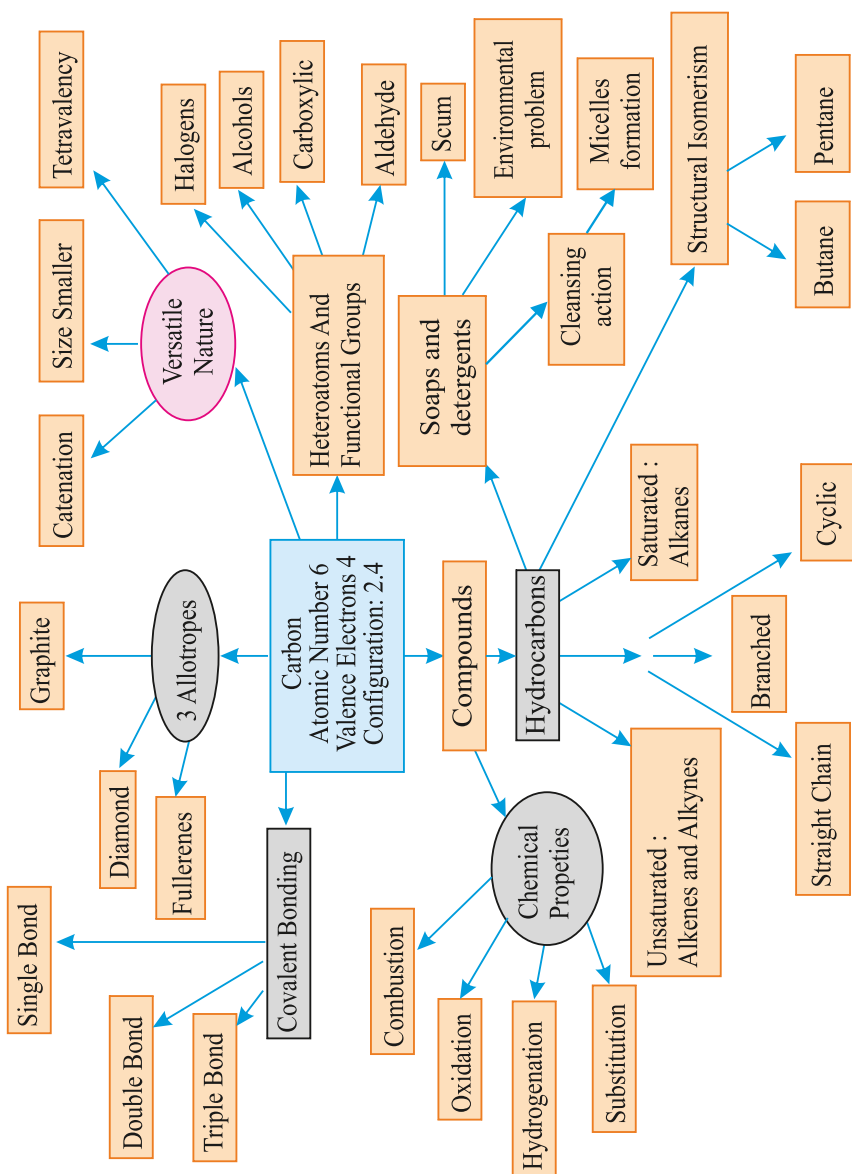


Chapter - 4

Carbon and its Compounds



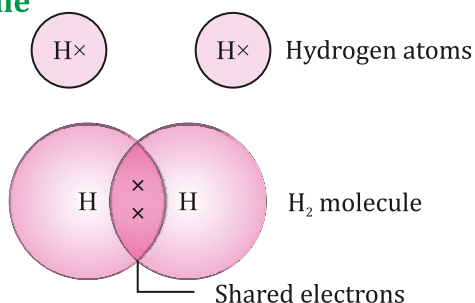
CARBON AND ITS COMPOUNDS

- Carbon is a versatile element.
- In earth's crust, carbon is 0.02% and found in form of minerals.
- Atmosphere has 0.03% of Carbon dioxide.
- All living structures are carbon based.
- Carbon is present in paper, plastic, leather and rubber.

