CARBON AND ITS COMPOUNDS

CHAPTER 4

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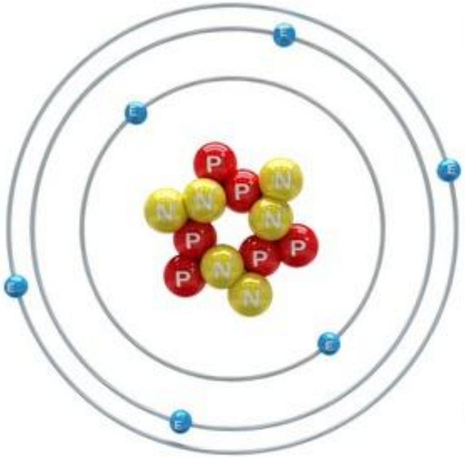
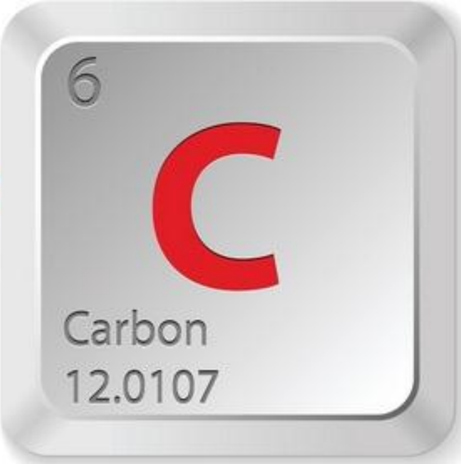
Carbon

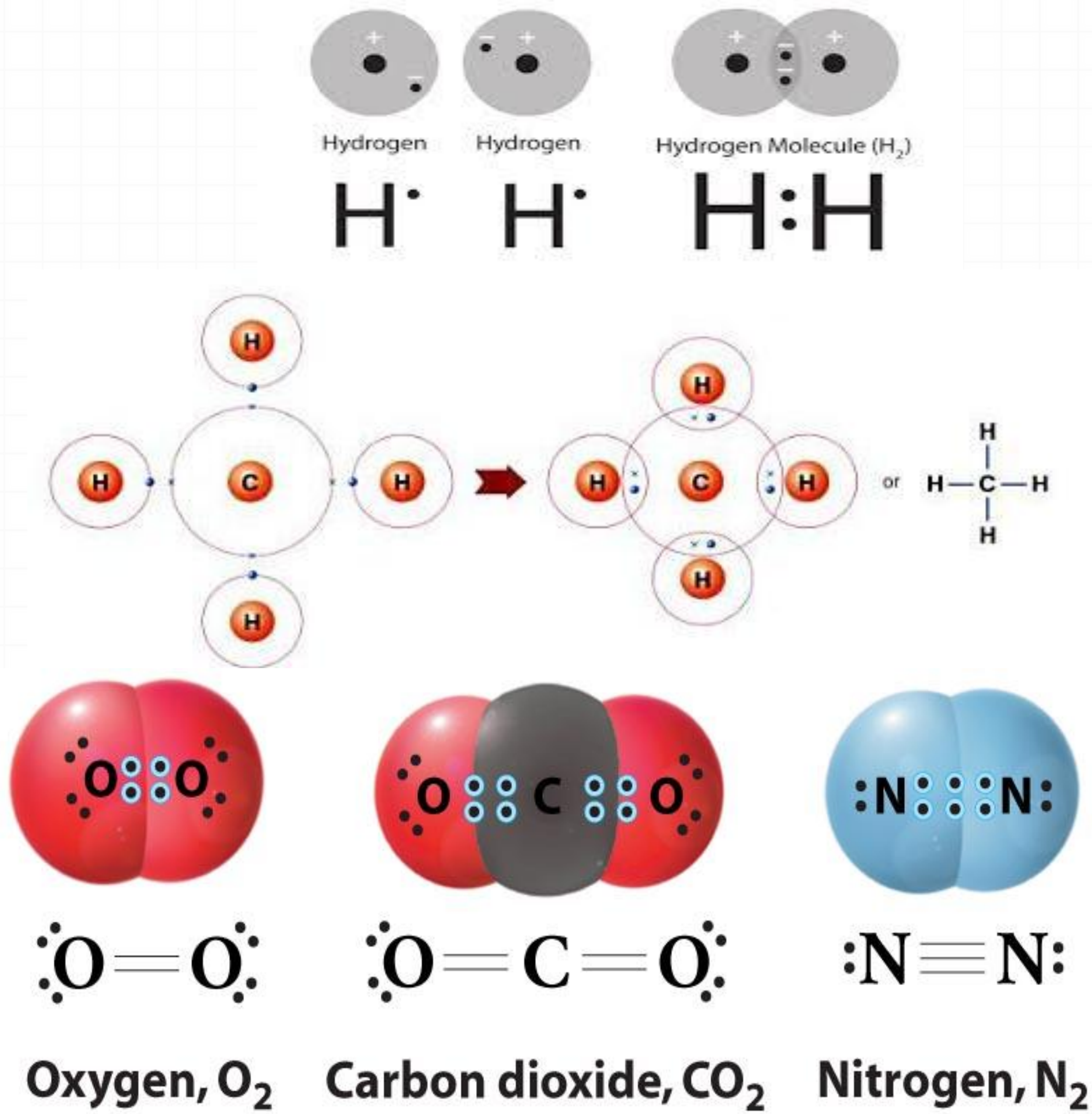
- Atomic number 6
- Atomic mass 12.0107
- Percentage composition
  - Earth's Crust- 0.02%
  - Atmosphere- 0.03%

