Class – X **Notes** **Carbon & its Compounds**

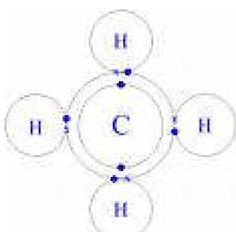
Covalent bond in Carbon:

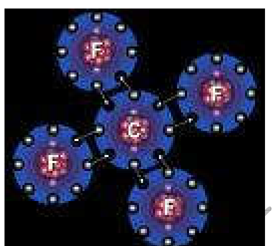
A covalent bond is defined 'as the force of attraction arising due to mutual sharing of electrons between the two atoms.' The combining atoms may share one, two or three pairs of electrons.

The covalent bond is formed between two similar or dissimilar atoms by a mutual sharing of electrons, which are counted towards the stability of both the participating atoms. When the two atoms combine by mutual sharing of electrons, each of the atoms does so, in order to acquire stable configuration of the nearest noble gas. A small line (-) between the two atoms is represents a covalent bond.

The compounds formed due to covalent bonding are called covalent compounds

Carbon has got only 4 valance electrons to share and form covalent bond.





Carbon forming covalent bond with 4 hydrogen atoms

Characteristics of carbon:

- Ability to bond together to form long chains.
- Ability to form multiple covalent bonds.

Why does a carbon atom form four covalent bonds?

(1) It could gain four electrons forming C^{4-} anion. But it would be difficult for then nucleus with six protons to hold on to ten electrons, i.e., four extra electrons.

(2) It could lose four electrons forming C^{4+} cation. But it would require a large amount of energy to remove four electrons leaving behind a carbon cation with six protons in its nucleus holding on to just two electrons.

Some examples of sharing of electrons (i.e. covalent bonding):

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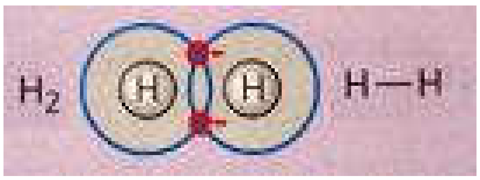
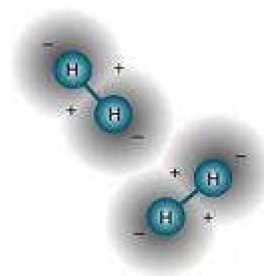
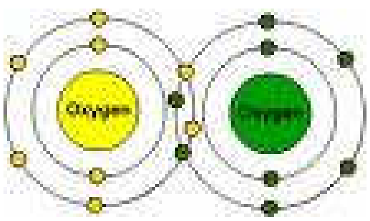
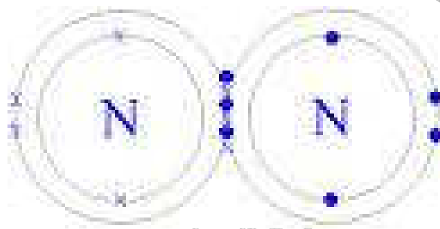




Single bond between two hydrogen atoms



Double bond between two oxygen atoms



Triple bond between two Nitrogen atoms

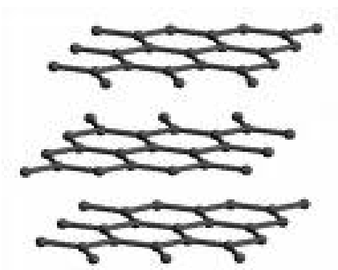
The Allotropes of Carbon:

- Allotropes are elements that can exist in two or more different physical forms
- *Diamond, graphite* and *Buckminsterfullerene* are allotropes of carbon.
- The allotropes of carbon are all the element carbon. The type of carbon is determined from the bonding that occurs.