COVALENT BOND IN CARBON

- The atomic number of carbon is 6 and its electronic configuration is 2, 4. To attain a noble gas configuration it can
 1. Gain 4 electrons: But it would be difficult for nucleus to hold 4 extra electrons.
 2. Lose 4 electrons: But it would require a large amount of energy to remove 4 electrons.
- It is difficult thus for an atom of carbon to either gain or lose electrons.
- Carbon attains the noble gas configuration by sharing its valence electrons, with other atoms. Atoms of other elements like hydrogen, oxygen, nitrogen, chlorine also show sharing of valence electrons.
- Shared electrons belong to the outer shells of both atoms, which thereby achieve noble gas configuration.
- Formation of H_2 , O_2 and N_2 is shown as below:

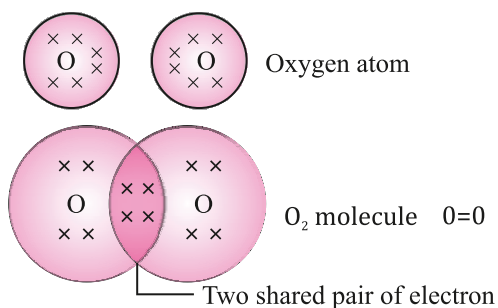
(i) H_2 molecule



A molecule of hydrogen

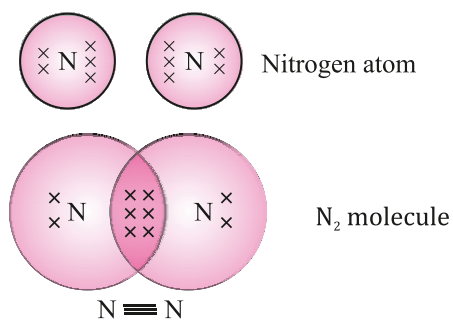
A molecule of hydrogen

(ii) O_2 molecule

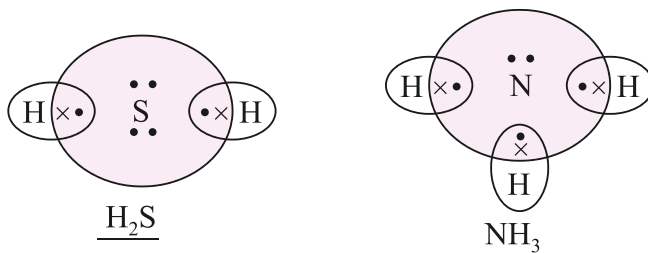
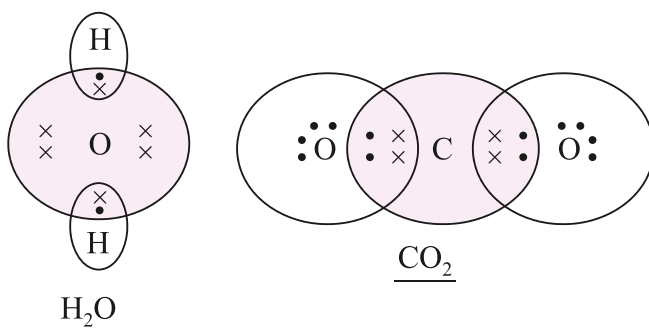


Double bond between two oxygen atoms

(iii) N_2 molecule



Triple bond between two nitrogen atoms



- It is evident that the number of shared pair of electrons can be one, two or three.
- Bond formed by the sharing of an electron pair between two atoms is called covalent bond.
- Covalently bonded molecules have low melting and boiling points because of comparatively weaker intermolecular forces, unlike ionic compounds.
- These molecules are generally poor conductor of electricity since no charged particles are formed.

