

# Unit 1 Chemical Substances: Nature & Behaviour



## Chapter 4:

# Carbon & Its Compound

→ **Carbon** - The atomic number of carbon is 6. Carbon attains stability when it has 4 electrons in its outermost shell. While it is theoretically possible for carbon to gain four electrons and form a carbon anion, the process of removing electrons poses significant energy challenges. The gain or loss of electrons profoundly influences the formation of chemical bonds in compounds.

## → What is Covalent Bond?

- Carbon solves this issue by sharing its outer electrons with other carbon atoms.
- This sharing facilitates both atoms in achieving a stable electron configuration to noble gases.
- This sharing of electrons is termed as **covalent bonding**.

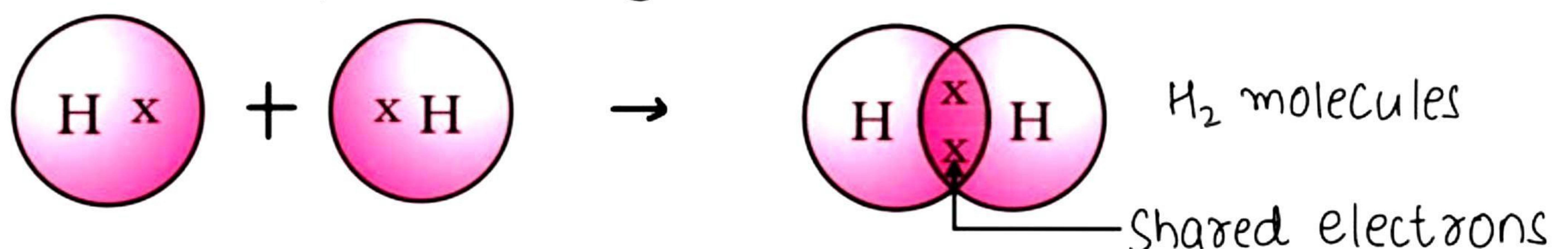
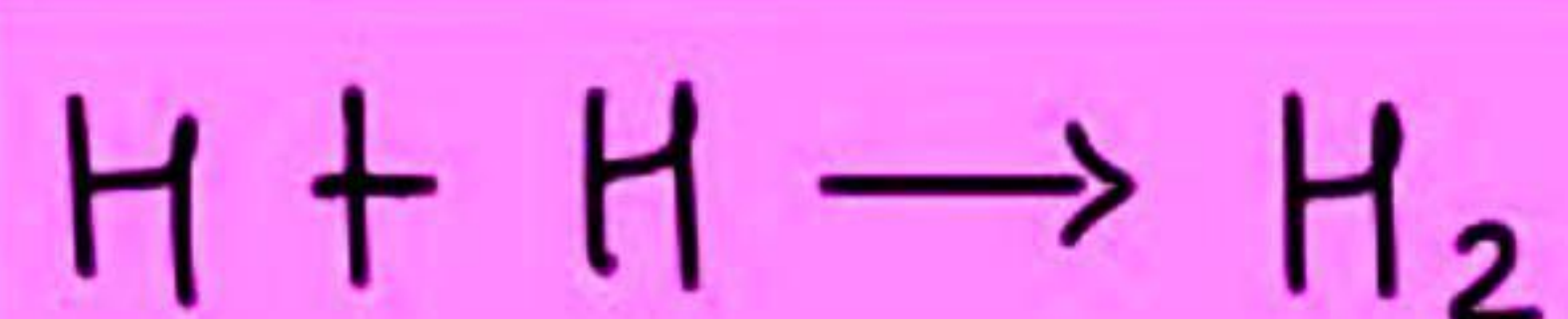
## → Covalent Bond

### 📌 Formation of hydrogen molecule:

The formation of a hydrogen molecule ( $H_2$ ) occurs as two hydrogen atoms approach each other closely.

In this process

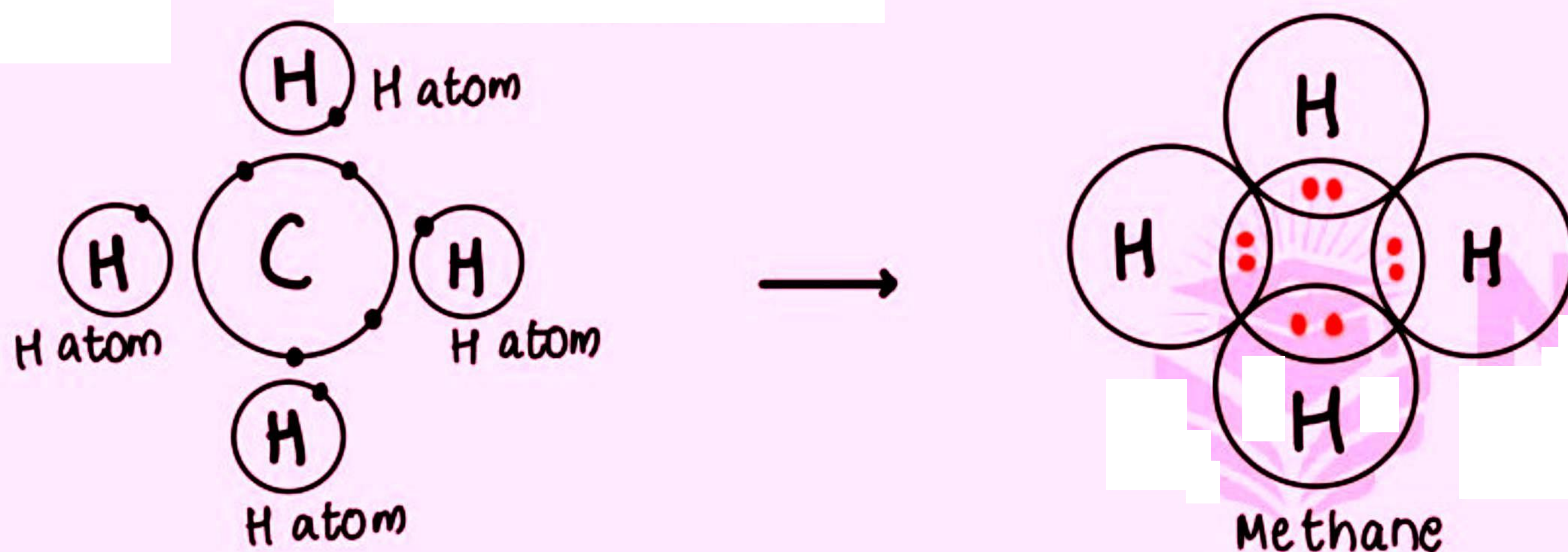
- Each hydrogen atom shares its electron with the other, establishing a covalent bond.
- This sharing enables both atoms to fulfill their outer electron shells, achieving stability.
- The chemical equation representing this process is





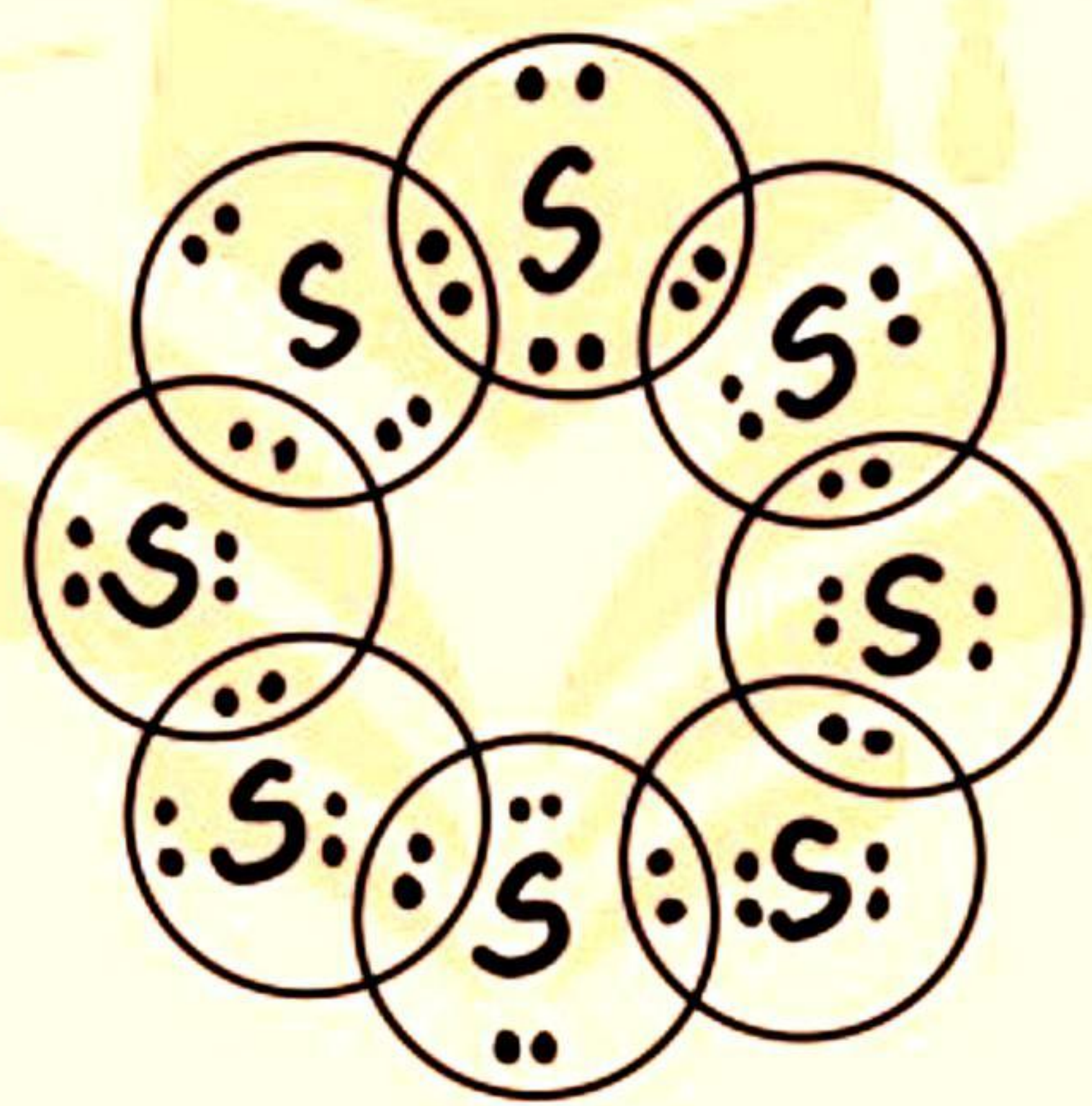
### Formation of Methane (CH<sub>4</sub>)

The formation of methane (CH<sub>4</sub>) occurs when one carbon atom combines with four hydrogen atoms. This process can be represented by the chemical equation  $C + 2H_2 \rightarrow CH_4$ . This equation signifies the combination of carbon and hydrogen to produce methane.