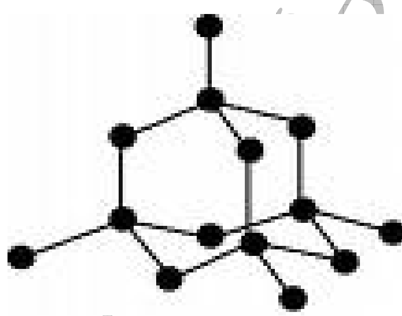
Difference in properties of diamond and graphite:

Diamond	Graphite
• Diamond is the hardest mineral known to man	Graphite is one of the softest.
• Diamond is an excellent electrical insulator	Graphite is a good conductor of electricity.
• Diamond is the ultimate abrasive	Graphite is a very good lubricant.
• Diamond is usually transparent	Graphite is opaque.
• Diamond crystallizes in Isometric system	Graphite crystallizes in hexagonal system

All of the differences between graphite and diamond are the result of the difference in their respective structures



Structure of Graphite



Structure of Diamond

Uses:

Graphite is used as a lubricant, for pencil tips, high temperature crucibles, dry cells and electrodes.
Diamonds are used in jewelry and - because they are so hard - in industry for cutting, drilling, grinding, and polishing.

Buckminsterfullerene:

Buckminsterfullerene was discovered by Sir Harry Kroto. The *basic C_{60} structure* consists of 60 carbon atoms that link together to form a hollow cage-like structure. *These carbon atoms are arranged in the shape of football.* The C_{60} molecule is extremely stable, being able to withstand high temperatures and pressures. They can be electrically insulating, conducting, semiconducting or even superconducting.

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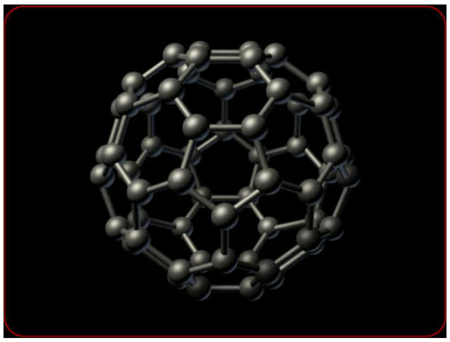
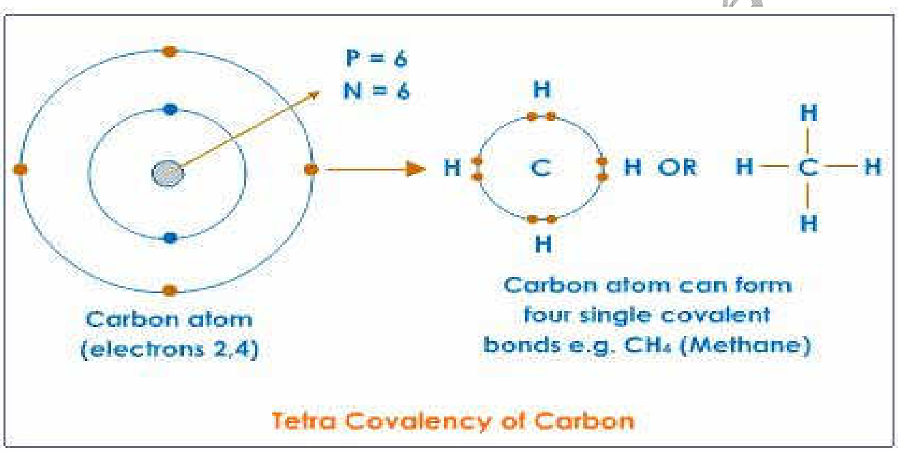


Versatile nature of carbon:

- **Catenation:** A unique property of carbon is 'catenation'. It is the property of forming bonds with the atoms of the same element. The catenation property of carbon is the basis of organic chemistry.
- **Tetravalency:** Carbon is tetravalent in nature and forms the single, double and triple covalent bonds to combine with elements hydrogen, oxygen, sulphur, nitrogen and chlorine to form various types of compounds



Tetra Covalency of Carbon

The tetra covalency of carbon atom allows it to combine easily with other carbon atoms to form a stable chain like structure i.e., exhibiting the property of catenation. Catenation usually occurs because the atom-to-atom covalent bond is quite strong. The chains having different chain lengths and structures and combines with different elements it leads to the formation of a large number of compounds.

Saturated Carbon Compounds:

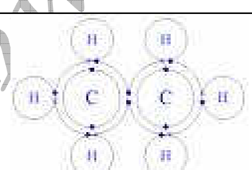
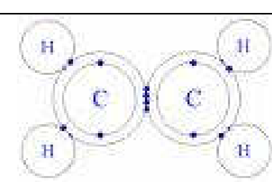
Compounds of carbon and hydrogen whose adjacent carbon atoms contain only one (carbon-carbon) bond are known as *saturated hydrocarbons*. Their carbon-hydrogen bonds are also single covalent bonds. They are called saturated compounds because all the four bonds of carbon are fully utilized and no more hydrogen or other atoms can attach to it. Thus, they can undergo *only substitution reactions.* These saturated hydrocarbons are called as *alkanes*.

