Chapter – 4

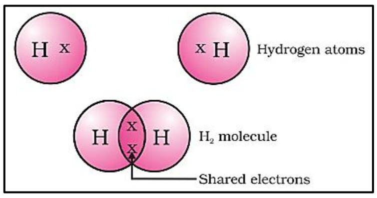
Carbon and Its Compounds

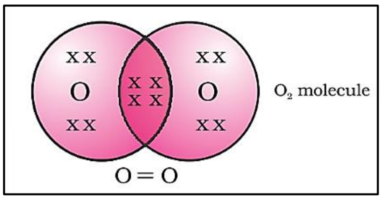
Introduction to Carbon

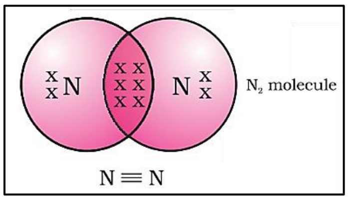
- Carbon is a **non-metal** element, symbol **C**, atomic number **6**.
- Electronic Configuration: **2, 4**
- Valence Electrons: It has **4 electrons** in its outermost shell.
- **Abundance:** Found in small amounts.
    - **Earth's Crust:** 0.02% (as minerals like carbonate, coal, petroleum)
    - **Atmosphere:** 0.03% (as CO_2)
    - Despite its low abundance, all living things (plants and animals) and most things we use (food, fuel, clothes, paper) are based on carbon.

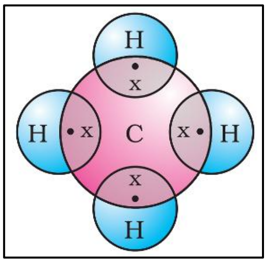
Bonding in Carbon: The Covalent Bond

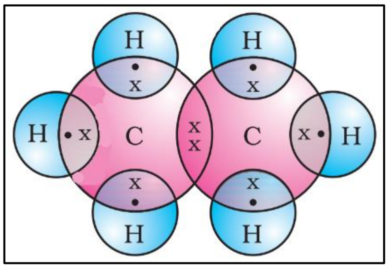
- **Covalent Bond:** A chemical bond formed by the **mutual sharing of electrons** between atoms of same or different elements.
- **Types of Covalent Bonds:**
    - **Single Bond:** Formed by sharing **1 pair** of electrons. Represented by a **single line** (—).
      Example: H_2, Cl_2, CH_4 (methane) etc.
    - **Double Bond:** Formed by sharing **2 pairs** of electrons. Represented by a **double line** (=).
      Example: O_2, C_2H_4 (ethene) etc.
    - **Triple Bond:** Formed by sharing **3 pairs** of electrons. Represented by a triple line (≡).
      Example: N_2, C_2H_2 (Ethyne) etc.

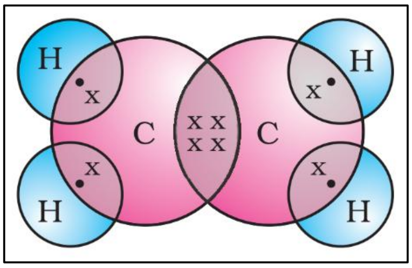










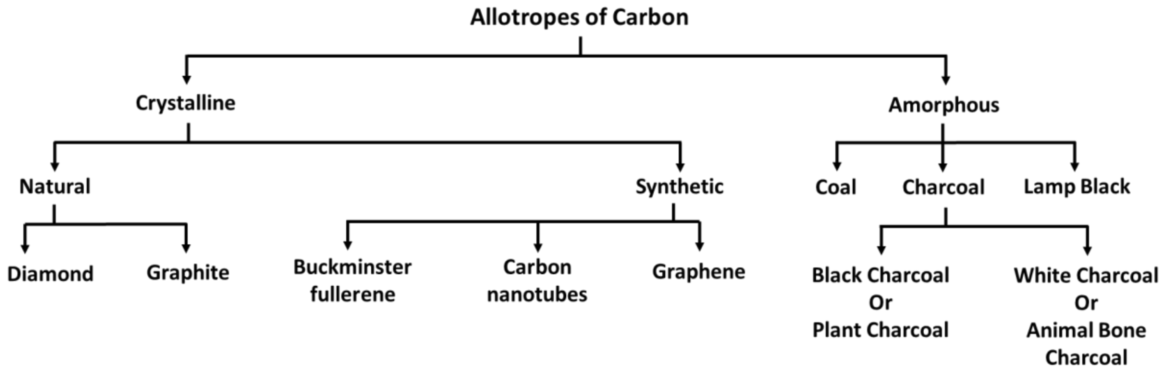


- Carbon has **4 electrons** in its valence shell; therefore, it can form **4 covalent bonds** and achieves a **stable noble gas configuration**.
- Covalently bonded molecules have **strong bonds within the molecule**, but have **weak intermolecular forces**.
    - This gives rise to the **low melting and boiling points** of these compounds.
    - Covalent compounds are generally **poor conductors of electricity**.

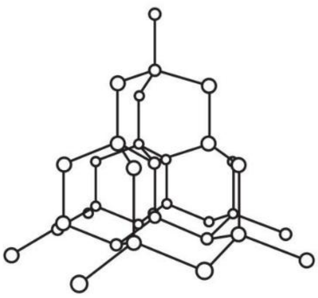
- **Why does Carbon form Covalent Bonds ?**
    - It **cannot lose 4 electrons** to form C^{+4} (cation) because it would require a **huge amount of energy**.
    - It **cannot gain 4 electrons** to form C^{-4} (anion) because its nucleus (with **6 protons**) cannot hold onto **10 electrons**.
    - Therefore, to **complete its octet**, carbon **mutually shares its 4 valence electrons** with the atoms of same or different elements. Hence, carbon forms **4 covalent bonds**.