Allotropes of carbon:

- Diamond:** Each of the carbon atom is bonded to four other atoms of carbon.
- Graphite:** Each of the carbon atom is bonded to three other atoms of carbon. The fourth valence electron can move, thus graphite becomes a good conductor of electricity.
- Fullerenes:** Smallest fullerene has 60 carbon atoms.

Use of (i) Diamond — making jewellery, thermometers.

(ii) Graphite — pencil leads, electrodes, dry lubricant.

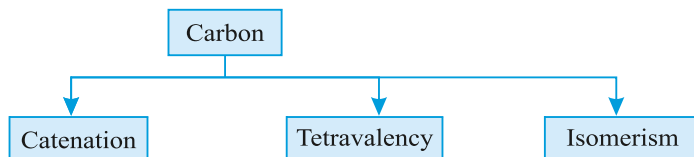
These allotropes have same chemical properties.

Difference between diamond and graphite

Diamond	Graphite
• It is hardest natural substance • It is an insulator of electricity but good conductor of heat. • It is transparent	• It is soft. • It is good conductor of both heat and electricity • It is opaque

VERSATILE NATURE OF CARBON ATOMS:

Three important properties of carbon atom enable carbon to form enormously large number of compounds.

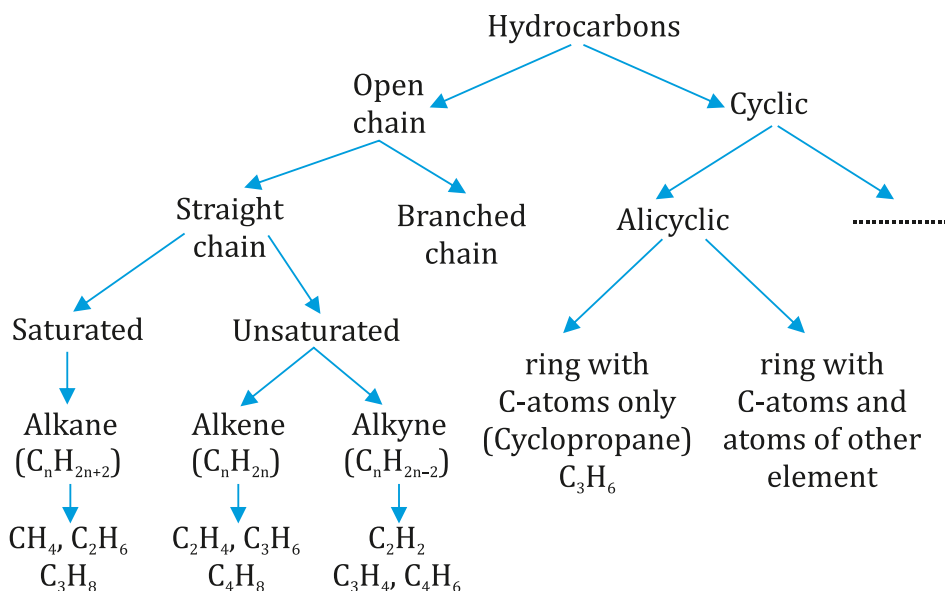


CATENATION: property of carbon atom to form bond with other atoms of carbon is called catenation. Like, carbon, silicon forms compounds with upto seven or eight atoms of silicon.

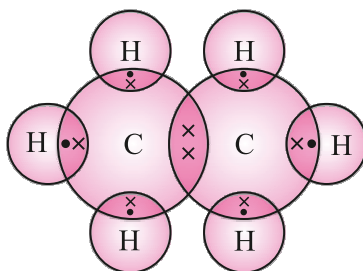
TETRAVALENCY: Having a valency of 4, carbon atom is capable of bonding with atoms of oxygen, hydrogen, nitrogen, sulphur, chlorine and other elements.

The smaller size of carbon atom enables nucleus to hold the shared pair of electrons strongly, thus carbon compounds are stable in general.