Unsaturated Hydrocarbons:

Compounds of carbon and hydrogen that contain one double covalent bond between carbon atoms (carbon=carbon) or a triple covalent bond between carbon atoms (carbon=carbon) are called *unsaturated hydrocarbons*. In these molecules, since all the bonds of carbon are not fully utilized by hydrogen atoms, more of these can be attached to them. Thus, they undergo *addition reactions* (add on hydrogen) as they have two or more hydrogen atoms less than the saturated hydrocarbons (alkanes).

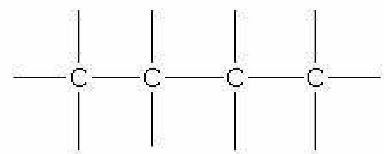
Unsaturated hydrocarbons can be divided into *'alkenes' and 'alkynes'* depending on the presence of double or triple bonds respectively.

Properties of Saturated and Unsaturated Compound:

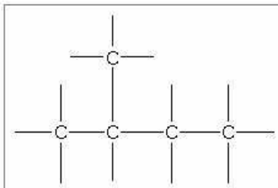
Saturated Organic Compounds	Unsaturated Organic Compounds
These organic compounds contain single carbon-carbon covalent bond.	These organic compounds contain at least one double or triple covalent bond. $>C=C<$ or $-C \equiv C-$
Due to the presence of all single covalent bonds, these compounds are less reactive.	Due to the presence of double and triple bonds, these compounds are more reactive.
Saturated compounds undergo substitution reactions. Example: $CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl$ (Chloromethane)	Unsaturated compounds under go addition reactions. Example: $C_2H_4 + Cl_2 \longrightarrow C_2H_4Cl_2$ (Ethene → 1,2 dichloroethane)
The number of hydrogen atoms is more when compared to its corresponding unsaturated hydrocarbon.	The number of hydrogen atoms is less when compared to its corresponding unsaturated hydrocarbon.
 Electron dot structure of ethane	 Electron dot structure of ethene

Chains, Branches and Rings:

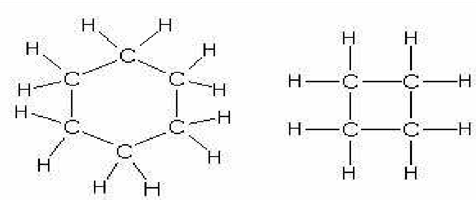
The properties of Tetravalency and catenation allow the formation stable chains of carbon atoms having different chain lengths and structures. The chains of carbon atoms may be linear or branched (open) or cyclic (closed) rings, sheets and three-dimensional lattices. For example



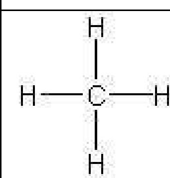
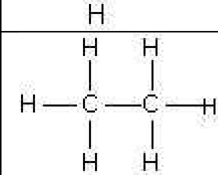
Linear Chain

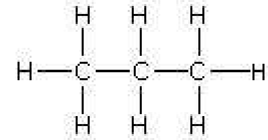
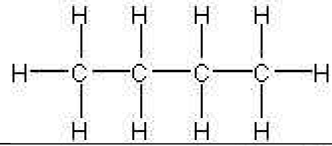
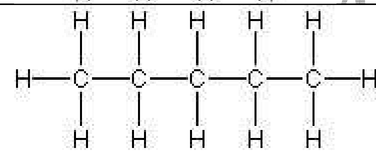


Branched Chain

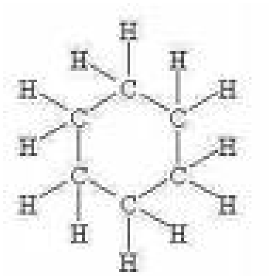


Cyclic Rings

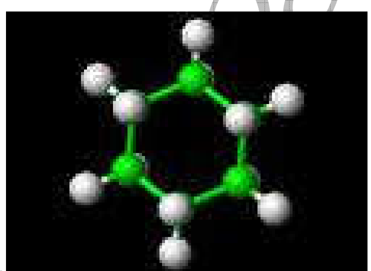
Name	Formula	Number of carbon atoms	Structure (straight)
Methane	CH_4	1	
Ethane	C_2H_6	2	