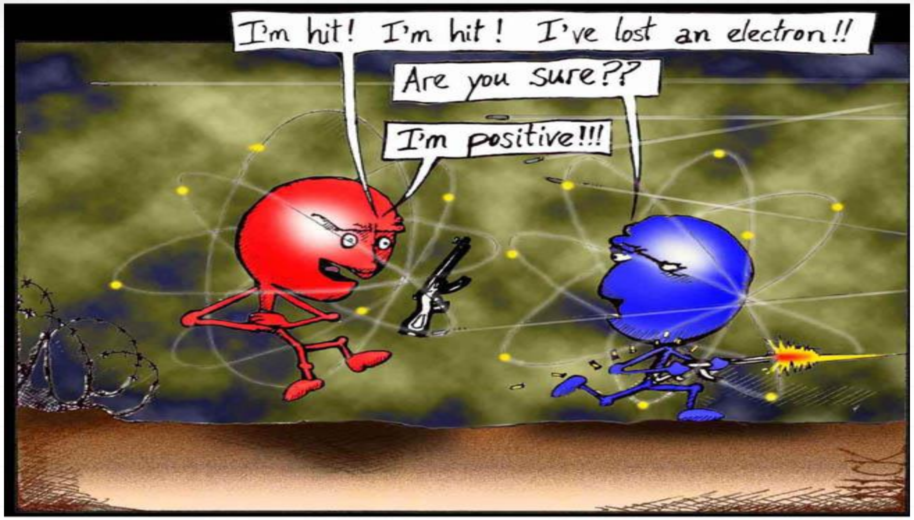




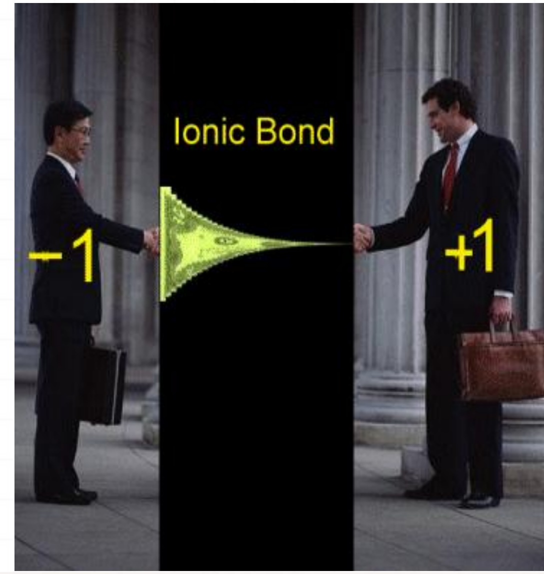
Bonding in Carbon- The Covalent bond

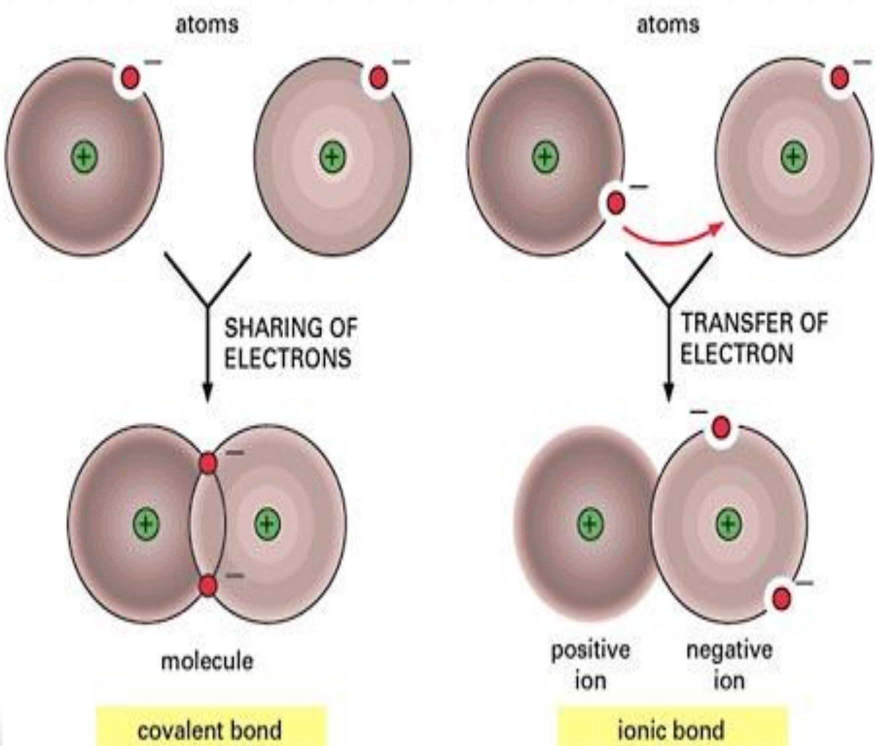
- Carbon compounds are bad conductors of electricity.
- Carbon compounds are having low melting and boiling points. [Above reasons conveys that carbon compounds are not ionic !!!!]
- Electronic configuration of carbon : 2,4
- Two ways to attain stability : Either gain 4 e or lose 4 e. But both ways won't work out.
- Carbon overcomes this problem by sharing its valence electrons with other atoms of carbon or atoms of other elements.