Allotropes of Carbon

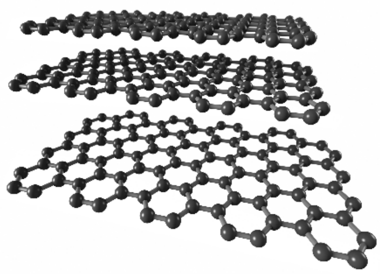
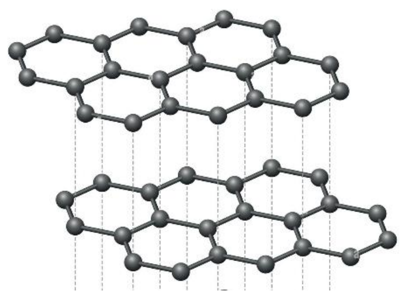
- **Allotropes** are *different **physical forms** of the **same element** that have **different physical properties** but **similar chemical properties***. These forms **arise due** to **different arrangements of atoms** in 3D space.
- **Allotropes of Carbon:** Diamond, Graphite, Fullerene, Carbon nanotubes Graphene, Coal, Lamp black etc.
- **Allotropes of Phosphorus:** Red phosphorus, White phosphorus, and Black phosphorus.



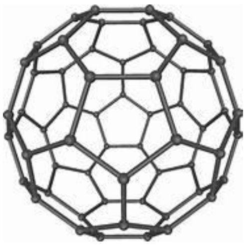
- **Diamond**
  - **Structure:**
    Each carbon atom is bonded to **four other carbon atoms**, forming a rigid **3D tetrahedral** structure. All **four valence electrons** of each carbon are involved in covalent bonding, leaving **no free electrons**.
  - **Properties:**
    - Diamond is the **hardest** natural substance known.
    - It is a **non-conductor of electricity** because it lacks free electrons.
    - Diamond is **transparent** and has a **high refractive index**, giving it brilliance.

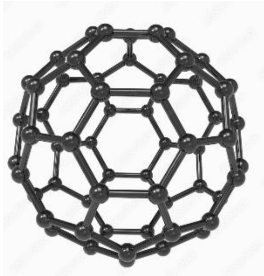


- **Graphite**
  - **Structure:**
    Each carbon atom is bonded to **three other carbon atoms** in same plane, **forming hexagonal rings.** These hexagonal rings combine to form **flat layers** (or sheets) that can **slide over one another** easily.
  - **Properties:**
    - Graphite is **soft and slippery** due to the **weak van der Waals forces** between its layers.
    - It is a **good conductor of electricity** because of the presence of **one free** (**delocalized**) **electron** per carbon atom.
    - Graphite is **opaque** and **black** in colour with a metallic lustre.

- **Fullerene (C-60)**
  - **60 carbon atoms** arranged in the shape of a **football** (pentagons and hexagons).
  - Since this looked like **the geodesic dome** designed by the US architect **Buckminster Fuller**, the molecule was named **fullerene**.





Practice Problems

1. What would be the electron dot structure of carbon dioxide which has the formula CO_2 ?
2. What would be the electron dot structure of a molecule of sulphur which is made up of eight atoms of sulphur? (**Hint** – The eight atoms of sulphur are joined together in the form of a ring.)
3. Draw the electron dot structures for:
   (a) ethanoic acid (b) H_2S (c) Propanone (d) F_2 (e) NH_3
   (f) $SiCl_4$ (g) PCl_3 (h) Formic acid
4. What will be the formula and electron dot structure of cyclopentane?
5. Define a covalent bond.
6. Why are covalent compounds generally poor conductors of electricity?
7. Distinguish between single, double, and triple covalent bonds with examples.
8. Write any two structural features of diamond.
9. Why can't carbon form C^{4+} or C^{4-} ions?
10. Explain why carbon forms covalent bonds instead of ionic bonds.
11. Why is graphite used as a lubricant in machines even though it is a solid?
12. Graphite conducts electricity but diamond does not. Explain why ?
13. Mention any two differences between the properties of covalent and ionic compounds.
14. Carbon shows a large number of compounds compared to other elements. Give two reasons for this property.

Versatile Nature of Carbon – Why does Carbon form so many compounds?

- Carbon forms millions of compounds due to **two** unique properties:
  - **Catenation (Self-linking property):**
    The unique ability of carbon to form **strong covalent bonds** with **other carbon atoms**, creating long chains, branched chains, and rings.
    Note
    No other element exhibits the property of catenation to the extent seen in carbon compounds. Silicon forms compounds with hydrogen which have chains of upto seven or eight atoms, but these compounds are very reactive.
  - **Tetravalency:**
    Carbon has a valency of **four** (means 4 electrons in valence shell).
    It can form **strong covalent bonds** with four other atoms (like C, H, O, N, S, Halogens).
- **Reason for Strong Bonds:**
  The **small size** of the carbon atom allows its nucleus to **hold the shared pairs of electrons** very strongly.

