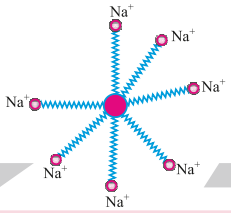
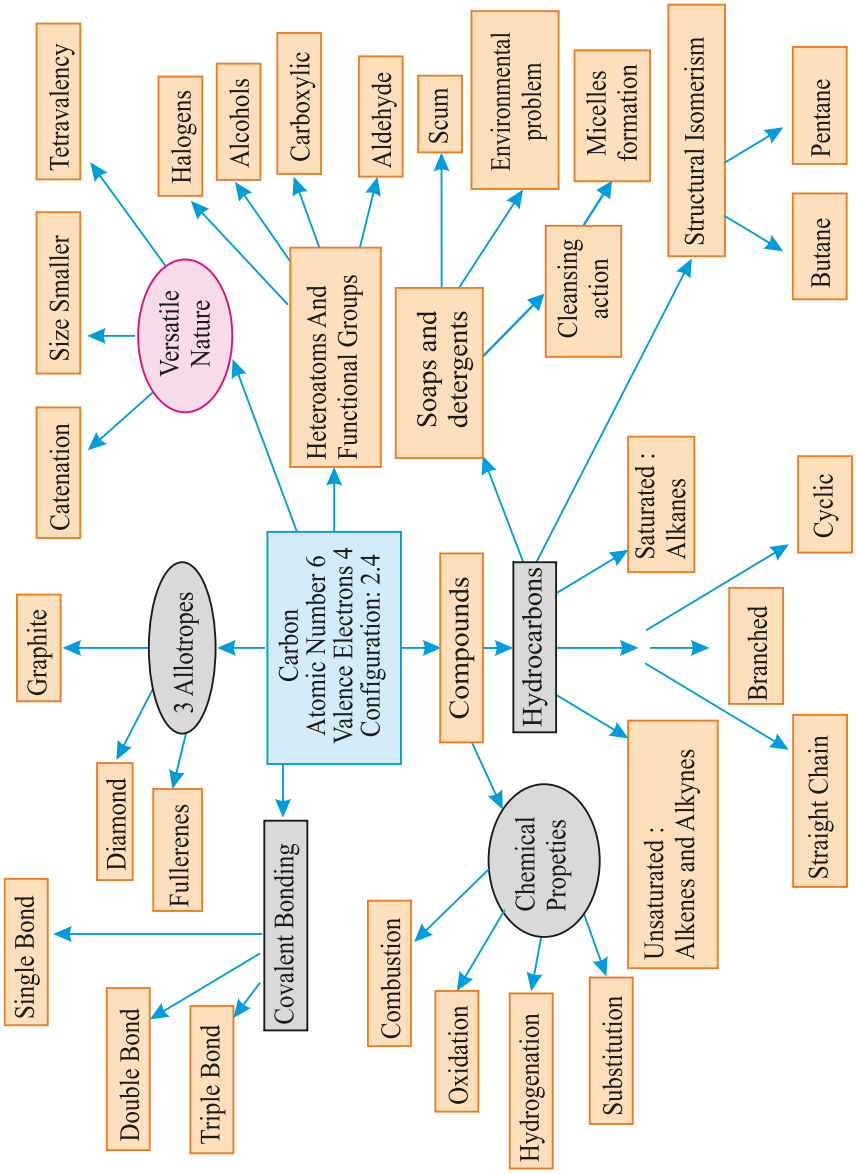


Chapter - 4

Carbon and its Compounds



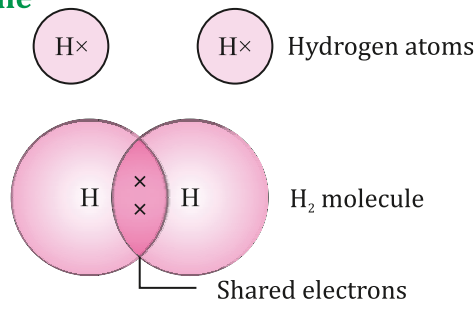
CARBON AND ITS COMPOUNDS

- 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 clectrons: 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:

