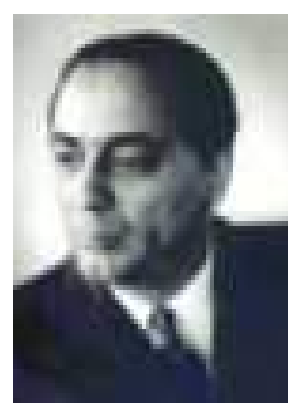


Improve your learning

1. Name the simplest hydrocarbon. (AS1)
2. What are the general molecular formulae of alkanes, alkenes and alkynes. (AS1)
3. Name the carboxylic acid used as a preservative. (AS1)
4. Name the product other than water formed on burning of ethanol in air. (AS1)
5. Give the IUPAC name of the following compounds. If more than one compound is possible name all of them. (AS1)
 - i. An aldehyde derived from ethane.
 - ii. A ketone derived from butane.
 - iii. A chloride derived from propane.
 - iv. An alcohol derived from pentane.
6. A mixture of oxygen and ethyne is burnt for welding; can you tell why a mixture of ethyne and air is not used? (AS1)
7. Explain with the help of a chemical equation, how an addition reaction is used in vegetable ghee industry. (AS1)
8.
 - a. What are the various possible structural formulae of a compound having molecular formula C_3H_6O ? (AS1)
 - b. Give the IUPAC names of the above possible compounds and represent them in structures. (AS1)
 - c. What is the similarity in these compounds? (AS1)
9. Name the simplest ketone and write its molecular formula. (AS1)
10. What do we call the Self linking property of carbon? (AS1)
11. Name the compound formed by heating ethanol at 443 K with excess of conc. H_2SO_4 . (AS1)
12. Give an example for esterification reaction. (AS1)
13. Name the product obtained when ethanol is oxidized by either chromic anhydride or alkaline potassium permanganate. (AS1)
14. Write the chemical equation representing the reaction of preparation of ethanol from ethane. (AS1)
15. Write the IUPAC name of the next homologous of $CH_3OHCH_2CH_3$. (AS1)
16. Define homologous series of carbon compounds; Mention any two characteristics of homologous series. (AS1)

17. Give the names of functional groups (i) -CHO (ii) -C=O . (AS1)
18. Why does carbon form compounds mainly by covalent bonding? (AS1)
19. Allotropy is a property shown by which class substance: elements, compounds or mixtures? Explain allotropy with suitable examples. (AS1)
20. Explain how sodium ethoxide is obtained from ethanol? Give chemical equations. (AS1)
21. Describe with chemical equation how ethanoic acid may be obtained from ethanol. (AS1)
22. Explain the cleansing action of soap. (AS1)
23. Distinguish between esterification and saponification reactions of organic compounds. (AS1)
24. Explain the structure of graphite in term of bonding and give one property based on this structure. (AS1)
25. Name the acid present in vinegar. (AS1)
26. What happens when a small piece of sodium is dropped into ethanol? (AS2)
27. Two carbon compounds A and B have molecular formula C_3H_8 and C_3H_6 respectively. Which one of the two is most likely to show addition? Justify your answer. (AS2)
28. Suggest a test to find the hardness of water and explain the procedure. (AS3)
29. Suggest a chemical test to distinguish between ethanol and ethanoic acid and explain the procedure. (AS3)
30. An organic compound 'X' with a molecular formula $\text{C}_2\text{H}_6\text{O}$ undergoes oxidation with alkaline KMnO_4 and forms the compound 'Y', that has molecular formula $\text{C}_2\text{H}_4\text{O}_2$. (AS3)
- Identify 'X' and 'Y'
 - Write your observation regarding the product when the compound 'X' is made to react with compound 'Y' which is used as a preservative for pickles.
31. Prepare models of methane, ethane, ethene and ethyne molecules using clay balls and match sticks. (AS4)
32. Collect information about artificial ripening of fruits by ethylene. (AS4)
33. Draw the electronic dot structure of ethane molecule (C_2H_6). (AS5)
34. How do you appreciate the role of esters in everyday life. (AS6)
35. How do you condemn the use of alcohol as a social practice. (AS7)
36. An organic compound with molecular formula $\text{C}_2\text{H}_4\text{O}_2$ produces brisk effervescence on addition of sodium carbonate / bicarbonate. Answer the following:
- Identify the organic compound. (AS1)
 - Write the chemical equation for the above reaction. (AS1)
 - Name the gas evolved. (AS2)
 - How will you test the gas evolved? (AS3)
 - List two important uses of the above compound. (AS1)

Homi Jehangir Bhabha



Homi J. Bhabha, (30 October 1909 – 24 January 1966) was a nuclear Physicist, founding Director and Professor of Physics at TIFR, Mumbai. He is known as the father of the Indian Nuclear Programme. Bhabha was the founding director of two well-known research institutions, namely the Tata Institute of Fundamental Research (TIFR) and the Bhabha Atomic Research Centre both institutions were the cornerstone of Indian development of nuclear reactors and nuclear energy which Bhabha also supervised as its director.

In January 1933, Bhabha received his doctorate in nuclear physics after publishing his first scientific paper, “*The Absorption of Cosmic radiation*”. The paper helped him win the Isaac Newton Studentship in 1934.