Propane	C_3H_8	3	
Butane	C_4H_{10}	4	
Pentane	C_5H_{12}	5	

Structure of cyclohexane (C_6H_{12}):



Complete molecule structure



3-D structure of cyclohexane

Structure of benzene (C_6H_6):

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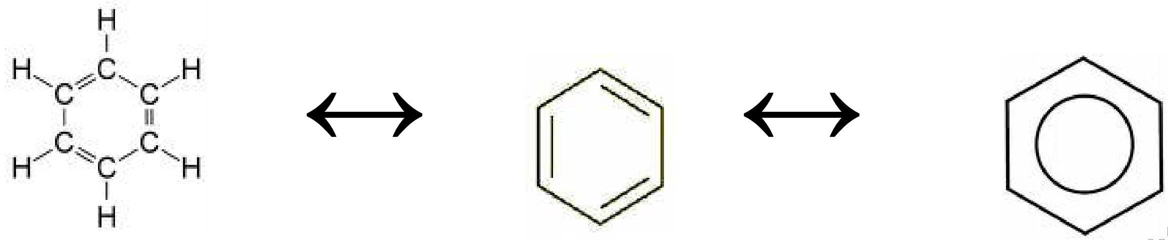

Homologous series:

A homologous series is a family of organic compounds containing a particular characteristic group and exhibiting similar properties. For example, the compounds given below belong to the alcohol family.

- CH_3OH methyl alcohol (methanol)
- $CH_3CH_2CH_2OH$ propyl alcohol (1-propanol)
- $CH_3CH_2.CH_2.CH_2OH$ butyl alcohol (1-butanol)

Characteristics of a Homologous Series:

All members of a homologous series exhibit some common characteristics. They are:

- All the members of a homologous series can be represented by a common general formula, as they have the same functional group. For example, alkanes can be represented by the formula $C_nH_{2n+2.}$

CH_4	C_2H_5	C_3H_8	C_4H_{10}
Methane	Ethane	Propane	Butane

- Each member of a homologous series has a common difference of $-CH_2$ from the next higher or lower member.
- Common general methods of preparation exist for all members of the series.
- All members exhibit similar chemical behavior.
- An increase in molecular mass of members within a homologous series show a similar regular gradation of the physical properties, such as, physical state, melting and boiling points etc

Naming of carbon compounds:

Step 1: Identify the number of carbon atoms in the compound. Use the following list for no. of carbon atoms. For ex. If a chain having *'2'* carbon atom it is named as *'eth'*

Prefixes for naming carbon chains:

Prefix	meth	eth	prop	but	pent	hex	hept	oct	non	dec
Number of Carbon atoms in the chain	1	2	3	4	5	6	7	8	9	10

Step 2: In case of functional group is present, it is indicated in the name of the compound using the following list with either suffix or prefix.

1. Naming halocarbons.
   - *Halo*carbons, organic compounds containing one or more *halo*gens,
   - Use the same group prefixes to describe the amount.
2. Naming alcohols.
   - An alcoh*ol* is a carbon chain with a hydroxide (OH^-) attached.
   - Name the carbon chain, using the suffix -*ol*.
   - Place a number in front to indicate what carbon the hydroxide is attached to.
     Ex: $CH_3CH_2CH_2(OH)$ is named 1-propanol. .
3. Naming Aldehyde.
   - An Aldehyde is a carbon chain with an oxygen double bonded to the last/first carbon.
   - Use the appropriate prefix for carbon chain and use the suffix -*al*. No position number is required. Ex: $CH_3CH(=O)$ is named ethanal.
4. Naming Ketone.
   - A Ketone is a carbon chain with oxygen bonded to a middle carbon. Use the suffix -*one* and use position numbers past propanone. Ex: $CH_3CH_2CH_2C(=O)CH_3$ is named 2-pentanone.
5. Naming carboxylic acids.
   - A carboxyl*ic acid* is a carbon chain with oxygen double bonded and a hydroxide bonded to the last/first carbon.
   - Use the suffix -o*ic acid*. No position number is required. Ex: $CH_3CH_2C(=O)OH$ is named propanoic acid.