Hydrocarbons: Saturated and Unsaturated

- **Hydrocarbons:** The compounds made of only **Carbon (C)** and **Hydrogen (H)**.
- **Saturated Hydrocarbons (Alkanes):**
  - Hydrocarbons in which carbon atoms are linked to each other by only **single bonds**.
  - They have general formula: C_nH_{2n+2}
  - They are relatively **less reactive**.
  - The mainly undergo in **substitution reactions**.
  - **Example:** Methane, Ethane, Propane, Butane, Pentane, etc.
- **Unsaturated Hydrocarbons (Alkenes and Alkynes):**
  - Hydrocarbons that contain one or more **double** or **triple bonds** between carbon atoms.
  - They are **more reactive** than saturated hydrocarbons.
  - They mainly undergo in **addition reactions**.
  - **Alkenes:**
    - Contain at least one **double bond** between carbon atoms.
    - They have general formula: C_nH_{2n}
    - Example: Ethene, Propene, etc.
  - **Alkynes:**
    - Contain at least one **triple bond** between carbon atoms.
    - They have general formula: C_nH_{2n-2}
    - Example: Ethyne, Propyne, etc.

IUPAC Nomenclature of Carbon Compounds

Nomenclature

- **IUPAC Name**
  (IUPAC = International Union of Pure and Applied Chemistry)
  - **Prefix**
    - Primary Prefix
    - Secondary Prefix
  - **Word root**
  - **Suffix**
    - Primary Suffix
    - Secondary Suffix
- **Common Name**

IUPAC Name : 2° Prefix + 1° Prefix + Word Root + 1° Suffix + 2° Suffix

- **2° Prefix** → Side chain or Sub-functional groups

$-CH_3$	methyl
$-CH_2CH_3$	ethyl
–F	fluoro
–Cl	chloro
–Br	bromo
–I	iodo

- **1° Prefix** → Cyclic arrangement of Carbon chain → cyclo

- **Word Root** → Number of carbon atoms

C1 = Meth
C2 = Eth
C3 = Prop
C4 = But
C5 = Pent
C6 = Hex
C7 = Hept
C8 = Oct
C9 = Non
C10 = Dec

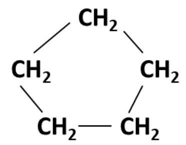
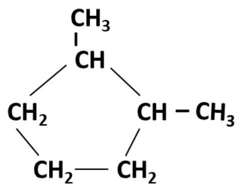
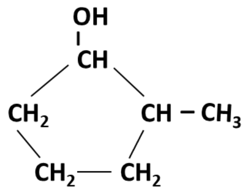
- **1° Suffix** → Linkage between carbon atoms

C – C	ane
C = C	ene
C ≡ C	yne

- **2° Suffix** → Main Functional groups

Carboxylic Acid	–COOH	oic acid
Aldehyde	–CHO	al
Ketone	–CO–	one
Alcohol	–OH	ol

- **Examples:**

Formula		IUPAC Name	Common Name
CH_4	Meth + ane	**Methane**	(Marsh gas)
$CH_3 – CH_3$	Eth + ane	**Ethane**	
$CH_2 = CH_2$	Eth + ene	**Ethene**	
$HC \equiv CH$	Eth + yne	**Ethyne**	
$CH_3 – CH_2 – CH = CH_2$	But + 1-ene	**But-1-ene**	
$CH_3 – CH = CH – CH_3$	But + 2-ene	**But-2-ene**	
$CH_3 – CHO$	Eth + ane + al	**Ethanal**	(Acetaldehyde)
$CH_3 – COOH$	Eth + ane + oic acid	**Ethanoic acid**	(Acetic Acid)
$CH_3 – CH_2 – OH$	Eth + ane + ol	**Ethanol**	(Ethyl alcohol)
$CH_3 – CO – CH_3$	Prop + ane + one	**Propanone**	(Acetone)
	Cyclo + pent + ane	**Cyclopentane**	
	1,2-Dimethyl + Cyclo + Pent + ane	**1,2-Dimethylcyclopentane**	
	2-Methyl + Cyclo + Pent + ane + ol	**2-Methylcyclopentanol**	

Isomers

- Compounds having the **same molecular formula** but **different structures**.
- **Examples:**
  - **Butane** (C_4H_{10}) has **two** chain isomers:

$CH_3 – CH_2 – CH_2 – CH_3$ (Butane)

$CH_3 – CH(CH_3) – CH_3$ (2-Methyl-propane)

  - **Pentane** (C_5H_{12}) has **three** chain isomers:

$CH_3 – CH_2 – CH_2 – CH_2 – CH_3$ (Pentane)

$CH_3 – CH(CH_3) – CH_2 – CH_3$ (2-Methyl-butane)

$CH_3 – C(CH_3)_2 – CH_3$ (2,2-Dimethyl-propane)

  - **Butene** (C_4H_8) has **two** position isomers:

$CH_3 – CH = CH – CH_3$ (But-2-ene)

$CH_3 – CH_2 – CH = CH_2$ (But-1-ene)

  - **Bromopentane** ($C_5H_{11}Br$) has **three** position isomers:

$CH_3 – CH_2 – CH_2 – CH_2 – CH_2 – Br$ (1-Bromo-pentane)

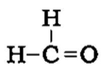
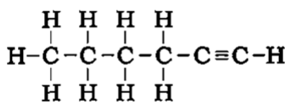
$CH_3 – CH_2 – CH_2 – CH(Br) – CH_3$ (2-Bromo-pentane)

$CH_3 – CH_2 – CH(Br) – CH_2 – CH_3$ (3-Bromo-pentane)