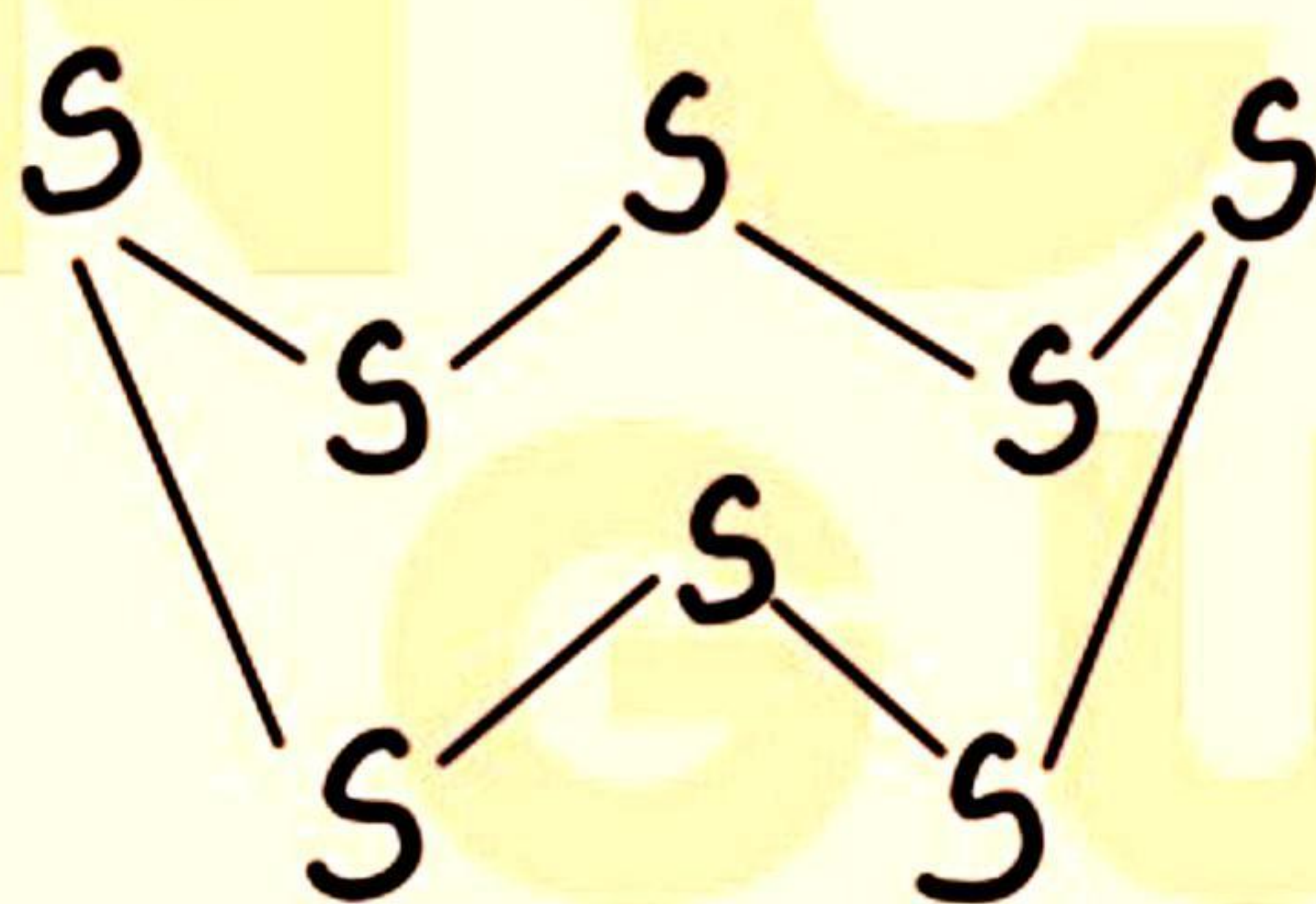


### Formation of Sulphur (S<sub>8</sub>)

Elemental Sulfur forms (S<sub>8</sub>) molecules through heating Sulfur powder. (S<sub>8</sub>) is a yellow solid, insoluble in water but soluble in nonpolar solvents and chemically reactive, used in various industrial processes and important in biological systems.



Ring structure of S<sub>8</sub> molecule



Crown shape of S<sub>8</sub> molecule

### Properties of Covalent Bond

- Covalent compounds have low melting and boiling points due to weak intermolecular forces.
- Molecules in covalent compounds are held together by weak forces.
- Covalent bonding involves electron sharing between atoms.
- Unlike ionic compounds, covalent compounds don't yield charged particles, electrons are shared, not transferred.

### Versatile Nature of Carbon

- Carbon's **tetravalency** enables diverse molecular structure by forming four covalent bonds.
- Exceptional **catenation** allows carbon to form long chains, branched

Structures, or closed rings, enriching molecule diversity.

- Carbon's **allotropy** yields unique forms like diamond, graphite, graphene, fullerenes and carbon nanotubes each with distinct properties and broad applications.
- **Isomerism** carbon compounds exhibit isomerism, with molecules sharing the same formula but differing in structure.
- **Polymerization** carbon's role in polymer formation yields a variety of synthetic materials with broad applications.