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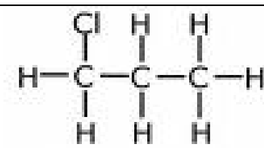
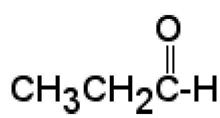
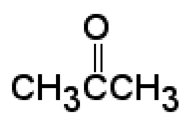
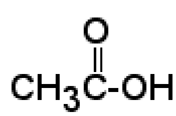
Nomenclature of carbon compounds:

Functional Group Name	Prefix or suffix	Structure	Name
Halogens	Chloro, bromo etc		Chloropropane
Alcohol	-ol	$CH_3CH_2CH_2OH$	propanol
Aldehyde	-al		Propanal
Ketone	-one		Propanone or acetone (common name)
Carboxylic Acid	-oic acid		ethanoic acid or acetic acid (common name)
Alkene	-ene	$CH_2=CHCH_3$	Propene
Alkyne	-yne	$CH\equiv CCH_3$	Propyne

Important Definitions:

1. **Alkyl group:** In chemistry, a group of atoms derived from an alkane (a hydrocarbon with no carbon-to-carbon multiple bonds) by the loss of a hydrogen atom.
2. **Functional groups**: An atom or group of atoms, such as a carboxyl group, that replaces hydrogen in an organic compound and that defines the structure of a family of compounds and determines the properties of the family. In other words, the group of atoms responsible for the characteristic reactions of a compound. The functional group is –OH for alcohols, –CHO for Aldehydes, –COOH for carboxylic acids, etc.
3. **Isomers:** Any of two or more substances that are composed of the same elements in the same proportions but differ in properties because of differences in the arrangement of atoms.
4. **Structural isomers:** Any of two or more chemical compounds, such as propyl alcohol and isopropyl alcohol, having the same molecular formula but different structural formulas.
5. **Glacial acetic acid:** ethanoic acid freezes at 290K to form colorless crystals which look like glaciers. That is why pure ethanoic acid is known as glacial acetic acid.

Chemical properties of carbon compounds:

1. **Combustion:**
   Combustion reactions always involve molecular oxygen O_2. A simple combustion reaction is given for methane. The combustion of methane means that it is possible to burn it. Chemically, this combustion process consists of a reaction between methane and oxygen in the air

$$C + O_2 \rightarrow CO_2 + \text{heat and light}$$

$$CH_4\,[g] + 2\,O_2\,[g] \rightarrow CO_2\,[g] + 2\,H_2O[g] + \text{heat and light}$$

- Saturated hydrocarbon gives clean flame
- Unsaturated hydrocarbon gives yellow flame with lots of smoke. It results in sooty deposits on the metal plate.
- Gas stove in home has inlets for air so that sufficiently oxygen rich mixture is used to give clean blue flame. If cooking vessels get blackened, it means that air holes are blocked and fuel is wasted.

$$CH_3CH_2OH \xrightarrow[Or\ Acidified\ K_2Cr_2O_7+Heat]{Alkaline\ KMnO_4+heat} CH_3COOH$$

2. **<u>Addition reaction:</u>**
Reactions which involve addition of two reactants to form a single product are called addition reactions.
Unsaturated hydrocarbons add hydrogen in the presence of catalysts such as palladium or nickel to give saturated hydrocarbons. This process is called catalytic hydrogenation. *Catalysts*

are substances that cause a reaction to occur or proceed at a different rate without the reaction itself being affected.

$$R_2C = CR_2 \ + H_2 \xrightarrow[473K]{Nickel} \ R_2CH - CHR_2$$

Vegetable oils generally have long unsaturated carbon chains while animal have saturated carbon chains.

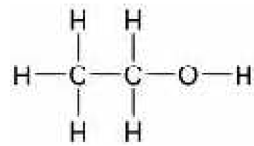
$$Vegetable\ oil\ (l) \ + H_2 \xrightarrow[473k]{Nickel} \ Vegetable\ ghee\ (s)$$

3. **<u>Substitution Reaction:</u>**
Reactions which involve the direct replacement (displacement or substitution) of an atom or a group of atoms in an organic molecule by another atom or group of atoms without any change in the rest of the molecule are called substitution reaction.
In the presence of sunlight, chlorine is added to hydrocarbons in a very fast reaction. Chlorine can replace the hydrogen atoms one by one.