Homologous Series

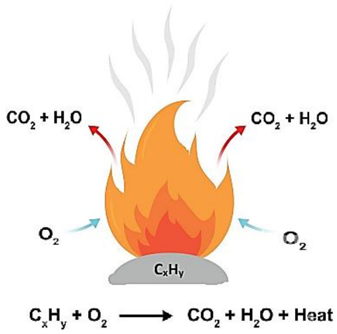
- A **homologous series** is a group of **organic compounds** having the **same functional groups**.
- **Characteristics of a Homologous Series:**
  - All members of the series have **similar chemical properties** because of the same functional group.
  - All members have the **same general formula**
    - Alkanes: $\mathbf{C_nH_{2n+2}}$, Alcohols : $\mathbf{C_nH_{2n+2}O_1}$, Carboxylic acids : $\mathbf{C_nH_{2n}O_2}$
  - Difference in molecular mass between **two consecutive members** is **14 u** (due to **one** $\mathbf{-CH_2-}$ unit).
  - They show a **gradual change in physical properties** (such as melting point, boiling point, and solubility) with **increasing molecular mass**.
    - Melting and boiling points generally increase with increasing molecular mass.
- **Examples:**
  - Members of **Alkane** homologous series are:
    - Methane, Ethane, Propane, Butane, Pentane, and so on.
  - Members of **Alkene** homologous series are:
    - Ethene, Propene, Butene, Pentene, and so on.
  - Members of **Alcohol** homologous series are:
    - Methanol, Ethanol, Propanol, Butanol, and so on.
  - Members of **Carboxylic acid** homologous series are:
    - Methanoic acid, Ethanoic acid, Propanoic acid, and so on.
  - Members of **Ketone** homologous series are:
    - Propanone, Butanone, Pentanone, and so on.

Practice Problems

1. How many structural isomers can you draw for pentane?
2. What are the two properties of carbon which lead to the huge number of carbon compounds we see around us?
3. Draw the structures for the following compounds.
   (i) Ethanoic acid (ii) Bromopentane* (iii) Butanone (iv) Hexanal.
   *Are structural isomers possible for bromopentane?
4. How would you name the following compounds?
   (i) $CH_3—CH_2—Br$ (ii)  (iii) 
5. Name the type of reaction shown by saturated hydrocarbons.
6. Write the molecular formula and IUPAC name of *marsh gas*.
7. Differentiate between saturated and unsaturated hydrocarbons (any two points).
8. Explain with examples the property of catenation in carbon. Why is this property not shown to the same extent by silicon?
9. Define homologous series. State any three characteristics of a homologous series.
10. Which hydrocarbon undergoes addition reactions — methane or ethene? Give reason.
11. What does the suffix '-ol' in a compound indicate? Give one example.
12. Name the functional group present in each of the following compounds:
    (a) CH_3COOH (b) CH_3CHO (c) CH_3COCH_3 (d) $CH_3CH_2CH_2OH$
13. How do position isomers differ from chain isomers? Explain with an example.
14. Write the structure and IUPAC name of second and third member of alkene and ketone homologous series.

Chemical Properties of Carbon Compounds

- **Combustion Reaction**
  - Burning a carbon compound in the **presence of oxygen** (O_2) to **produce CO_2, H_2O, heat, and light**.



  - **Types of Combustion Reaction:**
    - **Complete Combustion:**
      Saturated compounds generally burn with a **clean, blue flame** by giving **CO_2 and H_2O**.
      $CH_4 + O_2 \longrightarrow CO_2 + H_2O + Heat + Light$
      $CH_3CH_2OH + O_2 \longrightarrow CO_2 + H_2O + Heat + Light$
    - **Incomplete Combustion:**
      Unsaturated compounds generally burn with **yellow, sooty flame** by giving **CO_2, CO and H_2O**.
      $CH_2{=}CH_2 + O_2 \longrightarrow CO_2 + CO + H_2O + Heat + Light$
      $CH{\equiv}CH + O_2 \longrightarrow CO_2 + CO + H_2O + Heat + Light$

Note – 1

- **Fossil Fuels** such as **coal and petroleum** have some amount of **nitrogen and sulphur** in them.
- Their **combustion** results in the **formation of oxides of sulphur and nitrogen**, which are **major pollutants** in the environment.

Note – 2

- **Why Do Substances Burn With or Without a Flame?**
  - A **flame** is produced **only when gaseous substances burn.**
  - **Coal** or **charcoal** usually **glow red** and **give out heat** but **do not produce a flame** because they are **solid substances** and **do not vaporize easily.**
  - **Wood**, on the other hand, contains **volatile (easily vaporized) substances**. When wood starts burning, these volatile substances **vaporize** and **burn in the air**, producing a **flame**.
- **Luminous Flame**
  - A luminous flame is seen when **electrons of an atom are excited** by heating at a high temperature.
  - The **colour of the flame** depends on the **element** being heated.
  - **Example:** When a **copper wire** is heated in a gas flame, it emits a **bluish-green colour**.

Note – 3

- **Formation of Coal and Petroleum**
  - Both **coal** and **petroleum** were formed from **biomass**, i.e., remains of **plants and animals** that lived **millions of years ago**.
  - **Coal** was formed from the remains of **trees, ferns, and other plants** that grew in **swampy forests** millions of years ago. These remains were **buried under the earth** due to **natural forces** like **earthquakes or volcanic eruptions.** These remains **compressed and decomposed** slowly under **high temperature and pressure**. Over **millions of years**, this process converted plant material into **coal**.