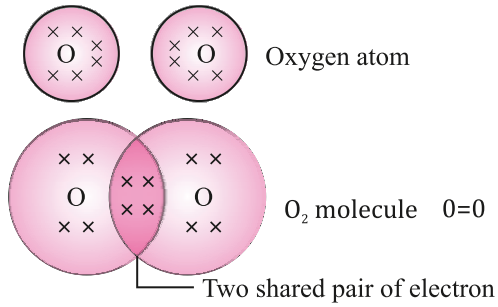
(i) H_2 molecule



A molecule of hydrogen

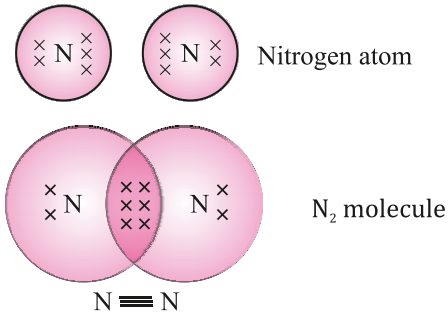
A molecule of hydrogen

(ii) O_2 molecule

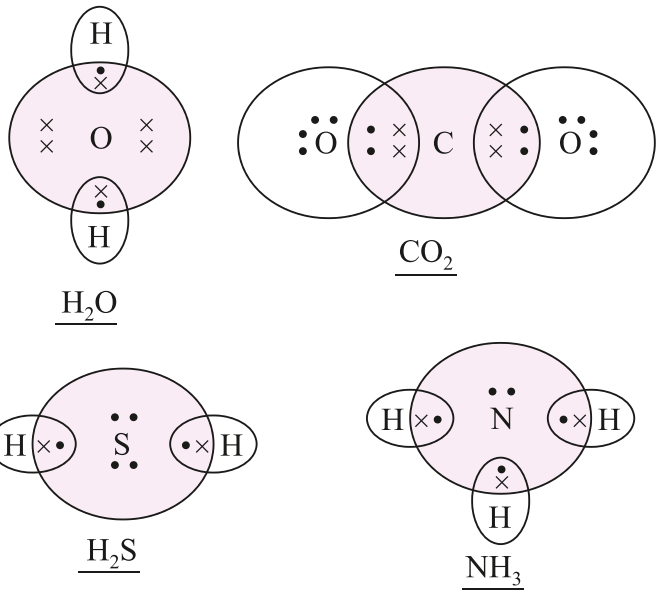


Double bond between two oxygen atoms

(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:

(i) **Diamond:** Each of the carbon atom is bonded to four other atoms of carbon.

(ii) **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.

(iii) **Fullerenes:** Smallest fullerene has 60 carbon atoms.

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

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

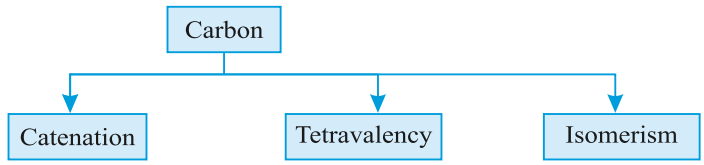
These allotropes have same chemical properties.

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 electrcity • It is opaque

VERSATILE NATURE OF CARBON ATOMS:

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

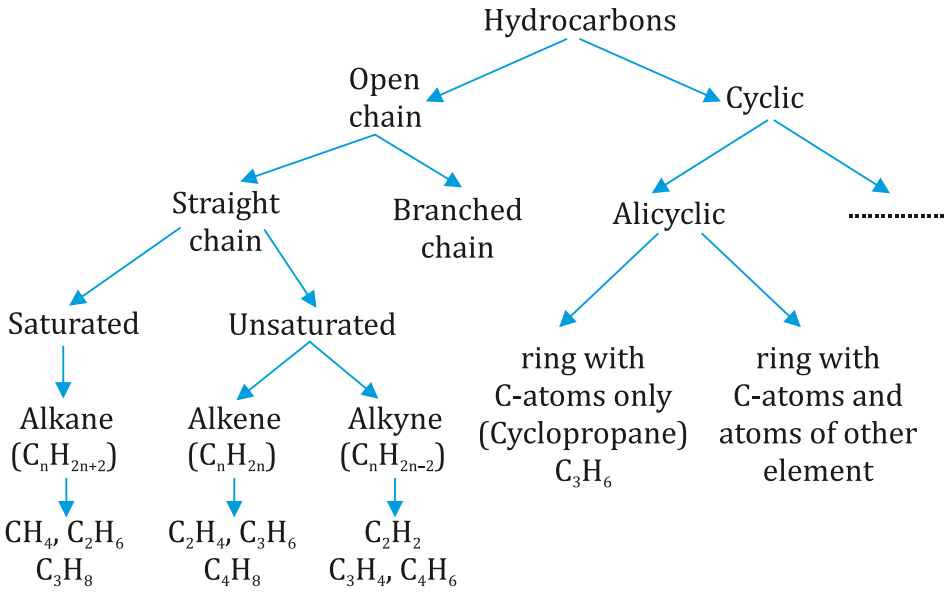


CATENATION: property of carbon atom to form bond with other atoms of carbon is called catenation. Like. carbon, silicon forms compounds with upto seven or eight atoms of silicon.

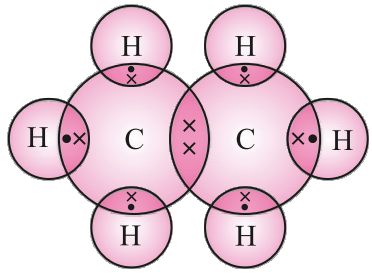
TETRAVALENCY: Having a valency of 4, carbon atom is capable of bonding with atoms of oxygen, hydrogen, nitrogen, sulphur, chlorine and other elements.

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

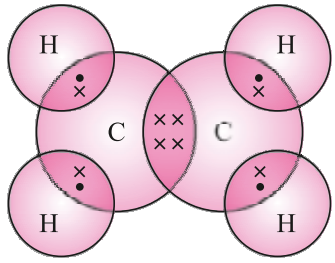
SATURATED AND UNSATURATED CARBON COMPOUNDS

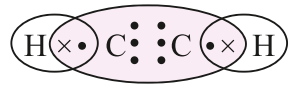


- To have a double/triple bond in chain, at least two carbon atoms are required. So, first member of alkene and alkyne have two-carbon atoms.
- Electron dot structure of a saturated carbon compound, ethane (C_2H_6):

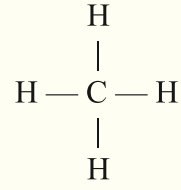
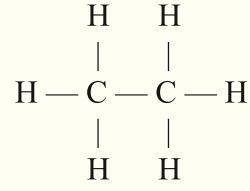
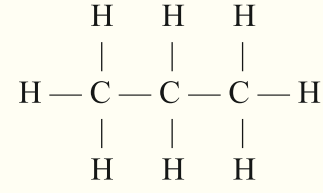
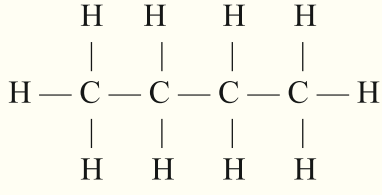


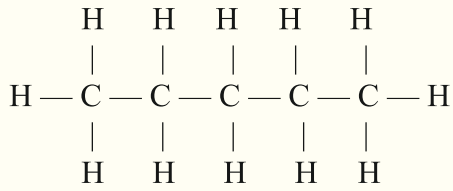
- Electron dot structure of an unsaturated carbon compound, ethene (C_2H_4) and ethyne (C_2H_2)