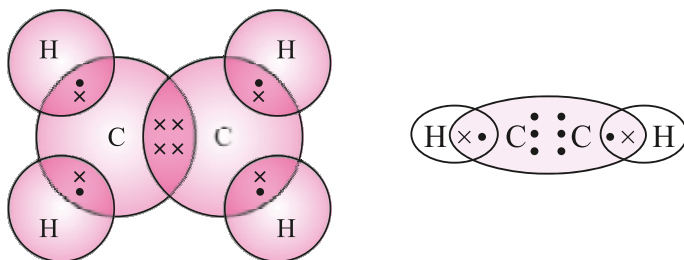
SATURATED AND UNSATURATED CARBON COMPOUNDS



- To have a double/triple bond in chain, at least two carbon atoms are required. So, first member of alkene and alkyne have two-carbon atoms.
- Electron dot structure of a saturated carbon compound, ethane (C₂H₆):



- Electron dot structure of an unsaturated carbon compound, ethene (C_2H_4) and ethyne (C_2H_2)



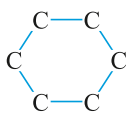
Formulae and structure of compounds of carbon and hydrogen

No. of carbon atoms	Name	Formula	Structure
1	Alkanes: Methane	CH_4	<pre> H H — C — H H </pre>
2	Ethane	C_2H_6	<pre> H H H — C — C — H H H </pre>
3.	Propane	C_3H_8	<pre> H H H H — C — C — C — H H H H </pre>
4.	Butane	C_4H_{10}	<pre> H H H H H — C — C — C — C — H H H H H </pre>

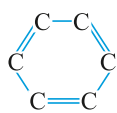
No. of carbon atoms	Name	Formula	Structure
5.	Pentane	C_5H_{12}	$ \begin{array}{ccccccccc} & H & H & H & H & H & & & \\ & & & & & & & & \\ H & - C & - C & - C & - C & - C & - H \\ & & & & & & & & \\ & H & H & H & H & H & & & \end{array} $

Name of Hydrocarbon	Molecular formula	Structural Formula
Alkenes :		
1. Ethene	C_2H_4	$ \begin{array}{ccccccc} & H & H & & & & \\ & & & & & & \\ H & - C & = C & - H \\ & & & & & & \end{array} $
2. Propene	C_3H_6	$ \begin{array}{ccccccc} & H & H & & & & \\ & & & & & & \\ H & - C & = C & - C & - H \\ & & & & & & \\ & H & & H & & & \end{array} $
3. Butene	C_4H_8	$ \begin{array}{ccccccc} & H & H & & & & \\ & & & & & & \\ H & - C & = C & - C & - C & - H \\ & & & & & & \\ & H & H & H & H & & \end{array} $
Alkynes :		
1. Ethyne	C_2H_2	$H - C \equiv C - H$
2. Propyne	C_3H_4	$ \begin{array}{ccccccc} & H & & & & & \\ & & & & & & \\ H & - C & \equiv C & - C & - H \\ & & & & & & \\ & & & H & & & \end{array} $
3. Butyne	C_4H_6	$ \begin{array}{ccccccc} & H & H & & & & \\ & & & & & & \\ H & - C & \equiv C & - C & - C & - H \\ & & & & & & \\ & & & H & H & & \end{array} $

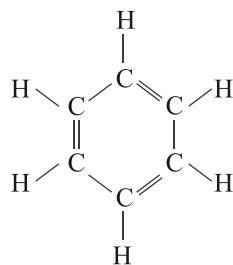
Cyclic structures:



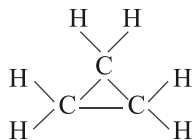
Cyclic Saturated



Cyclic unsaturated

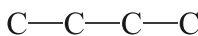


Benzene

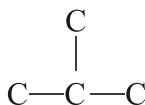


Cyclo-propane

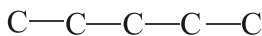
- **Structural isomers:** These are the compounds having identical molecular formula but different structures. Isomers of butane and pentane