- **Petroleum** and **natural gas** were formed from **microscopic plants and marine animals** that lived in **ancient seas**. After the death, bodies of marine animals **settled on the sea bed** and got **covered with layers of silt and sand. Bacteria** decomposed the organic matter **partially.** Over time, **heat and pressure** transformed the remains into **oil and natural gas.**

- **Oxidation Reaction**
  - It is the process of **addition of oxygen** to a substance.
  - **Alcohols** can be oxidized to **Carboxylic Acids** using **oxidizing agents**.

$$\underset{\text{Ethanol}}{CH_3 - CH_2 - OH} \xrightarrow[K_2Cr_2O_7\ /\ H_2SO_4,\ 373\ K]{KMnO_4\ /\ KOH} \underset{\text{Ethanoic acid}}{CH_3 - COOH}$$

  - **Oxidizing Agents:**
    Alkaline **$KMnO_4$** (Potassium Permanganate) or Acidified **$K_2Cr_2O_7$** (Potassium Dichromate).

- **Addition Reaction**
  - It is a type of chemical reaction in which **unsaturated hydrocarbons** (such as alkenes and alkynes) **add atoms of other elements** (like hydrogen, halogens, etc.) **across their multiple bonds**.
  - **<u>Hydrogenation of Unsaturated Hydrocarbons:</u>**
    Unsaturated hydrocarbons (such as alkene and alkynes) **add hydrogen (H_2)** in the presence of **catalysts** such as palladium **(Pd)**, platinum **(Pt)**, or nickel **(Ni)** to form **saturated hydrocarbons**.

1.) $$\underset{\text{Ethene}}{CH_2 = CH_2} + H_2 \xrightarrow[573\ K]{Ni,\ Pt\ or\ Pd} \underset{\text{Ethane}}{CH_3 - CH_3}$$

2.) $$\underset{\text{Ethyne}}{CH \equiv CH} + 2H_2 \xrightarrow[573\ K]{Ni,\ Pt\ or\ Pd} \underset{\text{Ethane}}{CH_3 - CH_3}$$

3.) $$\text{Vegetable Oil} + nH_2 \xrightarrow[573\ K]{Ni,\ Pt\ or\ Pd} \text{Vanaspati Ghee}$$

- **<u>Role of Catalyst:</u>**
  Catalysts are substances that **increase the rate** of a chemical reaction **without undergoing any permanent chemical change** themselves.
- **<u>Health Aspect:</u>**
  Vegetable oils contain **unsaturated fatty acids**, which are considered ***healthy*** for the heart. **Animal fats**, on the other hand, contain **saturated fatty acids**, which can **increase cholesterol** levels and are ***less healthy***.
  Therefore, **oils rich in unsaturated fatty acids** are recommended for cooking.

  - **<u>Halogenation of Unsaturated Hydrocarbons:</u>**
    The addition of **halogen molecules** (like chlorine or bromine) to **unsaturated hydrocarbons** (alkenes or alkynes) **across the double or triple bond**.

1.) $$\underset{\text{Ethene}}{CH_2 = CH_2} + Br_2 \xrightarrow{CCl_4} \underset{\text{1,2-Dibromoethane}}{\overset{Br\quad\ Br}{CH_2 - CH_2}}$$

2.) $$\underset{\text{Ethyne}}{CH \equiv CH} + 2Br_2 \xrightarrow{CCl_4} \underset{\text{1,1,2,2-Tetrabromoethane}}{\underset{Br\quad Br}{\overset{Br\quad Br}{CH - CH}}}$$

- **Observation:**
  The **reddish-brown** colour of bromine **disappears**, indicating the **presence of unsaturation**.
- **Use:**
  This reaction is commonly used as a **test for unsaturation** in organic compounds.

- **Substitution Reaction**
  - **Saturated hydrocarbons** (alkanes) are generally **unreactive** under normal conditions.
  - However, in the **presence of sunlight** (UV light), they react with **chlorine (Cl_2)** or **bromine (Br_2)**.
  - During the reaction **one or more hydrogen atoms** of saturated hydrocarbon are replaced by **halogen atoms**.

$$\underset{\text{Methane}}{CH_4} + Cl_2 \xrightarrow{\text{Sunlight}} \underset{\text{Chloromethane}}{CH_3-Cl} + HCl$$

Further substitution can produce **CH_2Cl_2**, **$CHCl_3$**, and **CCl_4**

$$\underset{\text{Chloro-methane}}{CH_3Cl} + Cl_2 \xrightarrow[-HCl]{\text{Sunlight}} \underset{\text{Dichloro-methane}}{CH_2Cl_2} \xrightarrow[Cl_2,\ -HCl]{\text{Sunlight}} \underset{\text{Trichloro-methane (Chloroform)}}{CHCl_3} \xrightarrow[Cl_2,\ -HCl]{\text{Sunlight}} \underset{\text{Carbon tetrachloride}}{CCl_4}$$

- **Elimination Reaction**
  - **Dehydration of Alcohol:**
    - When **ethanol** (C_2H_5OH) is heated at **443 K** with **excess concentrated sulphuric acid (H_2SO_4)**, it undergoes **dehydration** (loss of water) to form **ethene (C_2H_4)**.

$$\underset{\text{Ethanol}}{\overset{\beta}{C}H_2(H)-\overset{\alpha}{C}H_2(OH)} \xrightarrow[443\ K]{\text{Conc } H_2SO_4} \underset{\text{Ethene}}{CH_2=CH_2} + H_2O$$

    - **Concentrated H_2SO_4** acts as a **dehydrating agent**, meaning it removes a molecule of H_2O from ethanol.