## ALLOTROPE OF CARBON

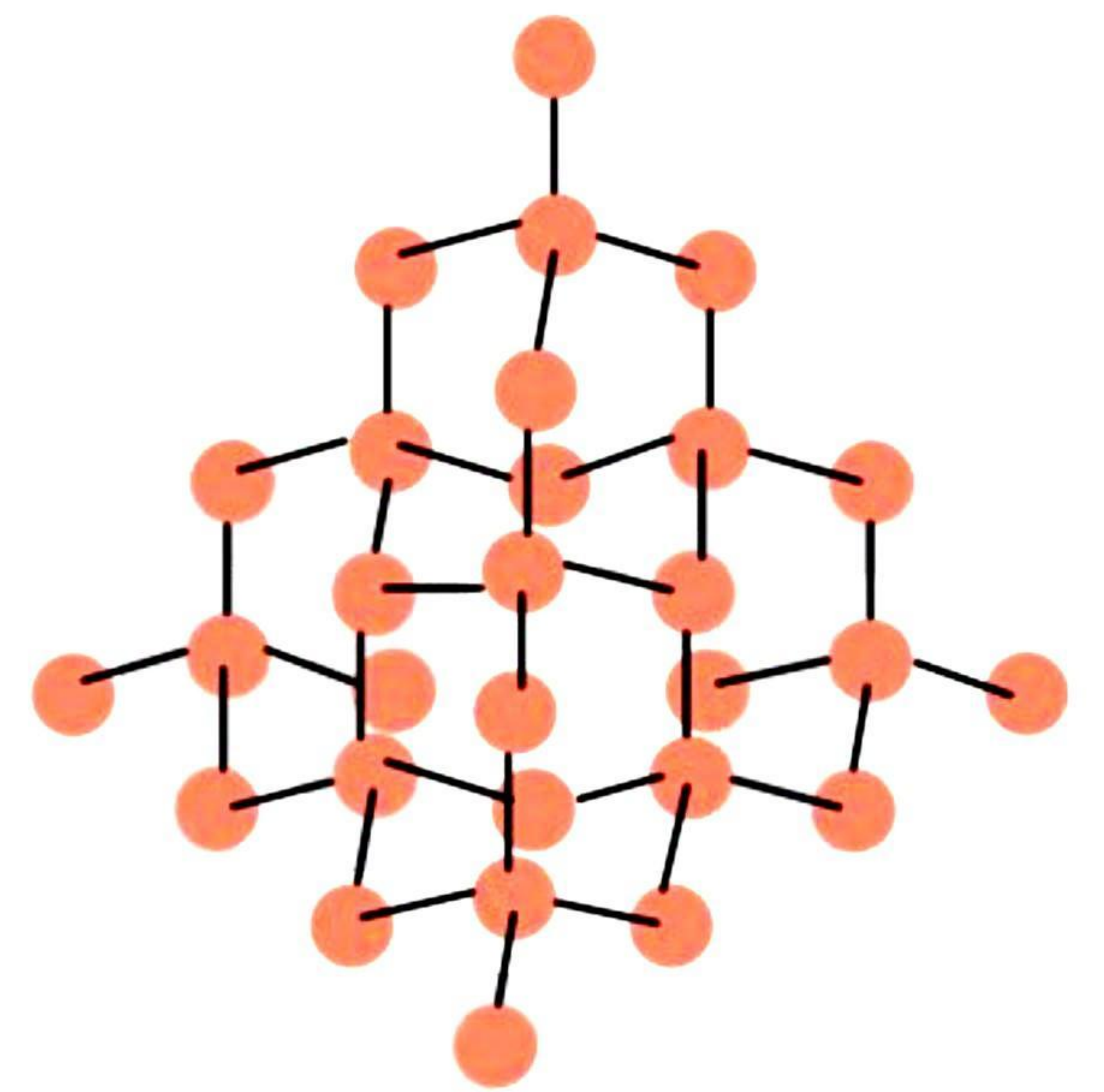
### Diamond

#### Properties

- Non-conductive
- Transparent
- Colorless

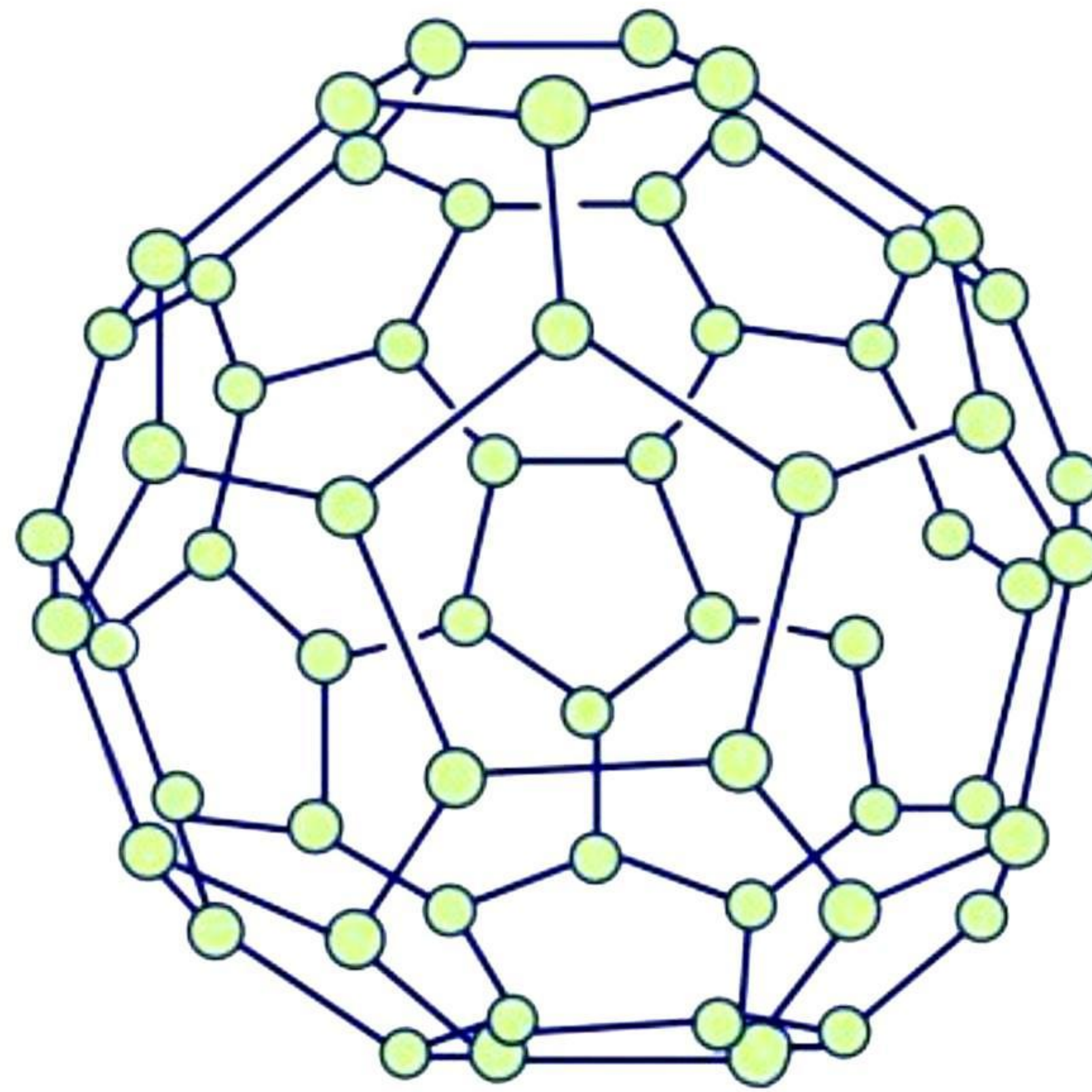
#### Uses

- Industrial cutting tools (hardness)
- Jewellery and Gemstones



The structure of diamond

C<sub>60</sub>, or Buckminsterfullerene, is named after Buckminster Fuller and consists of 60 carbon atoms.



The structure of C-60 Buckminsterfuller

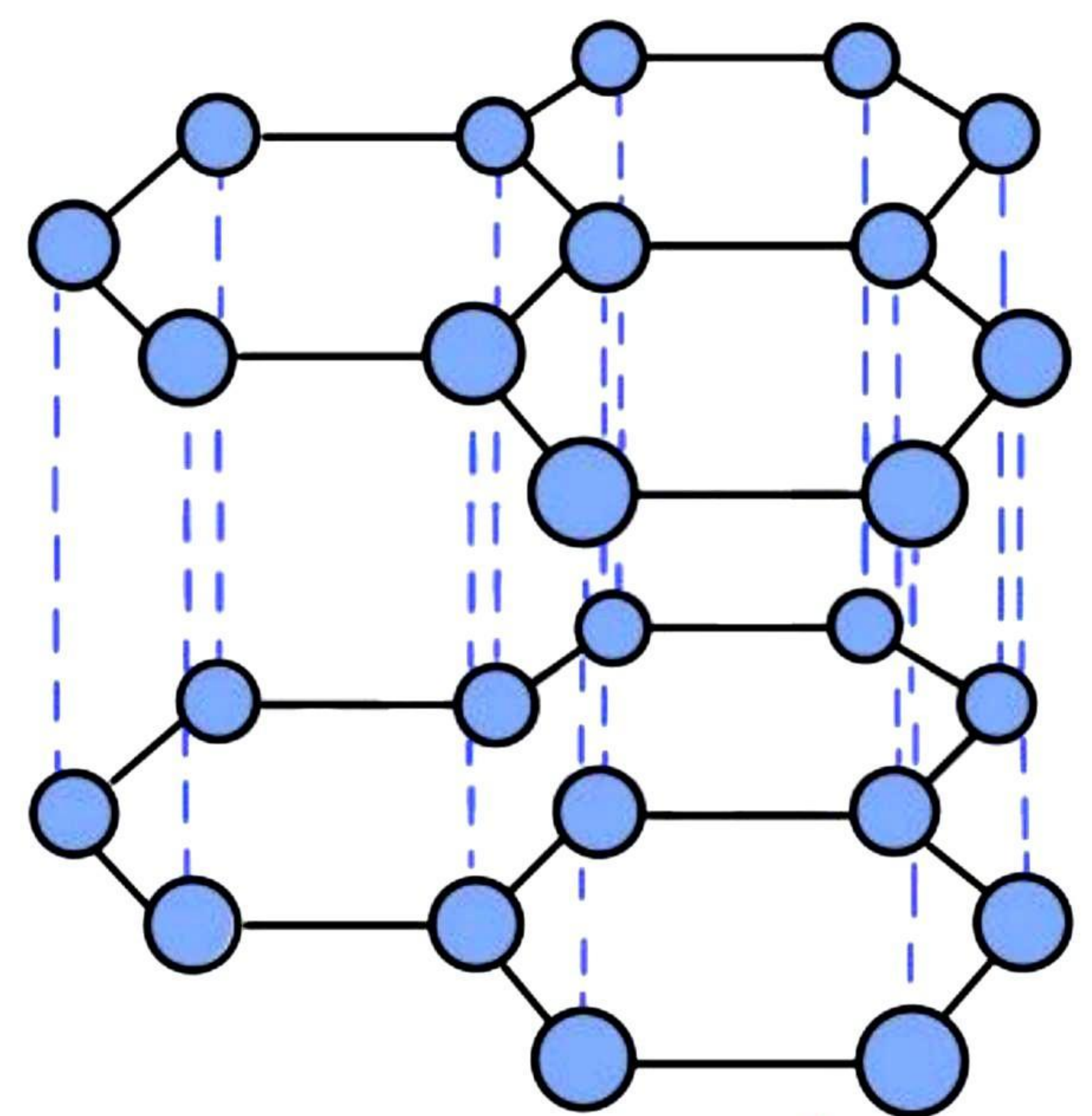
### Graphite

#### Properties

- Excellent electrical conductivity
- Single layer hexagonal lattice
- Exceptional strength

#### Uses

- Lubricants
- Battery electrodes
- Pencil lead
- Nuclear reactor moderators



The structure of Graphite

→ **Hydrocarbons** - composed of carbon and hydrogen, classified by carbon-carbon bond nature

(1) **Saturated**

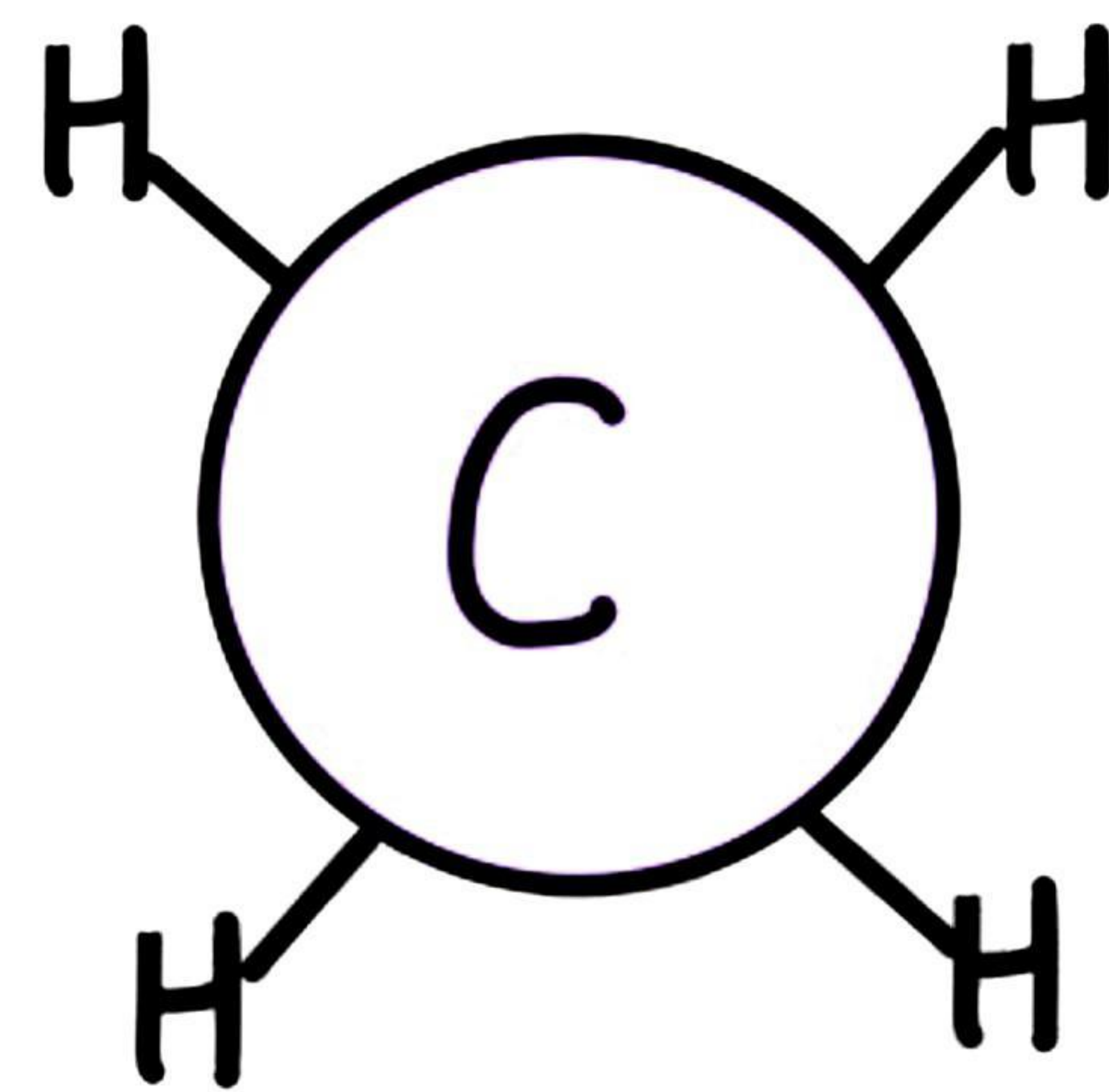
• These hydrocarbons consist of carbon atoms bonded exclusively by single bonds.