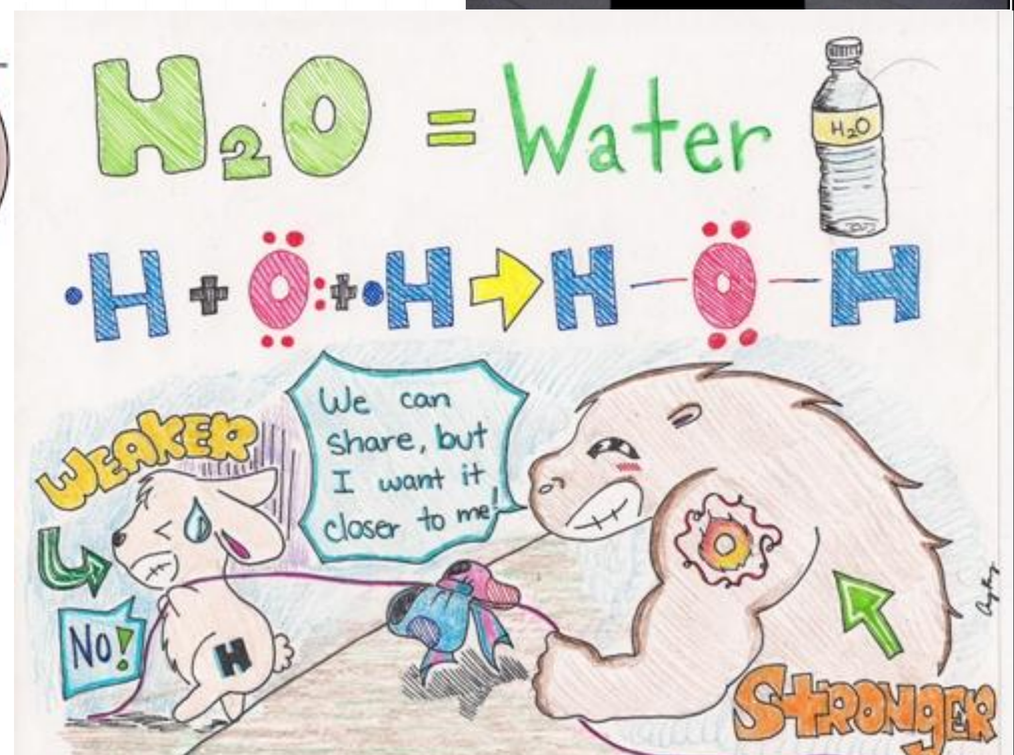




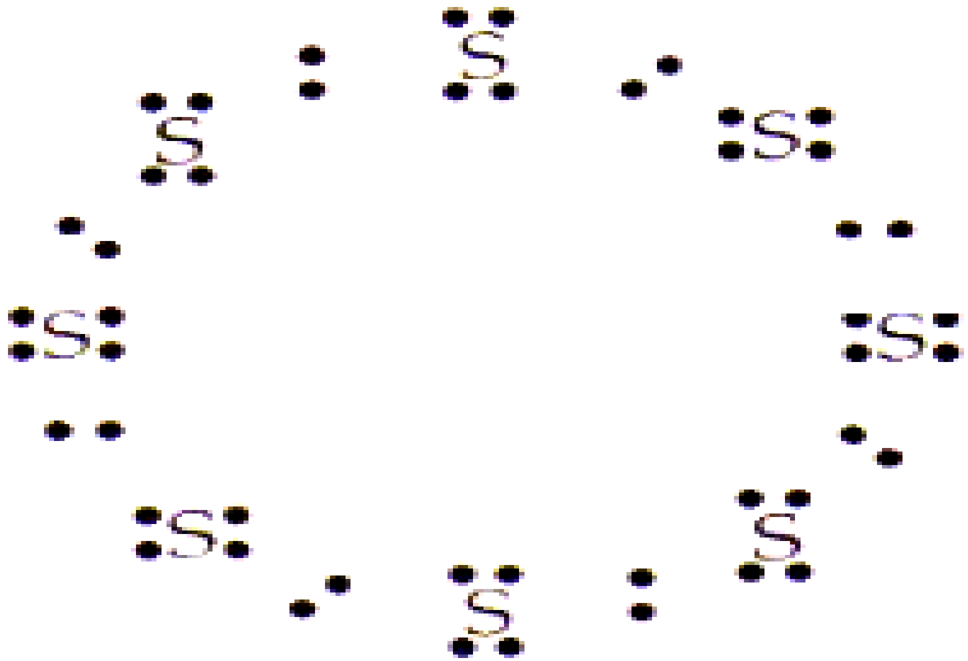
Another casualty in the War of the Atoms.