Practice Problems

1. Why is the conversion of ethanol to ethanoic acid an oxidation reaction?
2. A mixture of oxygen and ethyne is burnt for welding. Can you tell why a mixture of ethyne and air is not used?
3. Why are carbon and its compounds used as fuels for most applications?
4. What is hydrogenation? What is its industrial application?
5. Which of the following hydrocarbons undergo addition reactions: C_2H_6, C_3H_8, C_3H_6, C_2H_2 and CH_4.
6. Give a test that can be used to differentiate between saturated and unsaturated hydrocarbons.
7. Oils on treating with hydrogen in the presence of palladium or nickel catalyst form fats. This is an example of _________________ .
8. Chlorine reacts with saturated hydrocarbons at room temperature in the presence _____________ .
9. Unsaturated hydrocarbons contain multiple bonds between the two C-atoms and show addition reactions. Give the test to distinguish ethane from ethene.
10. Ethene is formed when ethanol at 443 K is heated with excess of concentrated sulphuric acid. What is the role of sulphuric acid in this reaction? Write the balanced chemical equation of this reaction.

11. Name the reaction which is commonly used in the conversion of vegetable oils to fats. Explain the reaction involved in detail.
12. Write the formula and draw electron dot structure of carbon tetrachloride.
13. How would you bring about the following conversions? Name the process and write the reaction involved. (a) ethanol to ethene. (b) propanol to propanoic acid.
14. Draw the possible isomers of the compound with molecular formula C_3H_6O and also give their electron dot structures.
15. Explain the given reactions with the examples:
    (a) Hydrogenation reaction (b) Oxidation reaction (c) Substitution reaction (d) Combustion reaction
16. An organic compound A on heating with concentrated H_2SO_4 forms a compound B which on addition of one mole of hydrogen in presence of Ni forms a compound C. One mole of compound C on combustion forms two moles of CO_2 and 3 moles of H_2O. Identify the compounds A, B and C and write the chemical equations of the reactions involved.

Important Carbon Compounds – Ethanol and Ethanoic acid

- **Ethanol (C_2H_5OH) and Its Properties**
  - **Properties and Uses**
    - Ethanol is a **liquid** at room temperature.
    - It has a low boiling point of around **351 K (78°C)**.
    - It is the **active ingredient** in **alcoholic beverages** (wine, rum, etc.).
    - **Completely miscible with water** (soluble in all proportions).
    - Used as a **solvent** in medicines such as **tincture iodine**, **cough syrups**, and **tonics**.
    - Used in preparation of **acetic acid**.

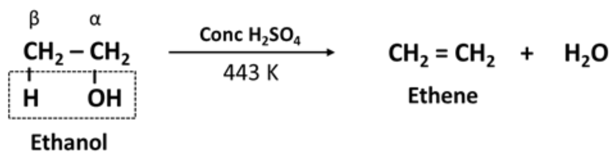
  - **Effect on Health**
    - Small quantities of dilute ethanol cause **drunkenness**.
    - **Pure (absolute) ethanol** is **highly toxic** and can be **lethal** even in small amounts.
    - **Long-term consumption** leads to **liver damage**, **nervous system disorders**, and other **health issues**.

  - **Reactions of Ethanol**
    - **Reaction with Sodium (Na):**
      - When sodium metal is added to ethanol, **hydrogen gas** is evolved.

$$\underset{\text{Ethanol}}{2CH_3CH_2\text{–}OH} + \underset{\text{Sodium}}{2Na} \longrightarrow \underset{\text{Sodium ethoxide}}{2CH_3CH_2\text{–}ONa} + \underset{\text{Hydrogen}}{H_2}$$

      - **Products** formed during the reaction are **sodium ethoxide** and **hydrogen gas**.

    - **Dehydration Reaction (Reaction with hot concentrated H_2SO_4):**
      - When ethanol is **heated at 443 K** with **excess concentrated sulphuric acid**, it undergoes **dehydration** to form **ethene** (unsaturated hydrocarbon).



      - **Concentrated H_2SO_4** acts as a **dehydrating agent**, meaning it removes a molecule of H_2O from ethanol.

Note -1 :

Effect of Methanol on living beings

- **Highly poisonous** even in small quantities.
- Oxidized in the liver to **methanal (formaldehyde)** and **methanoic acid (formic acid)** causing **damages the optic nerve**, leading to **permanent blindness** or **death**.

Note-2 :

Denatured Alcohol

Industrial ethanol is made **unfit for drinking** by adding **methanol** and **dyes** (blue colour). This process is called **denaturation**.

Note-3 :

Alcohol as a Fuel

- Ethanol is a **clean fuel** that produces only **CO_2 and H_2O** on burning in air.
- It can be used as an **additive** to **petrol** to reduce pollution.
- Many countries use **ethanol-blended fuels** to promote **environmentally friendly energy sources**.
- Ethanol can be obtained by **fermentation of molasses**, a by-product of **sugarcane juice**.

- ## Ethanoic acid (CH_3COOH) and Its Properties
  - ### Properties and Uses
    - **Ethanoic acid** (CH_3COOH) is commonly known as **acetic acid**.
    - It has a **strong pungent smell** and **sour taste**.
    - It is **soluble in water** due to **hydrogen bonding**.
    - It is **liquid** at room temperature with **melting point of 17 ℃**, hence, pure ethanoic acid **solidifies easily** in cold climates and is called **glacial acetic acid**. It has **boiling point 118 ℃.**
    - Ethanoic acid is a **weak acid** — it **partially ionizes in water** to produce hydrogen ions (H^+).
    - Due to **acidic nature**, ethanoic acid turns **blue litmus red**.
    - A **5–8% aqueous solution** of ethanoic acid is called **vinegar**, which is widely used as a **food preservative** (especially in pickles).
    - It is used in **manufacture of esters**.
    - It is used in **textile and plastic industries**.
  - ### Reactions of Ethanoic Acid
    - **Reaction with Bases or Alkali (Neutralization Reaction):**
      - Ethanoic acid reacts with **sodium hydroxide** (NaOH) to form a **salt** (**sodium ethanoate**) and **water**:

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

.