• Example - **Alkanes**

(2) **Unsaturated**

• In these hydrocarbons, carbon atoms are connected by or double or triple bonds.

• Example - **Alkenes, Alkynes**.



**Alkanes**

- Alkanes, also known as **paraffins**, are hydrocarbons where in all carbon atoms are linked by single covalent bonds.
- They adhere to the general formula:  $C_nH_{2n+2}$ .

**Alkenes**

- Unsaturated hydrocarbons with at least one double bond along with single bonds are called **alkenes** or **olefines**.
- General formula:  $C_nH_{2n}$ , where  $n > 4$ .

**Alkynes**

- Unsaturated hydrocarbons with one or more triple bonds along with single bonds are **alkynes**.
- General formula:  $C_nH_{2n-2}$

→ **IUPAC Nomenclature of Hydrocarbons**

IUPAC (**International Union of Pure and Applied Chemistry**) nomenclature is a systematic method used to name organic compounds, including hydrocarbons.

1) **Alkanes (Saturated Hydrocarbons)**

- End the name with "**-ane**".
- Number the carbon atoms in the longest continuous chain.
- Identify and name any substituents (side branches).
- Combine the names of the substituents with the chain name.
- Example -  $CH_3CH_2CH_2CH_3$  is **butane**.

Carbon	Name	Molecular Formula	Structural Formula
1	Methane	$\text{CH}_4$	$\text{CH}_4$
2	Ethane	$\text{C}_2\text{H}_6$	$\text{CH}_3\text{CH}_3$
3	Propane	$\text{C}_3\text{H}_8$	$\text{CH}_3\text{CH}_2\text{CH}_3$
4	Butane	$\text{C}_4\text{H}_{10}$	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$
5	Pentane	$\text{C}_5\text{H}_{12}$	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
6	Hexane	$\text{C}_6\text{H}_{14}$	$\text{CH}_3(\text{CH}_2)_4\text{CH}_3$
7	Heptane	$\text{C}_7\text{H}_{16}$	$\text{CH}_3(\text{CH}_2)_5\text{CH}_3$
8	Octane	$\text{C}_8\text{H}_{18}$	$\text{CH}_3(\text{CH}_2)_6\text{CH}_3$
9	Nonane	$\text{C}_9\text{H}_{20}$	$\text{CH}_3(\text{CH}_2)_7\text{CH}_3$
10	Decane	$\text{C}_{10}\text{H}_{22}$	$\text{CH}_3(\text{CH}_2)_8\text{CH}_3$

## 2) Alkenes (Unsaturated Hydrocarbons with Double Bonds)

- End the name with “-ene”
- Number the carbon atoms in the longest continuous chain.
- Identify the location of the double bond and include it in the name.
- Example -  $\text{CH}_2=\text{CH}-\text{CH}_3$  is propane.

## 3) Alkynes (Unsaturated Hydrocarbons with Triple Bonds)

- End the name with “-yne”.
- Number the carbon atoms in the longest continuous chain.
- Identify the location of the triple bond and include it in the name.
- Example -  $\text{CH}\equiv\text{C}-\text{CH}_2-\text{CH}_3$  is propane.

## → Steps for Writing IUPAC Names

### 1) Identify the longest carbon chain:

- Locate the longest continuous chain of carbon atoms in the molecule.

### 2) Number of carbon chain

- Number the carbon atoms in the chain from the end that gives substituents the lowest numbers.

### 3) Identify and Name substituents

- Identify and name any substituents (groups attached to the main carbon chain).

Follow IUPAC rules for naming hydrocarbons, especially alkanes, ensuring systematic and unique names based on structure.

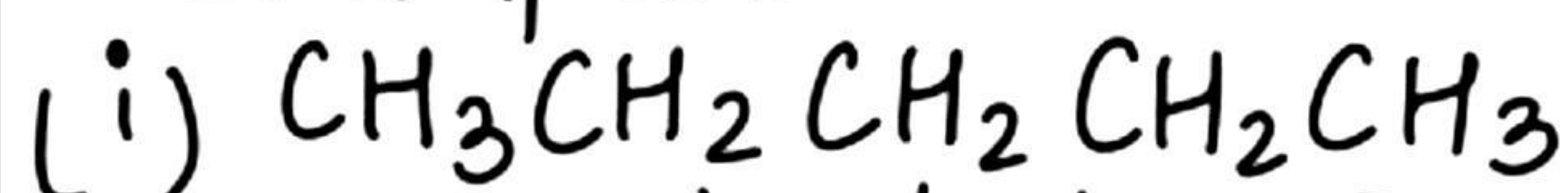
#### 4) Combine Chain and Substituent Names:

- Combine the names of the main carbon chain and substituents, alphabetizing them.

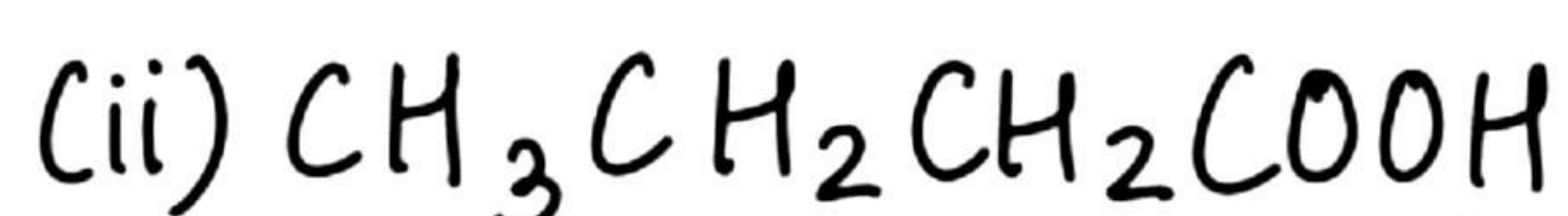
#### 5) Add Prefixes and Suffixes

- Add prefixes and suffixes based on the type of compound (alkane, alkene, alkyne).

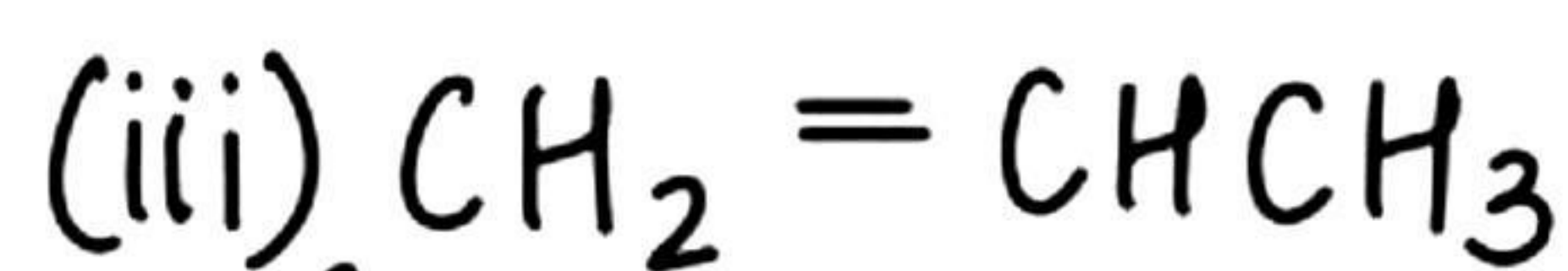
Examples:



- Longest chain: 5 carbon atoms (Pentane).
- IUPAC Name: Pentane.



- Longest chain: 4 carbon atoms (Butane).
- Substituent:  $\text{COOH}$  (carboxy).
- IUPAC Name: Butanoic acid.



- Longest chain: 3 carbon atoms (propene).
- IUPAC Name: Propene.



- Longest chain: 4 carbon atoms (Butane).
- Substituent:  $\text{COOH}$  (carboxyl).
- IUPAC Name: Butanoic acid.