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl \text{ (in the presence of sunlight)}$$

Ethanol:

- Formula: C_2H_6O
- Molecular weight: 46.0684g/mol
- Common name: Ethyl alcohol
- Chemical structure:



Physical Properties:

- Ethanol is a colorless liquid with a pleasant smell.
- It is liquid at room temperature.
- It is completely miscible with water

Chemical properties:

1. **Reaction of Ethanol with Sodium**
   Sodium reacts with ethanol at room temp to liberate hydrogen. The hydrogen atom of the hydroxyl group is replaced by a sodium atom, forming sodium ethoxide.

$$C_2H_5OH \quad + \quad Na \quad ==> C_2H_5ONa + H_2$$

2. **Dehydration of Ethanol:**
   When ethanol is mixed with concentrated sulphuric acid with the acid in excess and heated to 170 °C, ethylene is formed. (One mole of ethanol loses one mole of water)

$$C_2H_5OH \xrightarrow[170°C]{H_2SO_4} C_2H_4 + H_2O$$

Uses:

Ethanol is used:

- in the manufacture of alcoholic drinks, e.g. Vodka, etc.,
- as a widely used solvent for paint, varnish and drugs,
- in the manufacture of ethanal, (i.e. acetaldehyde), and ethanoic acid, (i.e. acetic acid),
- as a fuel (e.g. in Gasohol),
- as the fluid in thermometers, and
- in preserving biological specimens

Ethanoic acid:

- Formula CH_3COOH

- Common name: Acetic acid, glacial acetic acid, vinegar (when very dilute about 5-8%)
- Molecular wt: 60.05g/mol

Physical properties:

- White semi-transparent solid
- Colorless liquid when pure.
- Often used as a colorless solution in water.
- Stability: Stable
- Melting point: 16.7 °C
- Boiling point: 118 °C
- Water solubility: miscible in all proportions.

Chemical properties:

1. **Esterification reaction:** When ethanoic acid is heated with ethanol on presence of a few drops of conc. H_2SO_4 as catalyst, it forms the ester, ethyl ethanoate. This reaction is called Esterification reaction.

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Ethanol}}{C_2H_5OH} \xrightarrow{acid} \underset{\text{Ester}}{CH_3COOC_2H_5} + \underset{\text{water}}{H_2O}$$

2. **Saponification reaction**: when an ester is heated with dil. NaOH solution, it gets converted into the original alcohol and sodium salt of the original carboxylic acid. This reaction is used in preparation of soap so it is known as Saponification reaction.

$$CH_3COOC_2H_5 \xrightarrow{NaOH} CH_3COOH + C_2H_5OH$$

3. **Reaction with base:**

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

Ethanol	Ethanoic acid
Its molecular formula is CH_3CH_2OH and Mol. wt. is 46g/mol.	Its molecular formula is CH_3COOH and molecular wt. is 60g/mol.
It has sweet smell	It has pungent smell
Its freezing pt. is 156K while its boiling pt. is 351K	It has freezing pt. of 290K and boiling pt. is 391k
It is used in manufacture of alcoholic beverages	It is used in the production of soft drink bottles
95% of ethanol solution in water is rectified spirit which is used as an antiseptic for wounds	5-8% of ethanoic acid solution in water is vinegar which is used as preservative of pickles etc.

Soaps:

- Soaps are sodium or potassium salts of higher fatty acids containing 16-18carbon atoms.
- Soaps cannot be used in hard water: the Ca^{2+} and Mg^{2+} ions present in water produce curdy white precipitates called scum of calcium and magnesium soaps which are insoluble in water. As a result lots of soap is wasted.

  Soft water: Water that produces lather (foam) with soap is called soft water. Ex- rain water, distilled water etc.

  Hard water: Water that do not produce lather (foam) with soap is called soft water. Ex-sea water, river water.