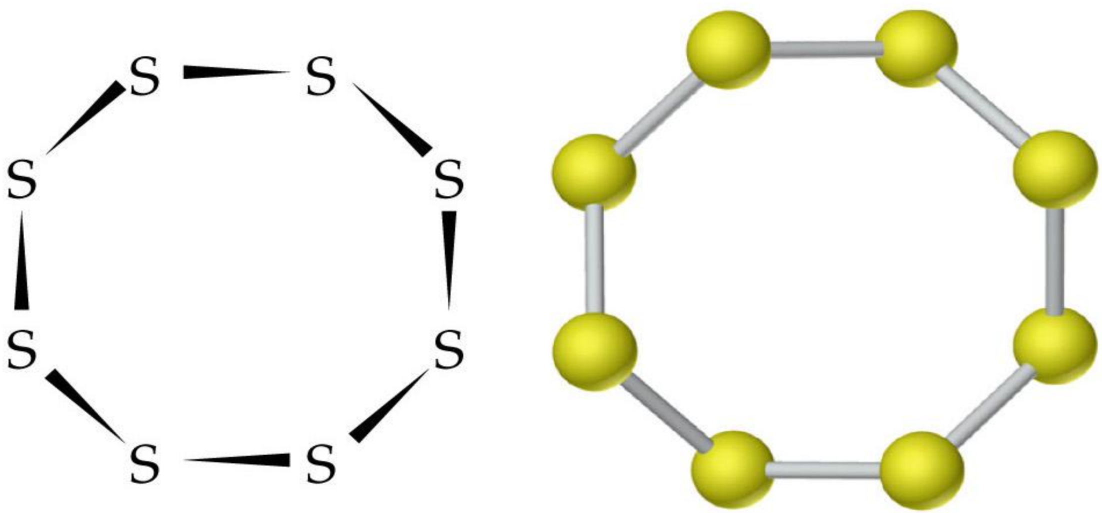




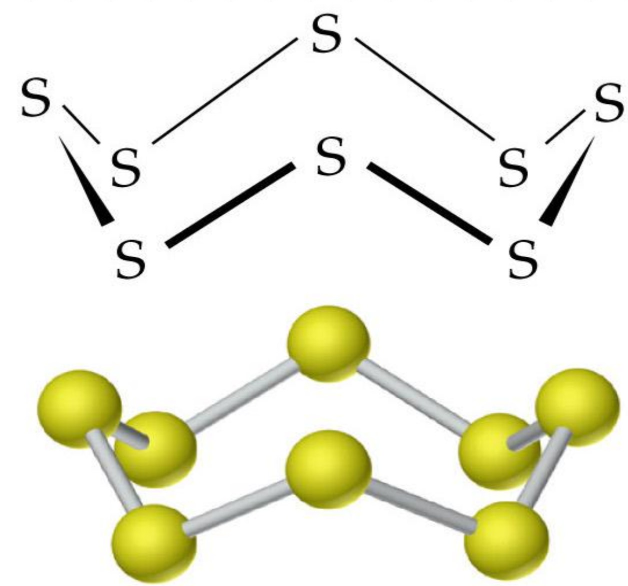


Ionic	**Covalent**
Metal–metal, non-metal–metal	Non-metal
Total transfer of electrons	Shared electrons
High melting and boiling points	Low melting and room temperature boiling points
Solids at room temperature	Liquids and gases at room temperature
Hard/brittle (inorganic compounds)	Relatively soft (organic compounds)
Strong bonds	Weak bonds
Electrically reactive	Does not normally conduct electricity
Soluble in water	Insoluble in water