### → Drawing Structure of Saturated and Unsaturated Compounds.

1. Connect All Carbon Atoms with single Bonds.

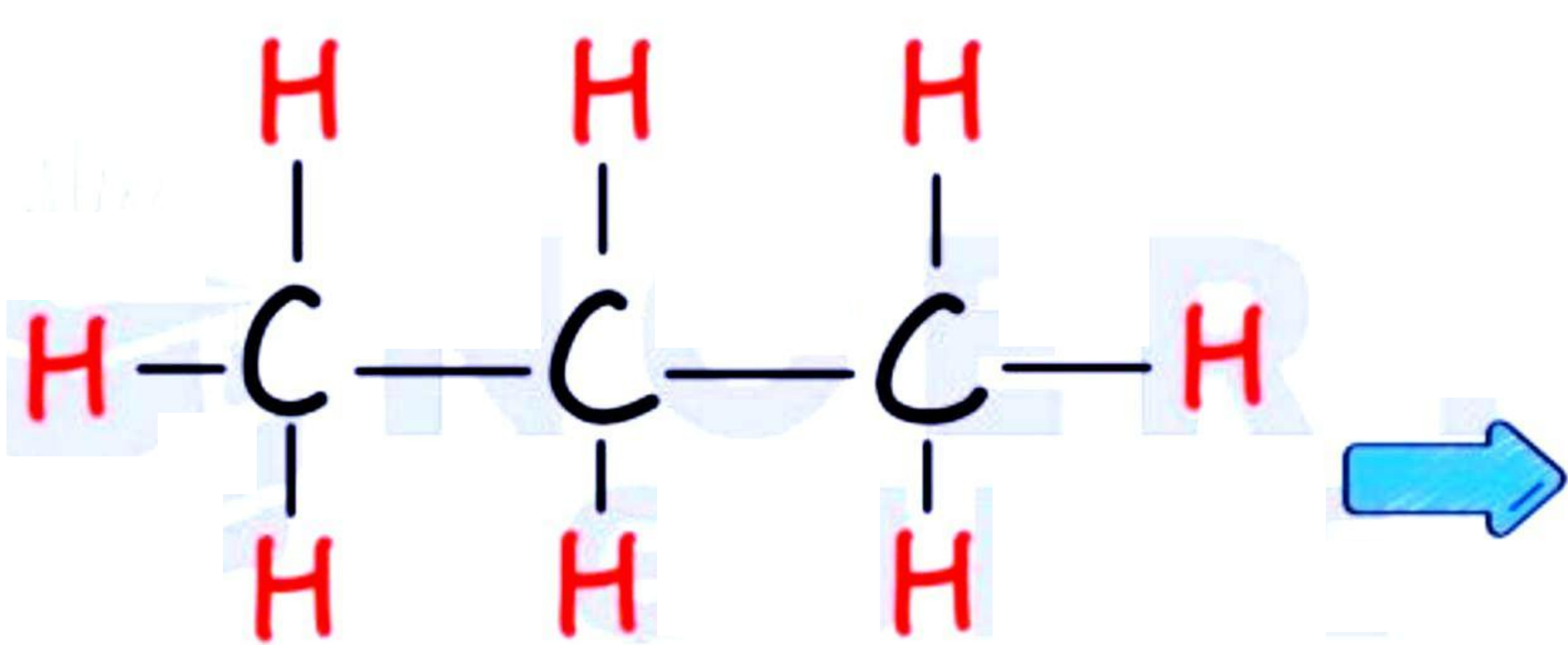
- Utilize single bonds to connect all carbon atoms together with in the molecule.

2. Satisfy Remaining Valencies of carbon with hydrogen Atoms.

- Attach hydrogen atoms to each carbon atom to complete their valency.
- Carbon typically forms 4 bonds owing to its 4 valencies.

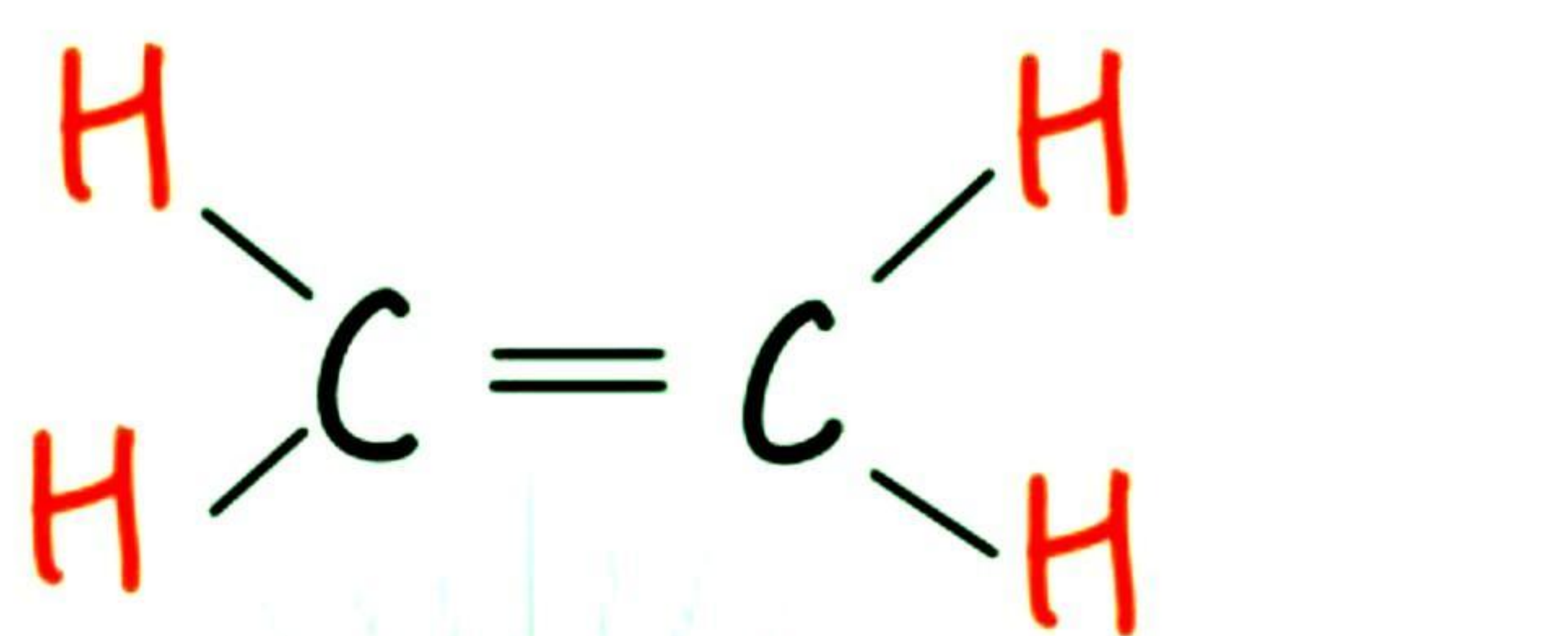
3. If Available Hydrogen Atoms are Insufficient.

- In cases where the available hydrogen atoms are insufficient to fulfill carbon's valency, employ double or triple bonds to meet the remaining bonding requirements.



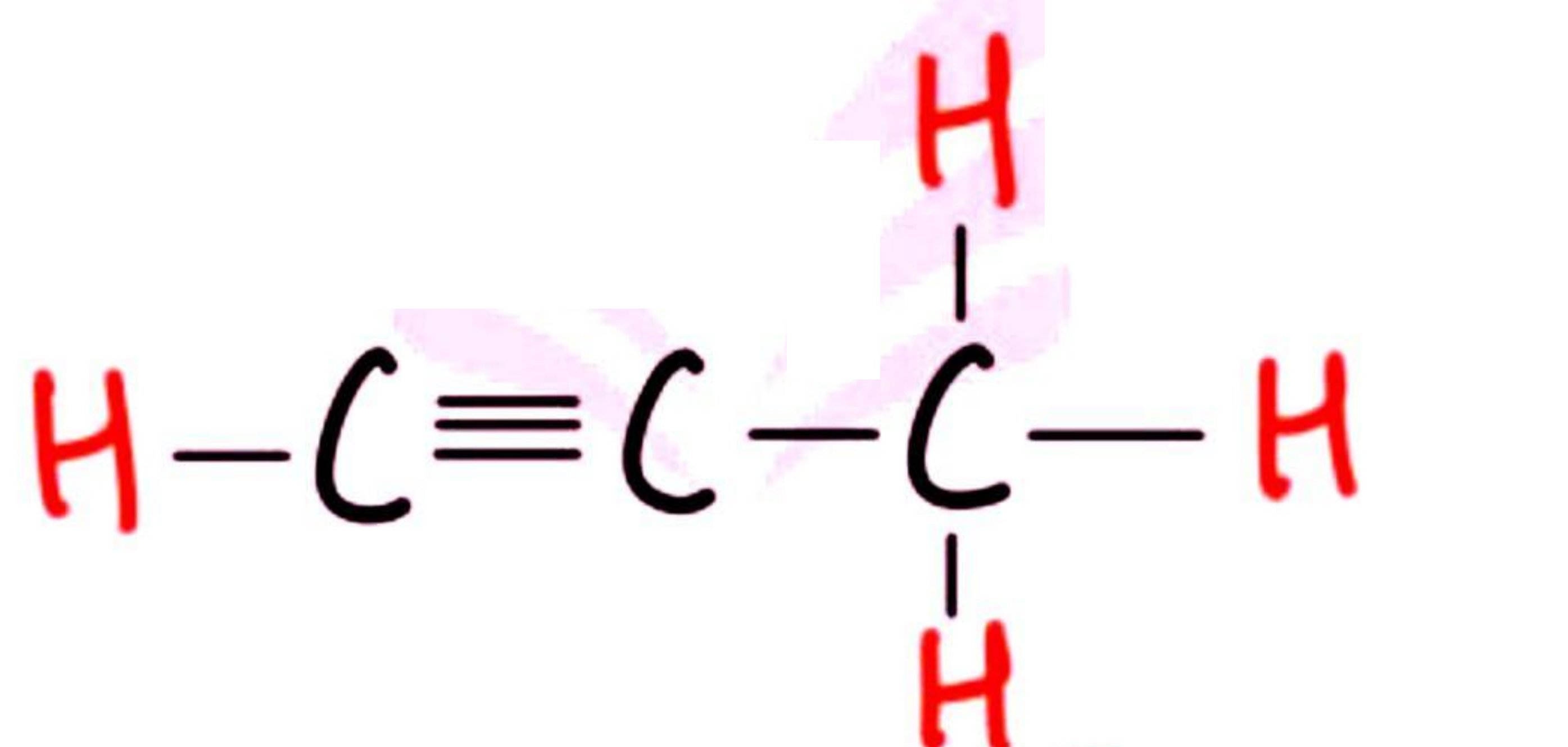
Structural formula  
for propane

This represents a straight-chain alkane with three carbon atoms each bonded to two hydrogen atoms. The carbon atoms are connected by single bonds.