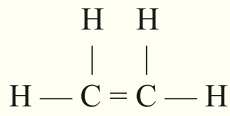
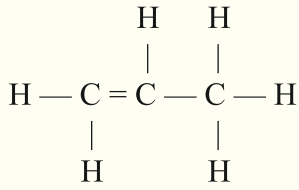
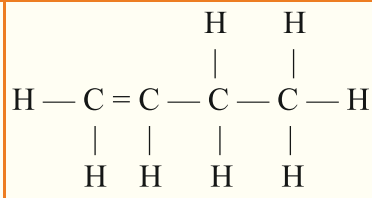
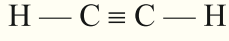
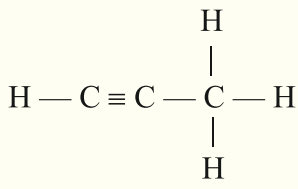
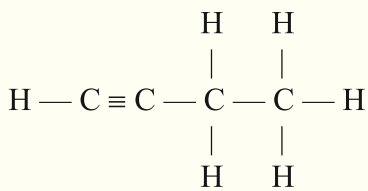




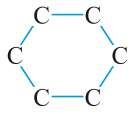
Formulae and structure of compounds of carbon and hydrogen

No. of carbon atoms	Name	Formula	Structure
1	**Alkanes:** Methane	CH_4	
2	Ethane	C_2H_6	
3.	Propane	C_3H_8	
4.	Butane	C_4H_{10}	

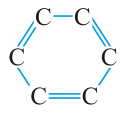
No. of carbon atoms	Name	Formula	Structure
5.	Pentane	C_5H_{12}	

Name of Hydrocarbon	Molecular formula	Structural Formula
Alkenes : 1. Ethene	C_2H_4	
2. Propene	C_3H_6	
3. Butene	C_4H_8	
Alkynes : 1. Ethyne	C_2H_2	
2. Propyne	C_3H_4	
3. Butyne	C_4H_6	

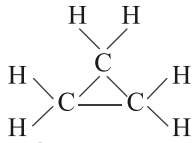
Cyclic structures:



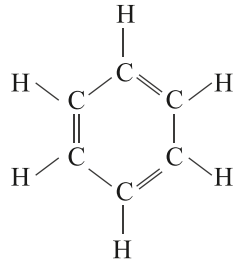
Cyclic Saturated



Cyclic unsaturated

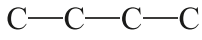


Cyclo-propane

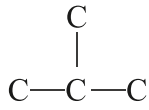


Benzene

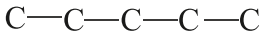
- **Structural isomers:** These are the compounds having identical molecular formula but different structures. Isomers of butane and pentane



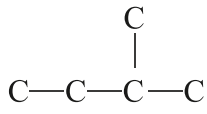
n-butane



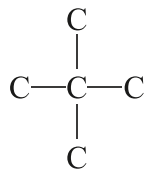
iso-butane



n-pentane



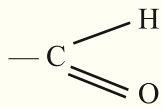
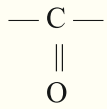
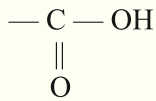
iso-pentane



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	 or — CHO
	3. Ketone	 or —CO—
	4. Carboxylic acid	 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, C_2H_5OH, C_3H_7OH, C_4H_9OH.
- The successive member differs by $-CH_2-$ 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.

$$CH_4 + 0_2 \longrightarrow CO_2 + H_2O + \text{heat and light}$$

* 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:

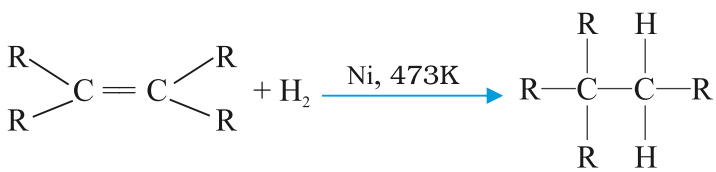
* Alcohols can be converted to caboxylic acids by oxidizing them using alkaline potassium permanganate or acidified poatassium dichromate (they add oxygen to the reactant, thus are called oxidizing agents)

$$CH_3CH_2OH + [O] \xrightarrow[\text{Alkaline } KMnO_4 + \text{heat}]{\text{Acidified } K_2Cr_2O_7} CH_3COOH + H_2O$$

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.