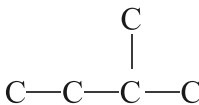
n-butane



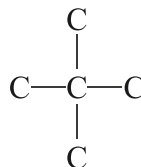
iso-butane



n-pentane



iso-pentane



neo-pentane

HETEROATOM AND FUNCTIONAL GROUP:

- In hydrocarbon chain, one or more hydrogen atoms can be replaced by other atoms in accordance with their valencies. The element that

Heteroatom	Functional Group	Formula
Cl/Br	Halo (Chloro/Bromo)	— Cl, — Br, — I
Oxygen	1. Alcohol	— OH
	2. Aldehyde	$\begin{array}{c} \text{H} \\ \diagup \\ \text{— C} \\ \diagdown \\ \text{O} \end{array}$ or — CHO
	3. Ketone	$\begin{array}{c} \text{— C —} \\ \\ \text{O} \end{array}$ or — CO —
	4. Carboxylic acid	$\begin{array}{c} \text{— C — OH} \\ \\ \text{O} \end{array}$ or — COOH

replaces hydrogen is called a heteroatom.

- These heteroatoms and the group containing them impart chemical properties to the compound and hence are called functional groups.

HOMOLOGOUS SERIES:

- It is a series of compounds in which the same functional group substitutes for hydrogen in a carbon chain.
- For instance, the alcohols: CH_3OH , $\text{C}_2\text{H}_5\text{OH}$, $\text{C}_3\text{H}_7\text{OH}$, $\text{C}_4\text{H}_9\text{OH}$.
- The successive member differs by $-\text{CH}_2$ unit and 14 units of mass.
- The chemical properties are imparted by the functional group thus all members have similar chemical properties. But the members have different physical properties.
- The physical properties vary among the members of homologous series due to difference in their molecular mass.
- Melting point and boiling point increases with increasing molecular mass.

NOMENCLATURE OF CARBON COMPOUNDS:

1. Identify the number of carbon atoms in the compound.
2. Functional group is indicated either by prefix or suffix.

FUNCTIONAL GROUP	SUFFIX	PREFIX
Alkene	-ene	
Alkyne	-yne	
Alcohol	-ol	
Aldehyde	-al	
Ketone	-one	
Carboxylic acid	- oic acid	
chlorine		chloro -

3. If a suffix is added, then final 'e' is removed from the name.eg. methanol (methane – e = methan + ol).

CHEMICAL PROPERTIES OF CARBON COMPOUNDS

1. COMBUSTION:

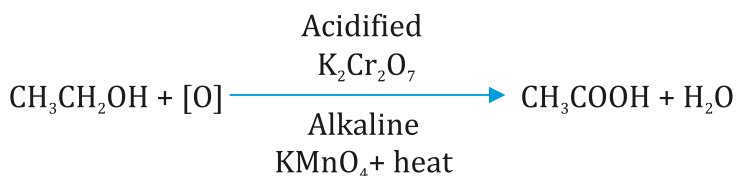
- * Carbon compounds generally burn (oxidize) in air to produce carbon dioxide and water, and release heat and light energy.



- * Saturated hydrocarbon burns generally with a blue flame in good supply of air and with a yellow sooty flame in limited supply of air.
- * Sooty flame is seen when unsaturated hydrocarbons are burnt in air.
- * Burning of coal and petroleum emits oxides of sulphur and nitrogen which are responsible for acid rain.

2. OXIDATION:

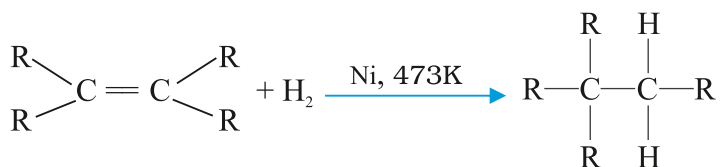
- * Alcohols can be converted to carboxylic acids by oxidizing them using alkaline potassium permanganate or acidified potassium dichromate (they add oxygen to the reactant, thus are called oxidizing agents)



3. ADDITION REACTION:

Hydrogen is added to unsaturated hydrocarbon which are more reactive due to double/triple bond, in presence of nickel, platinum or palladium as catalyst. This process is called hydrogenation.