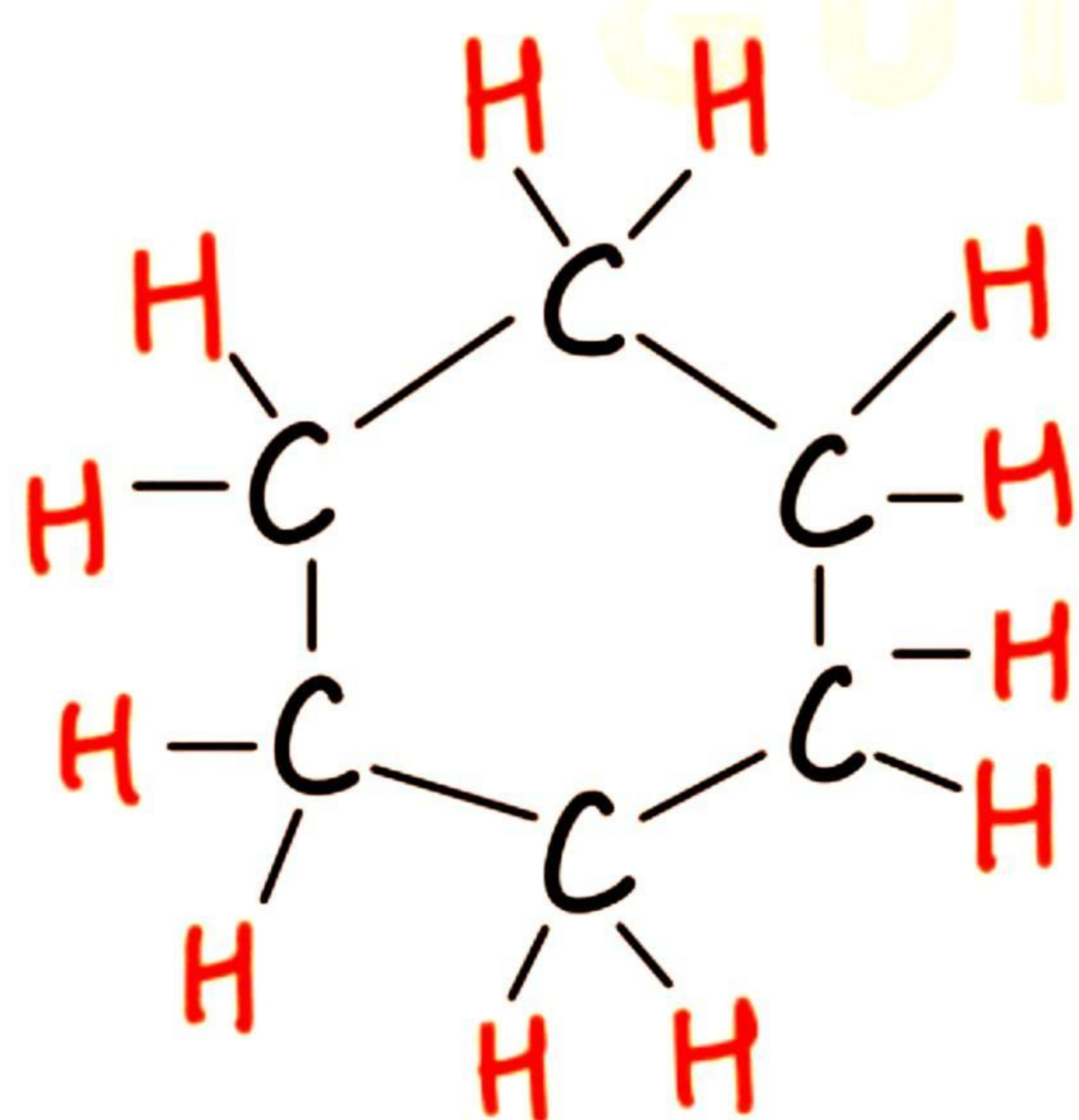
Structural Formula  
for Ethene

This represents an alkene with two carbon atoms and a double bond between them. Each carbon atom is bonded to two hydrogen atoms.



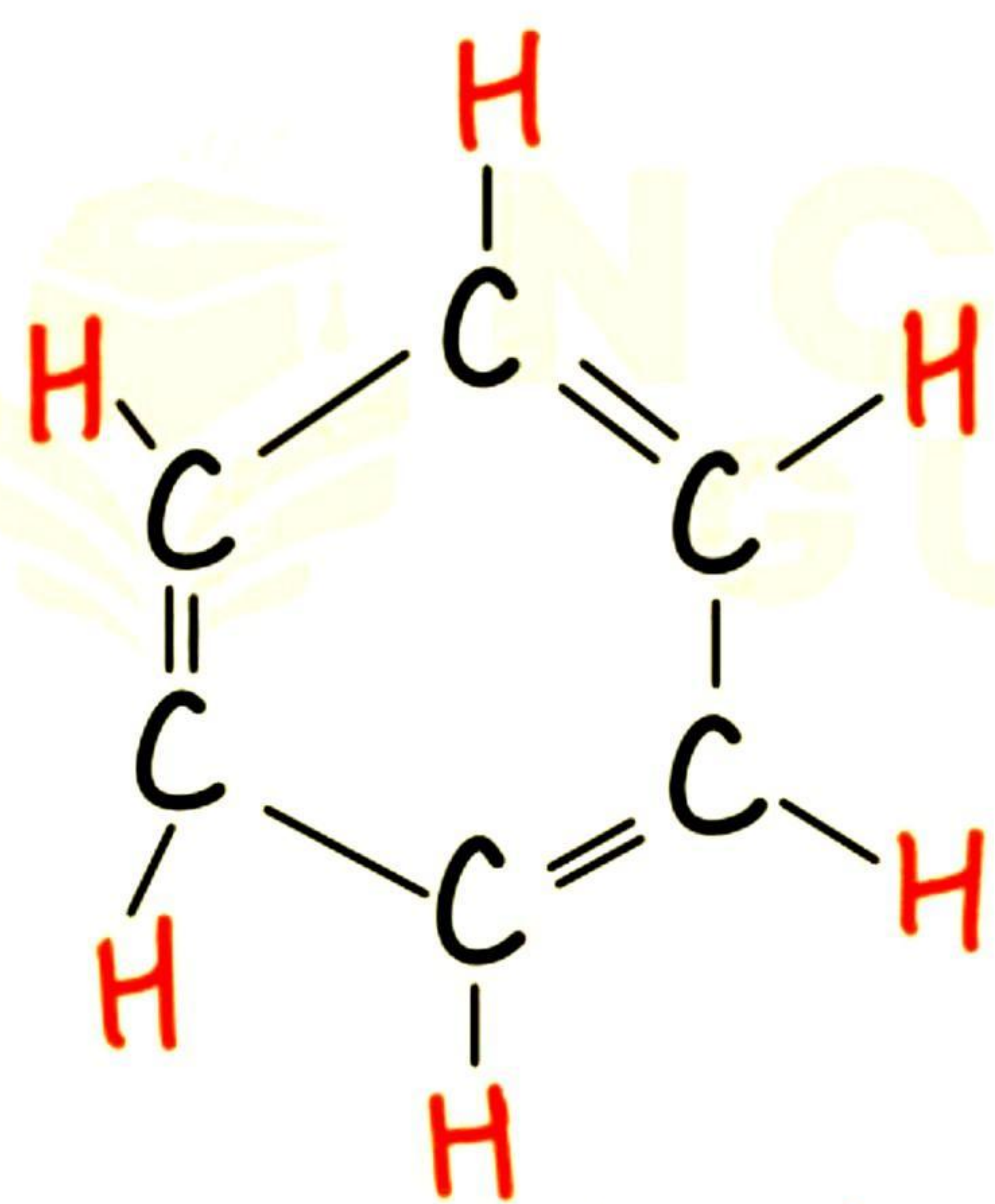
Structural Formula  
for propyne

This is a depiction of a three-carbon alkyne. The triple bond ( $\equiv$ ) is between the first and second carbon atoms. Each carbon atom is also bonded to one hydrogen atom.



Structural formula  
of cyclohexane

Cyclohexane is a cyclic alkane comprising a six-carbon ring with each carbon atom bonded to two hydrogen atoms. The bond angles within the ring are approximately 109.5 degrees, contributing to its stable and symmetrical structure.



Structural formula  
for benzene

This depiction illustrates benzene's stable and symmetrical ring structure composed of six carbon atoms. The circle within the hexagon symbolizes the delocalized pi electrons emphasizing benzene's resonance structure. Each carbon atom is bonded to one hydrogen atom, and all carbon bonds in benzene are identical.

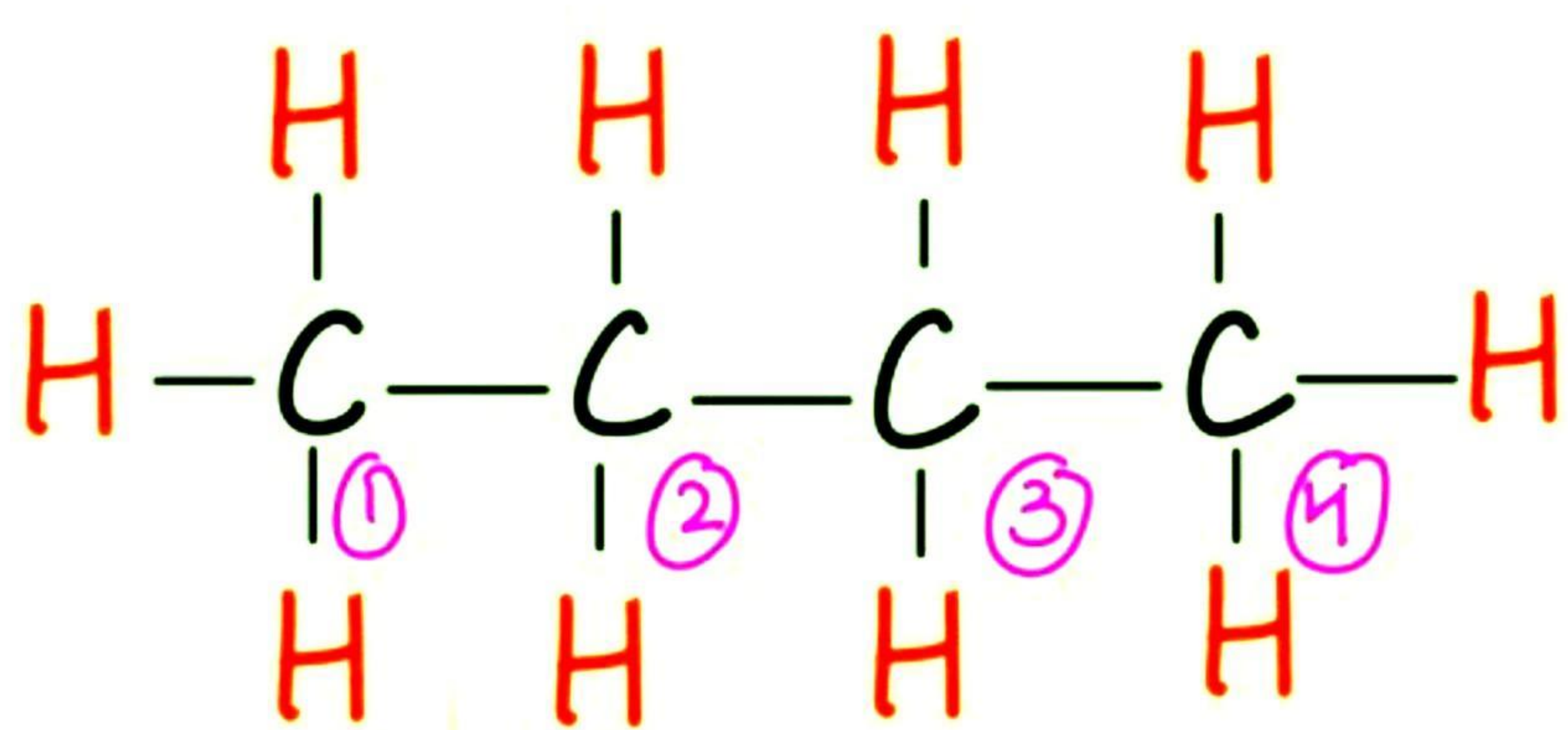
➔ **Functional Groups** - A functional group is an atom or group of atoms with a carbon compound that imparts reactivity and determines its chemical properties. When a compound contains a functional group, it is denoted in the compound's name through the use of either a prefix or a suffix.