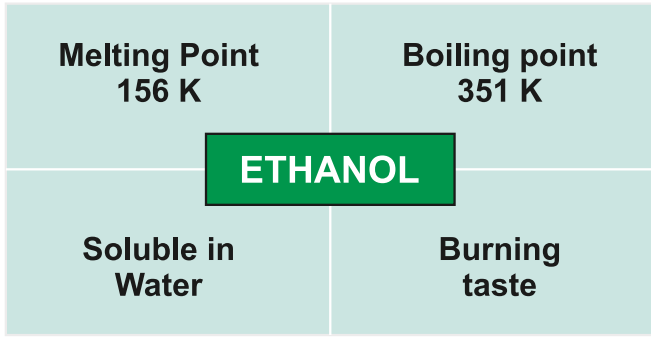
4. SUBSTITUTION REACTION:

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

$$CH_4 + Cl_2 \xrightarrow[\text{or } 520K]{\text{light}} CH_3Cl + HCl$$

IMPORTANT CARBON COMPOUNDS: ETHANOL AND ETHANOIC ACID

Ethanol:



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

Chemical properties of Ethanol

C_2H_5OH Reacts with sodium to form sodium ethoxide and hydrogen gas	When C_2H_5OH is heated with Concentrated sulphuric acid at 443 K, it is dehydrated to ethene

$$C_2H_5OH \xrightarrow{Na} C_2H_5ONa + H_2$$

$$C_2H_5OH \xrightarrow[\text{Dehydration}]{\text{conc. } H_2SO_4 \text{ at } 443K} C_2H_4 + H_2O$$

(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

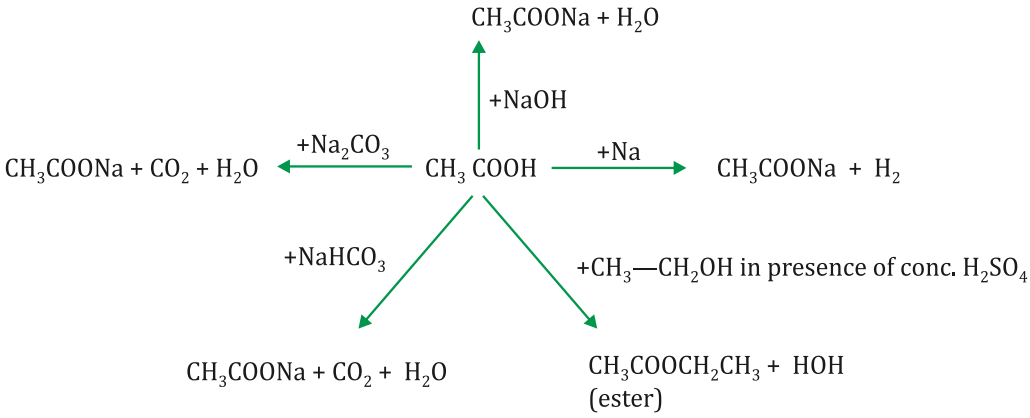
Freezes at 290 K	Boiling point 391 K
Ethanoic Acid	
Miscible in Water	Sour taste

* 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) $CH_3–CH_2OH$	• Ester and water



Esterification

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

$$RCO\boxed{OH} + \boxed{R'O}\boxed{H} \xrightarrow[H_2SO_4]{\text{conc.}} RCOOR' + H_2O$$

HYDROLYSIS

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

$$CH_3COOCH_2CH_3 + NaOH \longrightarrow CH_3COONa + CH_3—CH_2OH$$

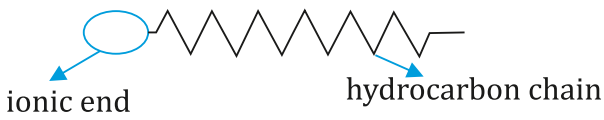
$$CH_3COOCH_2CH_3 \xrightarrow[\text{Heat}]{\text{Dil. } H_2SO_4} CH_3COOH + CH_3—CH_2OH$$

*Alkaline hydrolysis of ester is also called saponification.