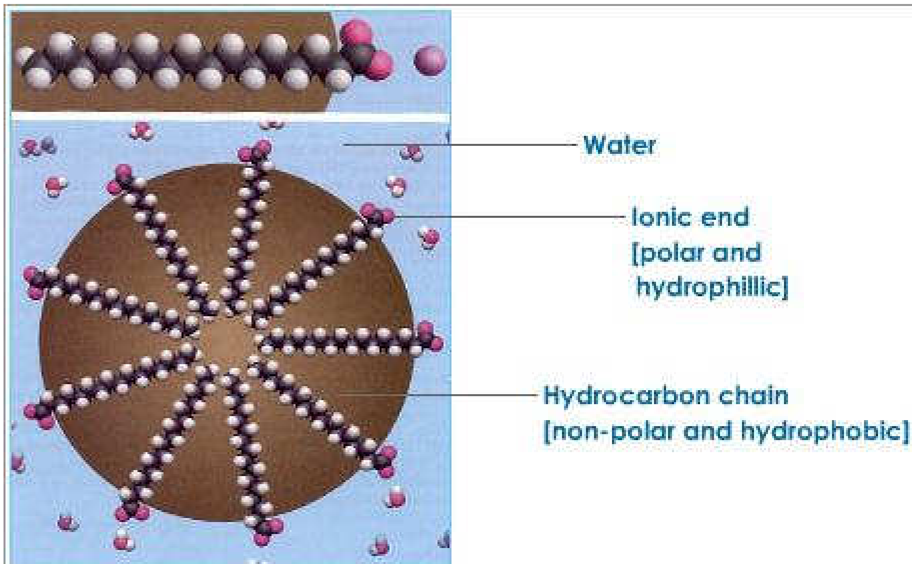
Detergents:

- Detergents are either ammonium salts or sulphonate salts of long chain hydrocarbon containing 12-18 carbon atoms.
- Detergents can be used in hard water since their calcium and magnesium salts like their (soaps) sodium and potassium salts are soluble in water.

Cleansing Action of Soaps and detergents:

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.

The cleansing action of soap is determined by its polar and non-polar structures in conjunction with an application of solubility principles. The long hydrocarbon chain is of course non-polar and hydrophobic (repelled by water). The "salt" end of the soap molecule is ionic and hydrophilic (water soluble).



Sodium lauryl sulphate is a synthetic detergent present in laundry soaps, toothpastes and shampoos. The formula of sodium lauryl sulphate is $CH_3\ (CH_2)_{11}SO_4^-\ Na^+$. It has a hydrophilic sulphate group and hydrophobic dodecyl ($C_{12}H_{25}$) group. When soap is added to water, the ionic-salt end of the molecule is attracted to water and dissolved in it. The non-polar hydrocarbon end of the soap molecule is repelled by water. The molecules of soap are sodium or potassium salts of long-chain carboxylic acids. The ionic-end of soap dissolves in water while the carbon chain dissolves in oil. The soap molecules thus form structures called micelles where one end of the molecules is towards the oil droplet while the ionic-end faces outside. This forms an emulsion in water. The soap micelle thus helps in dissolving the dirt in water and we can wash our clothes clean.

Micelles:

Soaps are molecules in which the two ends have differing properties, one is hydrophilic, that is, it dissolves in water, while the other end is hydrophobic, that is, it dissolves in hydrocarbons. When soap is at the surface of water, the hydrophobic 'tail' of soap will not be soluble in water and the soap will align along the surface of water with the ionic end in water and the hydrocarbon 'tail' protruding out of water. Inside water, these molecules have a unique orientation that keeps the hydrocarbon portion out of the water. This is achieved by forming clusters of molecules in which the hydrophobic tails are in the interior of the cluster and the ionic ends are on the surface of the cluster. This formation is called a micelle.

Detergents:

The cleansing action of detergent is much higher than soaps. While bathing that foam is formed with difficulty and an insoluble substance (scum) remains after washing with water. This is caused by the reaction of soap with the calcium and magnesium salts, which cause the hardness of water. This problem is overcome by using another class of compounds called detergents as cleansing agents. Detergents are generally ammonium or sulphonate salts of long chain carboxylic acids. The charged ends of these compounds do not form insoluble precipitates with the calcium and magnesium ions in hard water. Thus, they remain effective in hard water. Detergents are usually used to make shampoos and products for cleaning clothes.