Hetero atom	Class of compounds	Formula of functional group	Prefix - Suffix
Cl / Br	Halo - (chloro / bromo) alkane	-Cl, -Br (Substitutes for hydrogen atom)	Prefix - chloro
Oxygen	1. Alcohol	-OH	Suffix - ol
	2. Aldehyde	$\begin{array}{c} \text{H} \\ \diagup \\ \text{C} \\ \parallel \\ \text{O} \end{array}$	suffix - al
	3. Ketone	$\begin{array}{c} \text{O} \\ \parallel \\ \text{C} \end{array}$	suffix - one
	4. Carboxylic Acid	$\begin{array}{c} \text{O} \\ \parallel \\ \text{C} - \text{OH} \end{array}$	suffix - oic acid

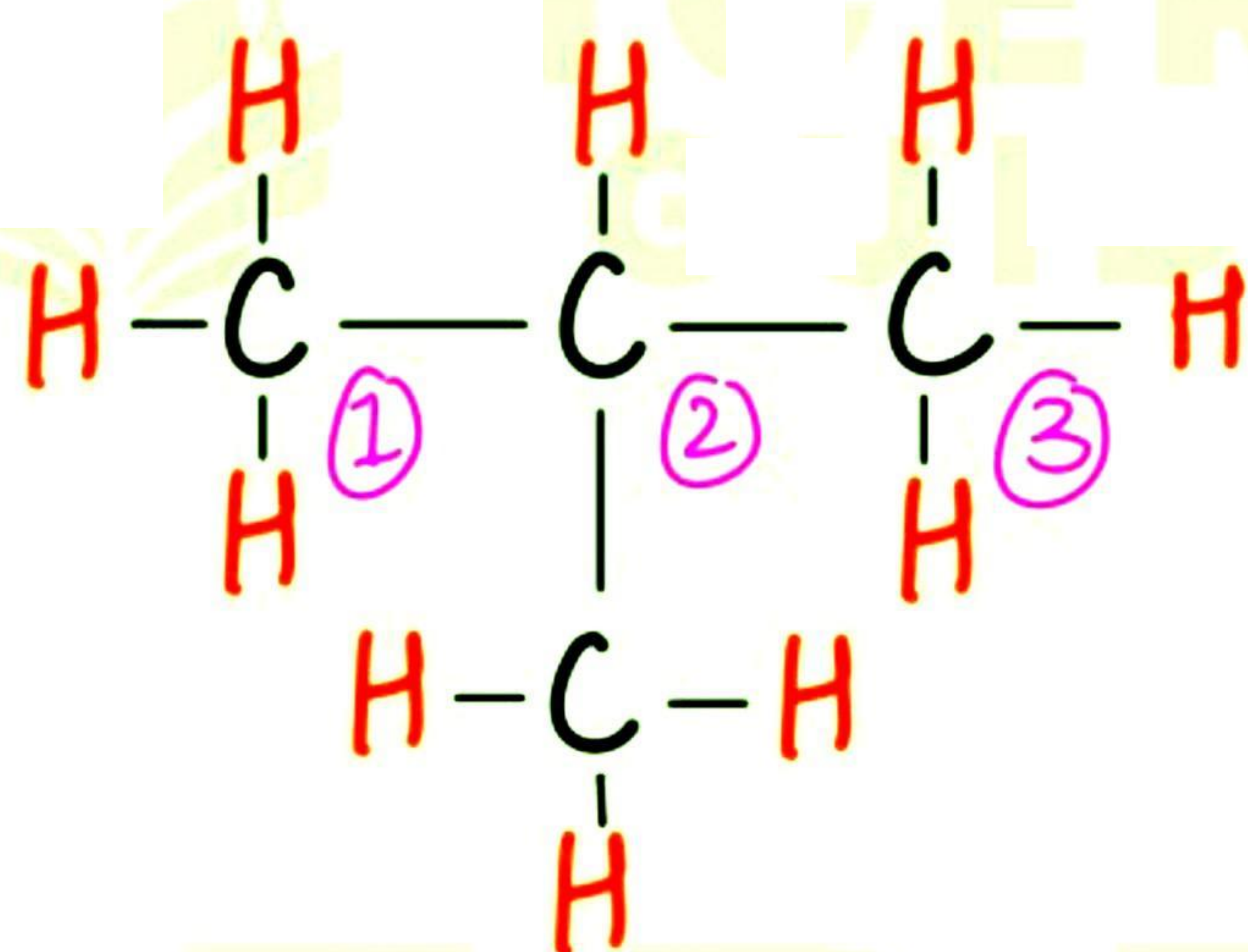
➔ **Homologous Series** - A homologous series refers to a collection of organic compounds characterized by similar structures and chemical behaviours within this series, successive members differ by the addition of a common  $\text{CH}_2$  group. For instance  $\text{CH}_3$ ,  $\text{C}_2\text{H}_5$  and  $\text{C}_3\text{H}_7$  exemplify such a series.

- All members share a common general formula.
- The distinction between successive members involves the addition of a  $\text{CH}_2$  group.
- Two adjacent members vary by the molecular mass of  $\text{CH}_2$ .
- While not necessarily identical in physical properties, all members demonstrate analogous chemical properties.

→ **Structural Isomerism** - Structural isomerism refers to compounds sharing the same molecular formula but exhibiting distinct arrangements of atoms or bonds within their structures.



n-butane



2-methyl Propane  
Isobutane (C.N)

→ **Important Carbon compounds**

### Ethanol ( $\text{C}_2\text{H}_5\text{OH}$ )

- A liquid compound that is soluble in water.
- Often referred to simply as alcohol, it serves as an active ingredient.
- Renowned for its excellent solvent properties, ethanol finds widespread use in various medicines such as tincture, iodine, cough syrups and numerous tonics.

### Acetic Acid ( $\text{C}_2\text{H}_4\text{O}_2$ )

- Commonly recognized as acetic acid.
- A solution containing 5-8% acetic acid in water is known as **vinegar** and is utilized as a preservative in pickles.
- With a melting point of 290K, it tends to solidify during winter.
- Carboxylic acids, including acetic acid are classified as weak acids.

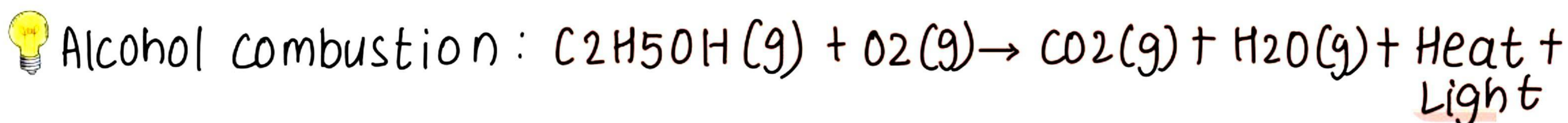
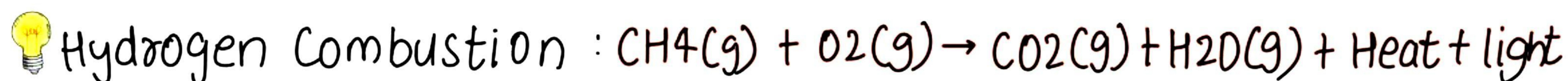
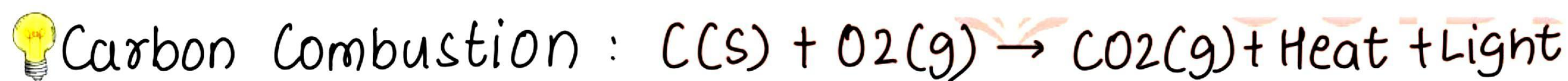
→ **Denatured Alcohol** - Denatured alcohol is a type of alcohol intentionally made unfit for consumption in significant amount due to its harmful

effects on health. Overconsumption of alcohol can disrupt metabolic functions and depress the central nervous system resulting in problems such as impaired coordination and drowsiness. To deter misuse, alcohol is deliberately modified by adding toxic substances like methanol and pyridine, along with coloured dyes. This altered version of alcohol, termed **denatured alcohol**, is specifically formulated to discourage ingestion.