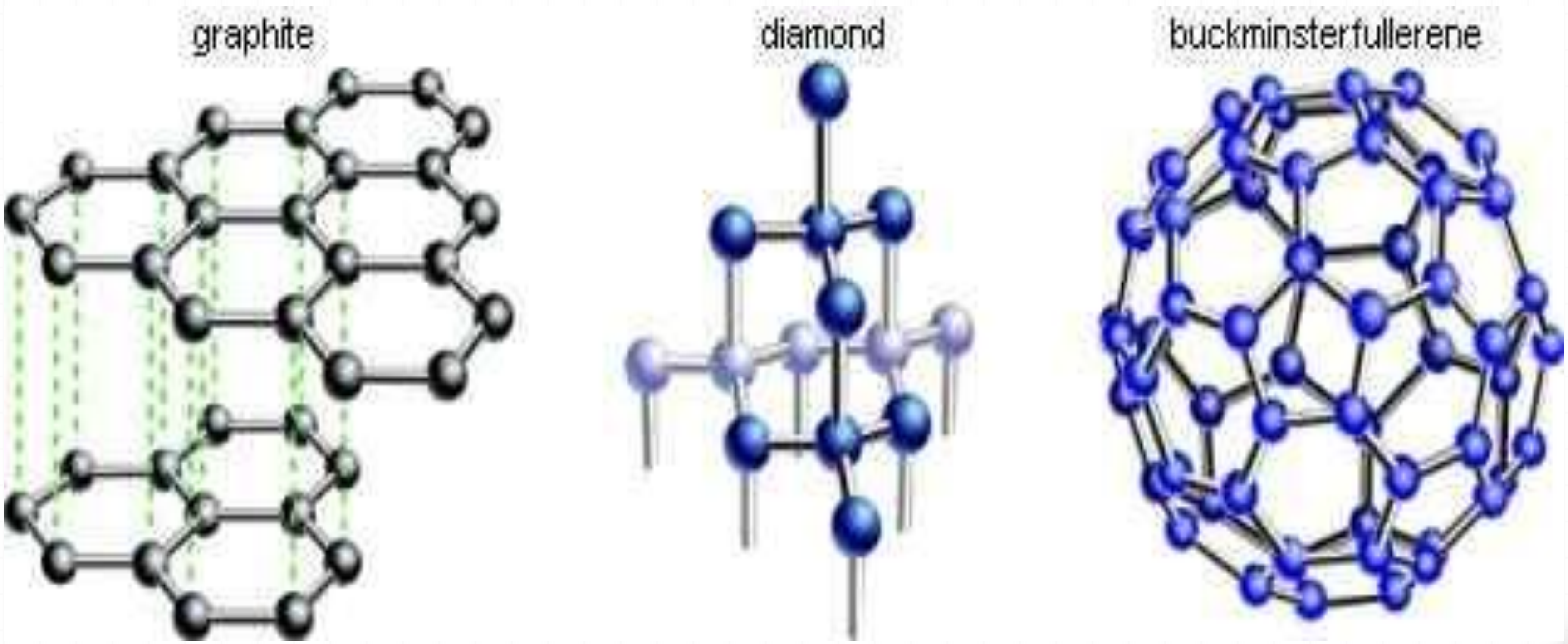
Top view



Side view

ALLOTROPES OF CARBON

- The different forms in which an element exist in nature are called allotropes.
- Carbon has 3 different forms; Graphite, Diamond and Fullerene.
- Diamond- Hardest substance.
- Graphite- Smooth and slippery; is a good conductor of electricity.
- Fullerenes- C-60



VERSATILE NATURE OF CARBON

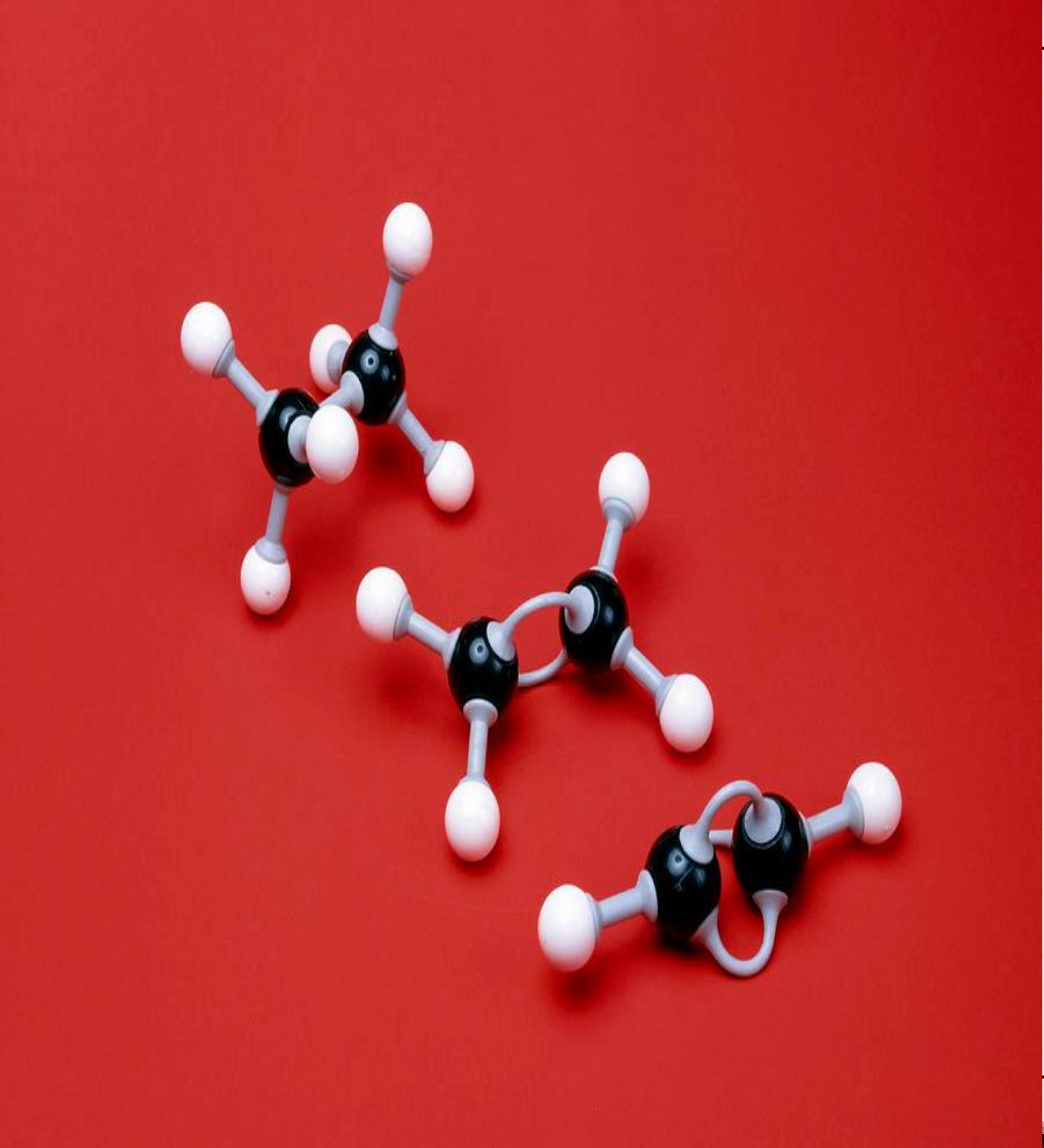
- Why carbon forms so many compounds ?
  - Carbon has the unique ability to form bonds with other atoms of carbon**. [Catenation].** The resultant compounds may be straight chains or branched chains or even ring compounds.
  - The bonds may be single bonds[saturated] or double or triple bonds[unsaturated].
  - Tetravalency of carbon
  - Bonds that carbon make with other elements show exceptional stability.