    - **Reaction with Carbonates and Hydrogencarbonates:**
      - Ethanoic acid reacts with **sodium carbonate** and **sodium hydrogencarbonate** to form a **salt (sodium ethanoate)**, **carbon dioxide**, and **water**.

$$\underset{\text{Ethanoic acid}}{2CH_3COOH} + \underset{\text{Sodium carbonate}}{Na_2CO_3} \longrightarrow \underset{\text{Sodium ethanoate}}{2CH_3COONa} + CO_2 + H_2O$$

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Sodium bicarbonate}}{NaHCO_3} \longrightarrow \underset{\text{Sodium ethanoate}}{CH_3COONa} + CO_2 + H_2O$$

- During reaction an **effervescence is observed** due to the **evolution of CO_2 gas**.
- Evolution of CO_2 can be confirmed by **passing the gas** through **lime water**, it will turn **lime water milky**.

▪ **Reaction with Sodium (Na):**

- When sodium metal is added to ethanoic acid, **hydrogen gas** is evolved.

$$\underset{\text{Ethanoic acid}}{2CH_3COOH} + \underset{\text{Sodium}}{2Na} \longrightarrow \underset{\text{Sodium acetate}}{2CH_3COONa} + \underset{\text{Hydrogen}}{H_2}$$

- **Products** formed during the reaction are **sodium acetate** and **hydrogen gas**.
- This reaction is **used in laboratories** to demonstrate **acidic nature** of carboxylic acids.

▪ **Reaction with ethanol (Esterification Reaction):**

- Ethanoic acid reacts with ethanol in the presence of **concentrated sulphuric acid** (a dehydrating agent) to form **esters**.

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Ethanol}}{CH_3CH_2{-}OH} \xrightarrow{\text{Conc. } H_2SO_4\text{, Heat}} \underset{\text{Ethyl ethanoate (ester)}}{CH_3COOCH_2CH_3} + H_2O$$

- Esters are **sweet-smelling** substances used in **perfumes and flavouring agents**

Note :

Saponification:

It is the process in which **esters** react with an **alkali (base)** such as sodium hydroxide **(NaOH)** or potassium hydroxide **(KOH)** to produce **soap** and **alcohol**.

$$\text{Ester} + \text{Alkali} \longrightarrow \text{Salt of fatty acid (soap)} + \text{Alcohol}$$

Example 1:

$$\underset{\substack{\text{Ethyl ethanoate}\\ \text{(Ester)}}}{CH_3COOCH_2CH_3} + \underset{\substack{\text{Sodium hydroxide}\\ \text{(Alkali)}}}{NaOH} \longrightarrow \underset{\substack{\text{Sodium ethanoate}\\ \text{(Soap)}}}{CH_3COONa} + \underset{\substack{\text{Ethanol}\\ \text{(Alcohol)}}}{CH_3CH_2{-}OH}$$

Example 2:

$$\underset{\text{Vegetable Oil}}{\begin{matrix} CH_2-OOC-C_{17}H_{35} \\ | \\ CH-OOC-C_{17}H_{35} \\ | \\ CH_2-OOC-C_{17}H_{35} \end{matrix}} + 3\,NaOH \xrightarrow{\text{Heat}} \underset{\text{Glycerol}}{\begin{matrix} CH_2{-}OH \\ | \\ CH{-}OH \\ | \\ CH_2{-}OH \end{matrix}} + \underset{\substack{\text{Sodium salt of fatty acid}\\ \text{(Soap)}}}{3\,C_{17}H_{35}COONa}$$

- **Vegetable oils** (like coconut oil, castor oil, palm oil, sunflower oil) are **natural esters of fatty acids** and **glycerol**.
- When treated with **NaOH or KOH**, these oils undergo **saponification** to form **soap** (sodium or potassium salt of fatty acids) and **glycerol**.

Practice Problems

1. How would you distinguish experimentally between an alcohol and a carboxylic acid?
2. Intake of small quantity of methanol can be lethal. Comment.
3. How is ethene prepared from ethanol? Give the reaction involved in it.
4. A compound 'X' is formed by the reaction of a carboxylic acid $C_2H_4O_2$ and an alcohol in presence of a few drops of H_2SO_4. The alcohol on oxidation with alkaline $KMnO_4$ followed by acidification gives the same carboxylic acid as used in this reaction. Give the names and structures of (a) carboxylic acid, (b) alcohol and (c) the compound 'X'. Also write the reaction.
5. A gas is evolved when ethanol reacts with sodium. Name the gas evolved and also write the balanced chemical equation of the reaction involved.
6. What is saponification? Write the reaction involved in this process.
7. A salt 'X' is formed and a gas is evolved when ethanoic acid reacts with sodium hydrogencarbonate. Name the salt 'X' and the gas evolved. Describe an activity and draw the diagram of the apparatus to prove that the evolved gas is the one which you have named. Also, write chemical equation of the reaction involved.
8. Esters are sweet-smelling substances and are used in making perfumes. Suggest some activity and the reaction involved for the preparation of an ester with well labeled diagram.
9. A compound 'C' (molecular formula, $C_2H_4O_2$) reacts with Na - metal to form a compound 'R' and evolves a gas which burns with a pop sound. Compound 'C' on treatment with an alcohol 'A' in presence of an acid forms a sweet-smelling compound 'S' (molecular formula, $C_3H_6O_2$). On addition of NaOH to 'C', it also gives 'R' and water. Compound 'S' on treatment with NaOH solution gives back 'R' and 'A'. Identify C, R, A, S and write down the reactions involved.
10. How would you bring about the following conversions? Name the process and write the reaction involved. (a) ethanol to ethene. (b) propanol to propanoic acid. Write the reactions.
11. An organic compound 'A' on heating with concentrated H_2SO_4 forms a compound 'B' which on addition of one mole of hydrogen in presence of Ni forms a compound 'C'. One mole of compound 'C' on combustion forms two moles of CO_2 and 3 moles of H_2O. Identify the compounds A, B and C and write the chemical equations of the reactions involved.