## → Chemical Properties of carbon compounds

### 1. Combustion

Combustion involves chemical reactions releasing heat and light

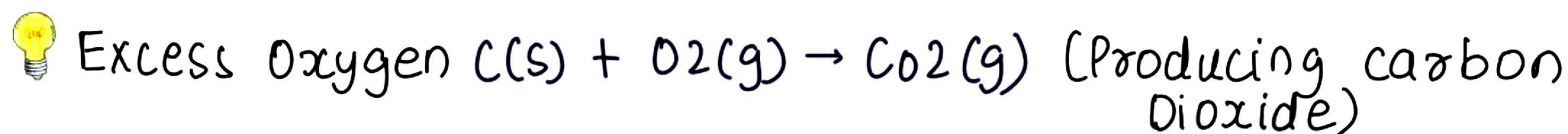
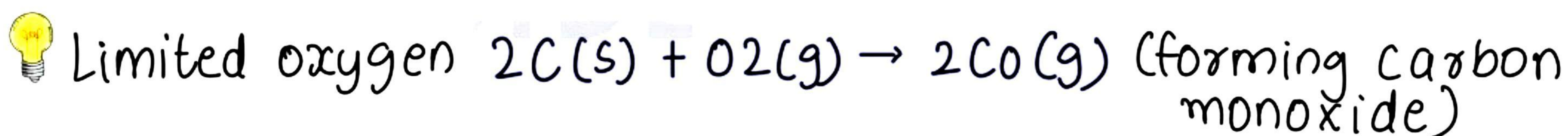


Flames vary with the type of fuel and oxygen availability:

- Saturated Hydrocarbons - Burn with a clear blue flame in oxygen.
- Limited Oxygen - Results in a sooty flame for saturated hydrocarbons.
- Unsaturated hydrocarbons - Burns with a yellow flame and significant smoke.
- Kerosene : Produces a clear, blue flame with sufficient oxygen.

### 2. Oxidation

Carbon compounds readily oxidize during combustion.



### Alcohol Oxidation

- Alkaline **KMnO<sub>4</sub>** and acidified **K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>** serve as oxidizing agents, providing oxygen for the oxidation process.

### 3. Addition Reaction

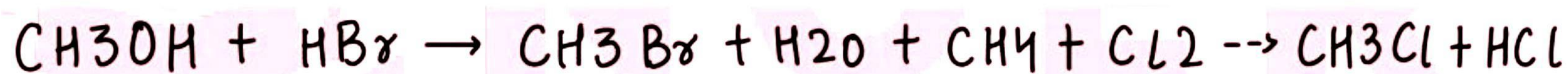
- In the presence of catalysts such as palladium or nickel unsaturated hydrocarbons can undergo addition reactions wherein hydrogen is added, resulting in the creation of saturated hydrocarbons. Catalysts are materials that enable a reaction to occur at a different rate, without undergoing any change themselves in the process.

#### ✿ Hydrogenation Reaction

This method is utilized in the hydrogenation process of vegetable oils usually contain lengthy unsaturated carbon chains, while animal fats contain saturated carbon chains. Saturated fatty acids, prevalent in animal fats, are often associated with adverse health effects.

### 4. Substitution Reaction

A substitution reaction is a chemical process in which one functional group in a chemical compound is exchanged with another functional group.



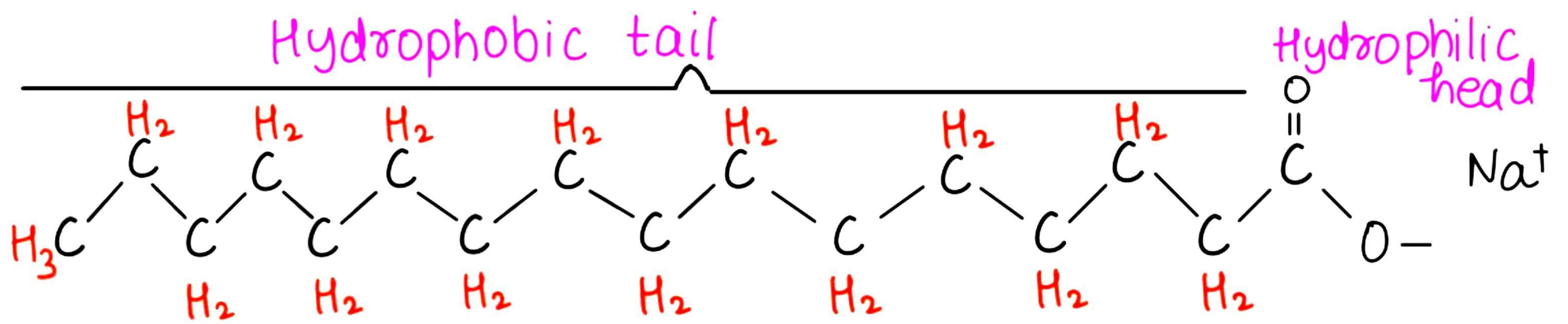
In these reactions, one functional group is substituted for another, resulting in the formation of new compounds.

#### ➔ Reactions of Ethanol

(i) Sodium Reaction - When two sodium atoms react with two molecules of ethanol ( $\text{CH}_3\text{CH}_2\text{OH}$ ), sodium ethoxide ( $\text{CH}_3\text{CH}_2\text{O}^-\text{Na}^+$ ) and hydrogen gas ( $\text{H}_2$ ) are produced.

(ii) Unsaturated Hydrocarbon Formation - Under the influence of hot concentrated sulfuric acid ( $\text{H}_2\text{SO}_4$ ), ethanol ( $\text{CH}_3\text{CH}_2\text{OH}$ ) undergoes a dehydration reaction, yielding ethylene ( $\text{CH}_2=\text{CH}_2$ ) and water ( $\text{H}_2\text{O}$ ). This dehydration process is facilitated by  $\text{H}_2\text{SO}_4$ , acting as a dehydrating agent by removing water from the reaction.

➔ Soaps and detergents - Soaps consist of sodium or potassium salts of long-chain carboxylic acids. The ionic end of the soap dissolves in water while the carbon chain dissolves in oil.

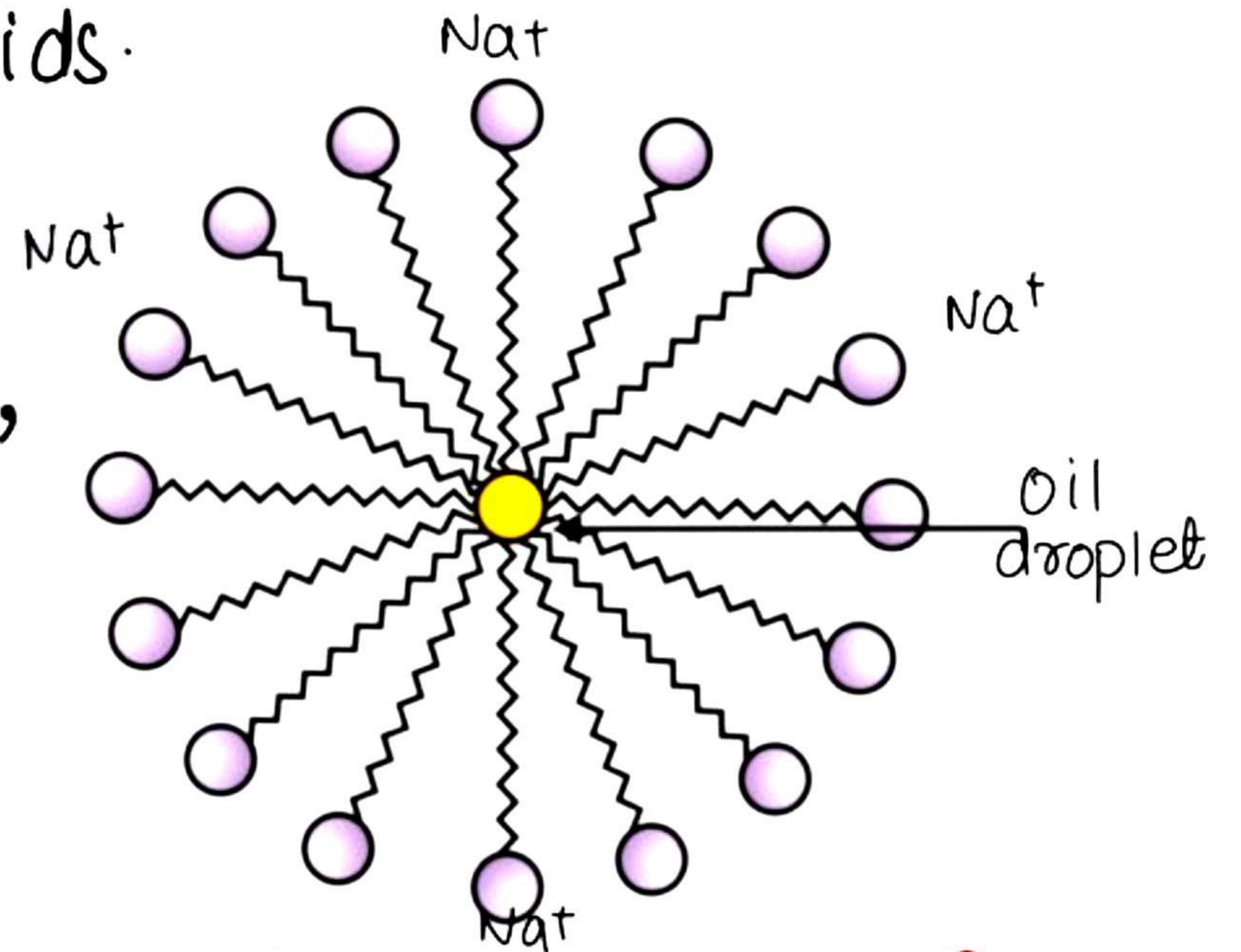


Detergents commonly consist of ammonium or sulfonate salts derived from long-chain carboxylic acids.

### Cleaning Action of Soap

- Much of the dirt encountered is oily, and oil doesn't dissolve readily in water.

Soap molecules organize into structures known as micelles



### Formation of Micelle

- Within micelles, one end aligns with the oil droplet while the other ionic end faces outward.
- Soap molecules, in the form of micelles, occupy the core of these structures.
- These micelles persist as a colloidal solution, preventing their aggregation and precipitation due to ion-ion repulsion.
- Soap micelles are of sufficient size to scatter light, resulting in the cloudy appearance of a soap solution.

### → Hardness of Water

- Hard water has high mineral content, forming scum when combined with soap due to calcium and magnesium salts.
- Soft water lacks significant calcium and magnesium salts, avoiding scum formation with soap.
- Detergents, made of ammonium or sulphonate salts, do not form insoluble precipitates in hard water, maintaining effectiveness.