SATURATED AND UNSATURATED COMPOUNDS

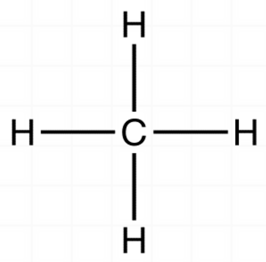
- Compounds of carbon in which valencies of all atoms are satisfied by single bonds- **Saturated**
- Ex: Ethane, Methane

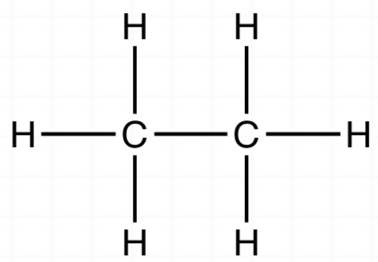
- Compounds of carbon having double or triple bonds between the carbon atoms- **Unsaturated**
- Ex: Ethene, Ethyne

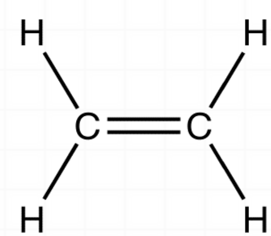
- Unsaturated are more reactive than saturated

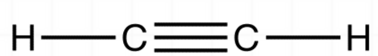


compound

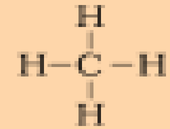
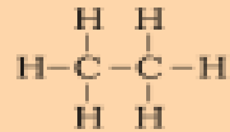
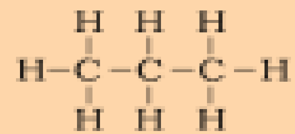
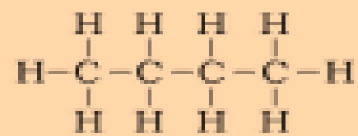
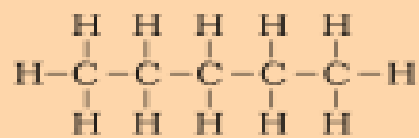
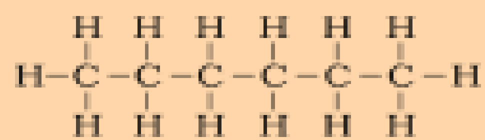