Vegetable oils are converted into vegetable ghee using this process.



Hydrogenation slows the rancidity of vegetable oils.

Saturated fatty acids are harmful for health and oils with unsaturated fatty acids should be used for cooking.

4. SUBSTITUTION REACTION:

In saturated hydrocarbons, the hydrogen attached to carbon can be replaced by another atom or group of atoms in presence of light or heat.



IMPORTANT CARBON COMPOUNDS: ETHANOL AND ETHANOIC ACID

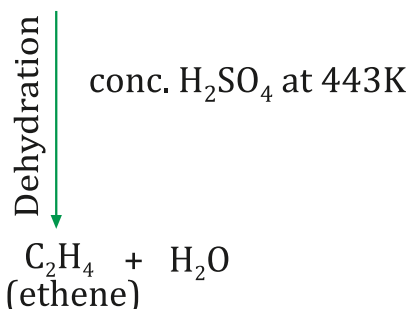
Ethanol:

Melting Point 156 K	Boiling point 351 K
ETHANOL	
Soluble in Water	Burning taste

* Consumption of dilute ethanol causes serious health issues and intake of pure alcohol is lethal.

Chemical properties of Ethanol

$\text{C}_2\text{H}_5\text{OH}$ Reacts with sodium to form sodium ethoxide and hydrogen gas	When $\text{C}_2\text{H}_5\text{OH}$ is heated with Concentrated sulphuric acid at 443 K, it is dehydrated to ethene
---	--



In preparation of transparent soaps, cosmetics	In alcoholic beverages
Uses of ETHANOL	
As a laboratory reagent	In Medicines and Tonics

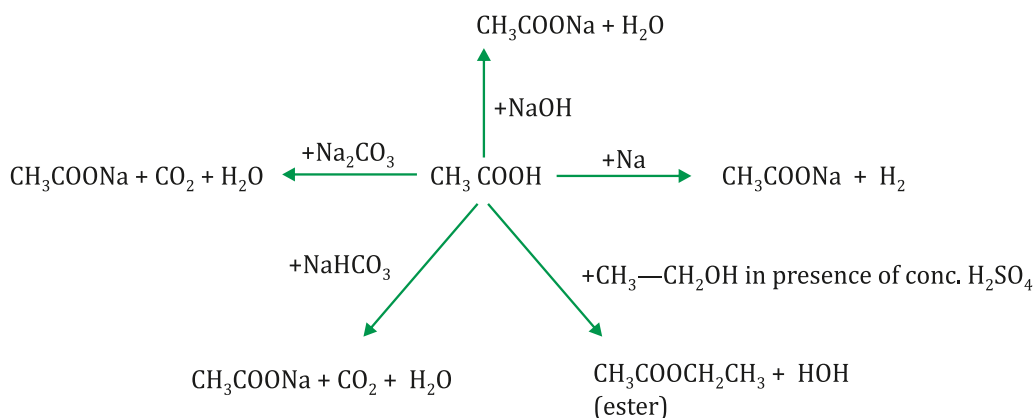
Ethanoic Acid (CH_3COOH)/Acetic Acid

Freezes at 290 K	Boiling point 391 K
Ethanoic Acid	
Miscible in Water	Sour taste

- * Pure acetic acid is called glacial acetic acid.
3–4% solution of acetic acid is called vinegar.