SOAPS AND DETERGENTS

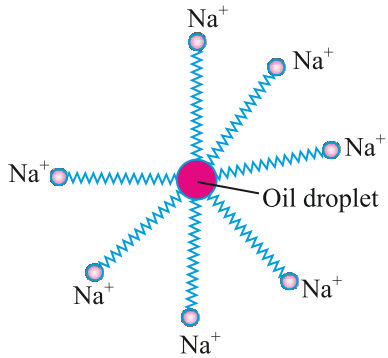
- Soap is sodium and potassium salt of carboxylic acids with long chain. ($C_{15}H_{31}COOH$), ($C_{17}H_{35}COOH$) (Palmitic acid, stearic acid)
- Soaps are effective with soft water only and ineffective with hard water.
- Detergents are ammonium or sulphonate salts of hydrocarbons with long chain,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

- An ionic part (hydrophillic) 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 result 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 reacts with soap molecule to form insoluble products called scum, thus obstructing the cleansing action. Use of detergents overcome 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 verstile 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 structual 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 react 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 cleanses with soft and hard water.

MULTIPLE CHOICE QUESTIONS

1. Which of the following metal is used as a catalyst in hydrogenation?
   a. Cu b. Ni
   c. Fe d. Na
2. The number of single bonds in hexane molecule are:
   a. 18 b. 19
   c. 20 d. 21
3. It is present in the molecule of N_2:
   a. Single bond b. Ionic bond
   c. double bond d. Triple bond

4. Which substance burns without producing flame?

a. Candle
b. Charcoal
c. Wood
d. LPG

5. It is a product of soap industry,

a. Glycerol
b. Glucose
c. Ester
d. Propanal

6. The third member of homologous series of alkyne is

a. Hexyne
b. Butyne
c. Propyne
d. Ethyne

7. Which of the following is used in cough syrups:

a. Sugar-methanol
b. Methanol
c. Ethanol-methanol
d. Sugar-ethanol

8. –CHO is :

a. Carboxylic acid
b. Ketone
c. Aldehyde
d. Alcohol

9 The molecular formula of benzene is:

a. C_6H_{12}
c. C_6H_{10}
b. C_6H_{14}
d. C_6H_6

10 Identify the false statements from the following:

i. Graphite is good conductor of electricity.
ii. Diamond melts at 373 K
iii. Alkaline $KMnO_4$ is a reducing agent
iv. Vegetable oil decolourise the bromine water solution.

a. i,iii
b. ii, iii
c. ii, iv
d. ii,iii,iv

11 Two compounds X and Y are added to acetic acid in two different test tubes(1 and 2). Carbon dioxide was formed only in test tube 2. Choose the correct option:

a. X-sodium hydroxide, Y- sodium bi carbonate
b. X- sodium bi carbonate, Y- sodium hydroxide

c. X-sodium hydroxide, y- sulphuric acid

d. X-sodium bi carbonate, Y-sulphuric acid

12 Which of the following can be used to test the presence of acetic acid

a. Sodium chloride
b. Sodium ethoxide
c. Sodium acetate
d. Sodium carbonate

13 Which of the following is generally correct about covalent compounds :

a. High melting point and low boiling point

b. Low melting point and low boiling point

c. Good conductor of electricity and low melting point

d. Water soluble and good conductor of electricity

14 Which element has twice as many electrons in its second shell as in its first shell?

a. Silicon
b. Boron
c. Carbon
d. Calcium

15 These two compounds produces ester.

a. Propanol and propanone
b. Propanol and propanoic acid
c. Propanol and propanal
d. Propanoic acid and propanal

MCQ correct options:

1	2	3	4	5	6	7	8
B	B	D	B	A	B	D	C
9	10	11	12	13	14	15	
D	B	A	D	B	C	B	

COMPETENCY BASED QUESTIONS:

Consumption of alcohol in large quantities slows down the metabolic processes and affects the central nervous system. It results in difficulties such as lack of coordination, mental confusions, drowsiness, lowering of normal inhibitions and finally stupor. Along with these harmful effects, ethanol is an important industrial solvent, it is used in different industries with water and with many organic solvents, including acetic acid,acetone, benzene, carbon tetrachloride. It is used as fuel in jet engines in countries like Brazil.