Soaps and Detergents

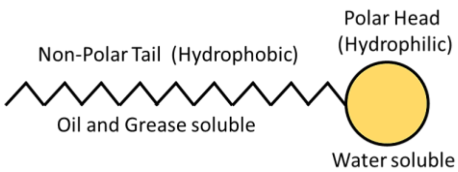
- **Chemical Nature:**
  - **Soaps** are the **Sodium (Na)** or **Potassium (K) salts** of long-chain **carboxylic acids** (fatty acids).

$$CH_3 - (CH_2)_{16} - COO^- \, Na^+ \quad \text{or} \quad CH_3 - (CH_2)_{16} - COO^- \, K^+$$

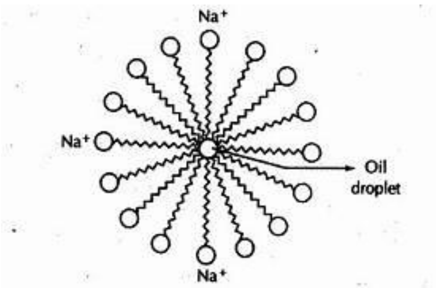
  - **Detergents** are generally the **sodium salts** of long-chain **sulphonic acids** or ammonium salts.

$$CH_3 - (CH_2)_{11} - OSO_3^- \, Na^+$$

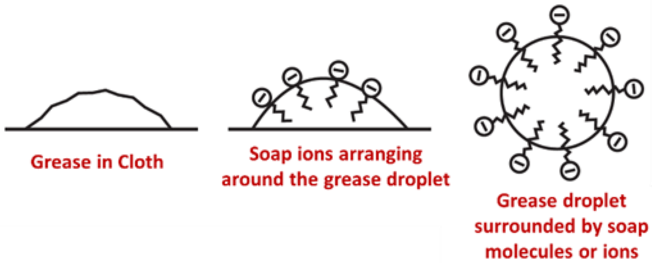
- **Similarities:**
  - Both **soap and detergent** molecules have **two distinct parts**:
    - **Hydrophilic Head (Water-loving):** It is the **ionic or** polar part that **interacts with water**. It is **$-COO^-Na^+$ in soaps** while **$-OSO_3^-Na^+$ in detergents**.
    - **Hydrophobic Tail (Water-hating):** It is **non-polar part** that **interacts with oil and grease**. It is consists of a **long hydrocarbon chain**.



- **Cleansing Action (Micelle Formation):**
  - When soap or detergent are **dissolved in H_2O**, their molecules **form clusters** called **micelles**.
  - In a micelle:
    - The **hydrophobic tails** point **inwards**, trapping the **oily dirt**.
    - The **hydrophilic heads** face **outwards**, interacting with **the water**.
  - This forms an **emulsion**, which **lifts the oily dirt** from the surface of clothes and allows it to be **rinsed away** along with water.



Micelle



- **Problem with Soaps in Hard water**
  - **Hard water** (such as river or lake water) contains **dissolved salts of calcium (Ca^{2+})** and **magnesium (Mg^{2+})** ions. These ions interfere with the cleaning action of soaps.
  - When **soap** is added to **hard water**, it reacts with **Ca^{2+}** and **Mg^{2+}** ions to form **insoluble precipitates** called **scum**.
  - Therefore, Soap **cannot form lather (foam)** in hard water and **loses its cleansing power**.

$$\underset{\text{Soap}}{2C_{17}H_{35}COONa} + \underset{\substack{\text{Calcium ion} \\ \text{(from Hard water)}}}{Ca^{+2}} \longrightarrow \underset{\substack{\text{Insoluble ppt} \\ \text{(Scum)}}}{(C_{17}H_{35}COO)_2Ca} + 2Na^+$$

Note-1 :

- **Detergents** do **not form insoluble precipitates** (scum) with **Ca^{2+}** and **Mg^{2+}** ions in hard water.
- Therefore, they can **form lather (foam)** and **retain their cleansing power** even in hard water.
- However, **most detergents** are **non-biodegradable**, which causes **environmental pollution**.

Practice Problems

1. Would you be able to check if water is hard by using a detergent?
2. People use a variety of methods to wash clothes. Usually after adding the soap, they 'beat' the clothes on a stone, or beat it with a paddle, scrub with a brush or the mixture is agitated in a washing machine. Why is agitation necessary to get clean clothes?
3. Explain the mechanism of the cleaning action of soaps.
4. Explain the formation of scum when hard water is treated with soap.
5. Why does micelle formation take place when soap is added to water? Will a micelle be formed in other solvents such as ethanol also?
6. What are soaps chemically made of?
7. What type of salts are detergents made from?
8. Why do soaps not work well in hard water?
9. Explain why detergents are effective even in hard water.
10. What is a micelle? Describe its structure briefly.
11. Discuss one advantage and one disadvantage of using detergents instead of soaps.