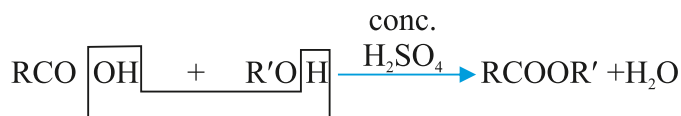
Ethanoic Acid:

	React with	Products
1.	Sodium(Na)	Sodium ethanoate and hydrogen gas
2.	Sodium Carbonate Na_2CO_3 sodium	Sodium ethanoate, carbon dioxide and water
3.	Sodium Bicarbonate NaHCO_3 sodium	Sodium ethanoate, carbon dioxide and water
4.	Ethanol (in presence of conc. sulphuric acid) $\text{CH}_3-\text{CH}_2\text{OH}$	Ester and water



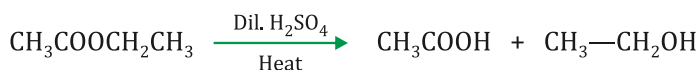
Esterification

Carboxylic acids react with alcohols in presence of few drops of concentrated sulphuric acid as catalyst and form sweet smelling compounds called ester.



HYDROLYSIS

On heating with an acid or a base, the ester forms back the original alcohol and carboxylic acid.



*Alkaline hydrolysis of ester is also called saponification.

SOAPS AND DETERGENTS

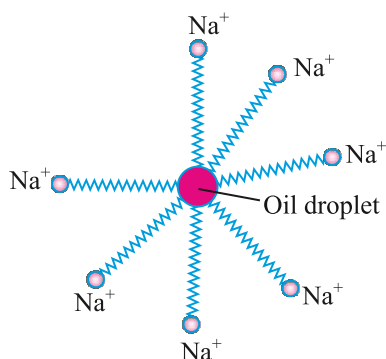
- Soap is sodium and potassium salt of carboxylic acids with long chain. ($\text{C}_{15}\text{H}_{31}\text{COOH}$), ($\text{C}_{17}\text{H}_{35}\text{COOH}$) (Palmitic acid, stearic acid)
- Soaps are effective with soft water only and ineffective with hard water.
- Detergents are ammonium or sulphonate salts of hydrocarbons with long chain, they are effective with both soft as well as hard water.

- An ionic part (hydrophilic) and a long hydrocarbon chain (hydrophobic) part constitutes the soap molecule



Cleansing action of Soaps:

- Most dirt is oily in nature and the hydrophobic end attaches itself with dirt, while the ionic end is surrounded with molecules of water. This results in formation of a radial structure called micelles.



- An emulsion is thus formed by soap molecule. The cloth needs to be mechanically agitated to remove the dirt particles from the cloth.
- Scum: The magnesium and calcium salts present in hard water react with soap molecule to form insoluble products called scum, thus obstructing the cleansing action. Use of detergents overcomes this problem as the detergent molecule prevents the formation of insoluble product and thus clothes get cleaned.
- Soaps are completely biodegradable, while detergents are not. Soaps are environmental friendly but detergents are not.

CARBON AND ITS COMPOUNDS IN BRIEF

- Carbon is a versatile non-metal
- Carbon atom, like atoms of other non-metals like oxygen, nitrogen, hydrogen and chlorine, shares electrons.

- Carbon forms large number of compounds due to catenation, tetravalency and isomerism.
- Carbon can form single, double and triple covalent bonds
- The compound of hydrogen and carbon are called hydrocarbons which can be saturated or unsaturated.
- Structurally hydrocarbons can have straight chain, branches or cyclic structure.
- Difference in structural arrangement of same molecule gives the isomers.
- In a hydrocarbon, a hetero atom can replace the hydrogen atom and impacts its chemical properties. Homologous series is a series of compounds with same general formula and same chemical properties but different physical properties.
- Carbon based compounds are excellent fuels.
- Ethanol is an important industrial compound. It reacts with reactive metals and is also dehydrated to ethene.
- Ethanoic acid is another important compound. It combines with ethanol to form sweet smelling esters.
- Soaps and detergents are used as cleansing agents. Detergents efficiently cleanse with soft and hard water.

MULTIPLE CHOICE QUESTIONS

- Which of the following metal is used as a catalyst in hydrogenation?

a. Cu	b. Ni
c. Fe	d. Na
- The number of single bonds in hexane molecule are:

a. 18	b. 19
c. 20	d. 21
- It is present in the molecule of N_2 :

a. Single bond	b. Ionic bond
c. double bond	d. Triple bond