1. Identify the heteroatom in ethanol.
   a. Carbon b. Hydrogen
   c. Bromine d. Oxygen
2. Which acid is constituent of vinegar?
   a. Ethanoic acid b. Carbonic acid
   c. Oxalic acid d. Lactic acid
3. Complete the following chemical equation.
   $C_2H_5OH + CH_3COOH \xrightarrow{\text{conc. } H_2SO_4}$ _____ + _____
4. Draw the structure of ethanol molecule.
5. Describe the harmful effects of consuming alcohol?

VSA 1 MARK

1. How does an atom of carbon attain noble gas configuration?
2. Draw the electron dot structure of molecule of CCI_4
3. Define catenation.
4. The kerosene/gas stoves have inlets for air. Give reason.
5. Write only the balanced chemical equation for dehydration of ethanol by hot concentrated sulphuric acid.
6. Draw the structure for propyne.
7. Write the formula of first member of ketone.
8. What is an oxidising agent? Give example.
9. Which energy is used to convert methane into chloromethane?
10. Write a balanced chemical equation for burning of ethanol in oxygen.

In the following questions, two statements are given- one labeled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

(a) Both A and R are true, and R is correct explanation of the assertion.

(b) Both A and R are true, but R is not the correct explanation of the assertion.

(c) A is true, but R is false.

(d) A is false, but R is true.

1. ASSERTION: Butane is less reactive than butene.

   REASON: Presence of double bond increases the reactivity of molecule.

2. ASSERTION: Unsaturated hydrocarbons burn in air with blue flame.

   Reason: Incomplete combustion of hydrocarbons causes a yellow flame.

3. ASSERTION: Detergents are not environment-friendly.

   Reason: Detergents are not easily bio-degradable.

4. ASSERTION: Alkanes show addition reaction.

   Reason: Addition reaction is a charateristic property of unsaturated hydrocarbons.

5. ASSERTION: Pentane has three isomers.

   Reason: For structural isomerism hydrocarbons should have 4 or more carbon atoms.

2 Marks

1. Define saponification. Write a chemical equation for it.
2. Covalent compounds generally don't conduct electricity. Why?
3. Specify the condition due to which ethanol undergo oxidation to form ethanoic acid. Write the chemical equation.
4. Define structural isomerism. Draw the structures of two isomers of butane.
5. Identify the functional group in the following compounds, methanoic acid, methanal, bromo ethane and hexanol.
6. Why is ethanoic acid called as glacial acetic acid. Write the chemical equation for esterification.

7. Draw the structure of benzene.
8. Why are carboxylic acids known as weak acids? Name the alcohol which produces methanoic acid on oxidation.
9. A mixture of oxygen and ethyne is burnt for welding. Can you tell why a mixture of air and ethyne is not used?
10. (i) Which property of ethanol makes it suitable for making cough syrups and tincture iodine?

    (ii) What is the function of concentrated sulphuric acid in the formation of ethene from ethanol?

3 Marks

1. What is a homologous series? List any of its four features.
2. State any three charcteristics of structural isomers of any compound.
3. Propanal and propanone are structural isomers. Explain.
4. Explain why carbon atom is unable to form either cation or anion?
5. Describe substitution reaction with the help of an example.
6. Give a test that can be used to differentiate between saturated and unsaturated hydrocarbons.
7. Explain the formation of scum when hard water is treated with soap.
8. Distinguish between soap and detergent.
9. Describe the two properties of carbon which lead to the formation of huge number of compounds.

5 Marks

1. Explain the mechanism of the cleaning action of soaps with the help of diagram.
2. A neutral organic compound X of molecular formula C_2H_6O on oxidation with alkaline $KMnO_4$ gives compound Y. Compound X and Y react on warming in presence of concentrated sulphuric acid to produce a sweet smelling substance Z. Identify X,Y and Z. Also write the corresponding chemical equations.

HINT

1. Soap molecule structure, application on wet dirty cloth, micelles formation process, mechanical agitation, suitable diagrams
2. X- ethanol, Y- ethanoic acid, Z- ester ethyl ethanoate, chemical equations.