Starting his scientific career from Great Britain, Bhabha returned to India and accepted a post of reader in physics at the Indian Institute of Science (IISc), Bangalore, headed by Nobel Laureate Sir C.V. Raman. During this time, Bhabha played a key role in convincing Jawaharlal Nehru who later became India’s first Prime Minister, to start the ambitious nuclear programme. In 1945, he established the Tata Institute of Fundamental Research (TIFR), Bombay and set up the Atomic Energy Commission in 1948, serving as its first chairman. In the 1950s, Bhabha represented India in IAEA conferences, and served as President of the UN Conference on the Peaceful Uses of Atomic Energy in Geneva in 1955.

Bhabha gained international prominence after deriving a correct expression for the probability of scattering positrons by electrons, a process now known as Bhabha scattering. His major contribution included his work on Compton scattering, R-process and furthermore the advancement of nuclear physics. He was awarded Padma Bhushan by Government of India in 1954. In January 1966, Bhabha died in a plane crash near Mont Blanc, while heading to Vienna, Austria to attend a meeting of the IAEA’s Scientific Advisory Committee.



Chintamani Nagesa Ramachandra Rao

C.N.R. Rao was born in Bangalore in a Kannada family to Hanumantha Nagesa Rao and Nagamma Nagesa Rao. He completed secondary school leaving certificate in first class in 1947. He studied BSc at Central College, Bangalore. He obtained his bachelor’s degree from Mysore University in 1951, in first class, and only at the age of seventeen. He obtained a master’s in chemistry from BHU two years later. In 1953 he was granted a scholarship for PhD in IIT Kharagpur. His first research paper was published in the Agra University Journal of Research in 1954. He completed PhD in 1958, only after two years and nine months, at age twenty-four.

- Rao is an eminent scientist and a well recognised international authority on solid state and materials chemistry.
- He is currently the Head of the Scientific Advisory Council to the Prime Minister of India.
- He has published over 1,400 research papers and 45 books.
- Rao was awarded Hughes Medal by the Royal Society in 2000, and he was first recipient of the India Science Award in 2004.
- Some of the major areas of his research are transition metal oxide systems, (new synthesis and novel structures, metal-insulator transitions, CMR materials, superconductivity, multiferroics etc), hybrid materials and nanomaterials including nanotubes and graphene.
- Rao’s current passion is graphene, the new wonder material, and artificial photosynthesis.
- He was awarded ‘**Bharat Ratna**’ by the Government of India in the year 2013.

REFERENCE BOOKS

S.No.	Name of the Book	Author(s)	Synopsis
1	Conceptual Physics	Paul G Hewitt	Explain the principles of Physics with examples.
2.	Feynman Lectures on Physics	Feynman	Discussions and analysis on concepts of Physics.
3.	Flying circus of Physics	Jearl Walker	Contains applications and daily life experiences.
4.	Concise Inorganic Chemistry	J.D. Lee	Explains concepts in chemistry
5.	Problems and Questions in School Physics	Tarasova & Tarasov	Explains principles of Physics in a dialogue form. It is useful for seminars and symposiums
6.	Physics	Cutnell & Johnson	Useful for teaching school Physics and preparing for competition exams.
7.	The elements of Physical Chemistry	Atkins	Explain the concepts of Physical Chemistry in detail
8.	Chemistry	Mc Murray & Fay	Explains concepts of Chemistry in a simple way
9.	Thinking Physics	C Epstein	Contains questions and reason behind every scientific phenomena.
10.	University Physics	Harris Benson	Contains good problems
11.	Physics can be fun	Y Perel man	Contains good applications with experiments
12.	Vogali text book of Quantitative Chemical Analysis	Jefery & Others	An experimental book
13.	Organic Chemistry	Wade Jr. & Singh	Explain the concepts of Organic Chemistry in detail
14.	Vogali text book of Practical Organic Chemistry	Jefery & Others	An experimental book

WEBSITES AND e-RESOURCES

<http://unesdoc.unesco.org/images/0010/001023/102321eb.pdf> Provides ideas on how to make school science equipment using inexpensive materials.

<http://unesdoc.unesco.org/images/0007/000728/072808eb.pdf> Provides ideas on how to make school science equipment using inexpensive materials.

<http://www.freeindia.org/biographies/greatscientists/> has biographies of Indian scientists.

<http://www.calcuttaweb.com/people/snbose.shtml> has some more biographies of Indian scientists.

<http://www.bbc.co.uk/schools/gcsebitesize/chemistry/classifyingmaterials/> contains exercises for assessing classification of matter, atomic structure, bonding and formulae/equations for class VIII and above

<http://www.bbc.co.uk/schools/gcsebitesize/physics/electricity/> has some thinking-type questions for class VIII and above

<http://www.bbc.co.uk/schools/gcsebitesize/physics/forces/> has excellent questions for classes VII, VIII and above

<http://www.fordham.edu/Halshall/science/sciencebook.html> is an internet sourcebook for the History of Science

<http://www.learner.org/resources/series90.html> has a set of videos on the science of teaching science

<http://edugreen.teri.res.in/index.asp> is a website for children that makes environmental learning fun

<http://www.nuffieldcurriculumcentre.org/go/Default.html> provides links to websites of various science projects that undertake to enliven science teaching