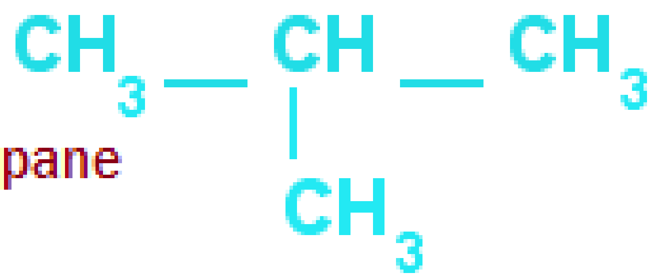
Chains

No. of C atoms	Name	Formula	Structure
1	Methane	CH_4	
2	Ethane	C_2H_6	
3	Propane	C_3H_8	
4	Butane	C_4H_{10}	
5	Pentane	C_5H_{12}	
6	Hexane	C_6H_{14}	

Branches

n-butane $CH_3-CH_2-CH_2-CH_3$

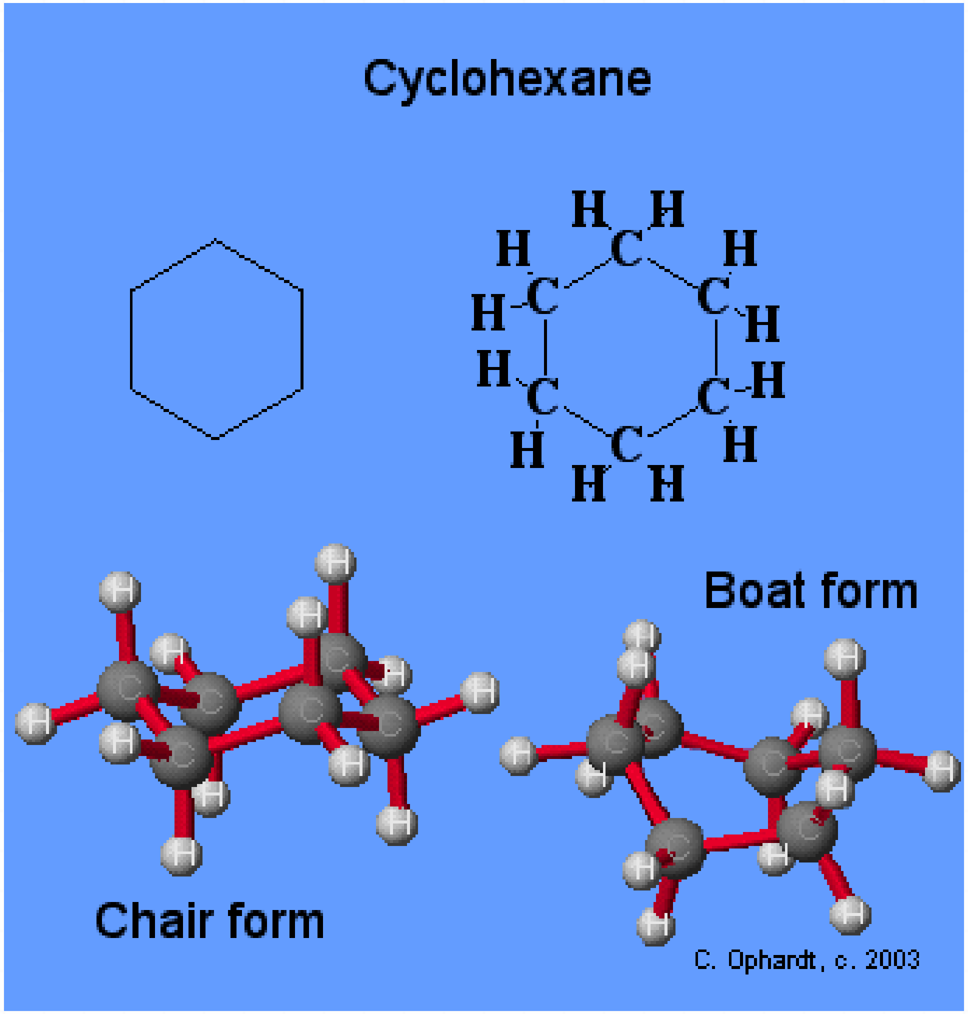
2 methyl propane



- Isomers : Having same molecular formulae but different structural formulae.

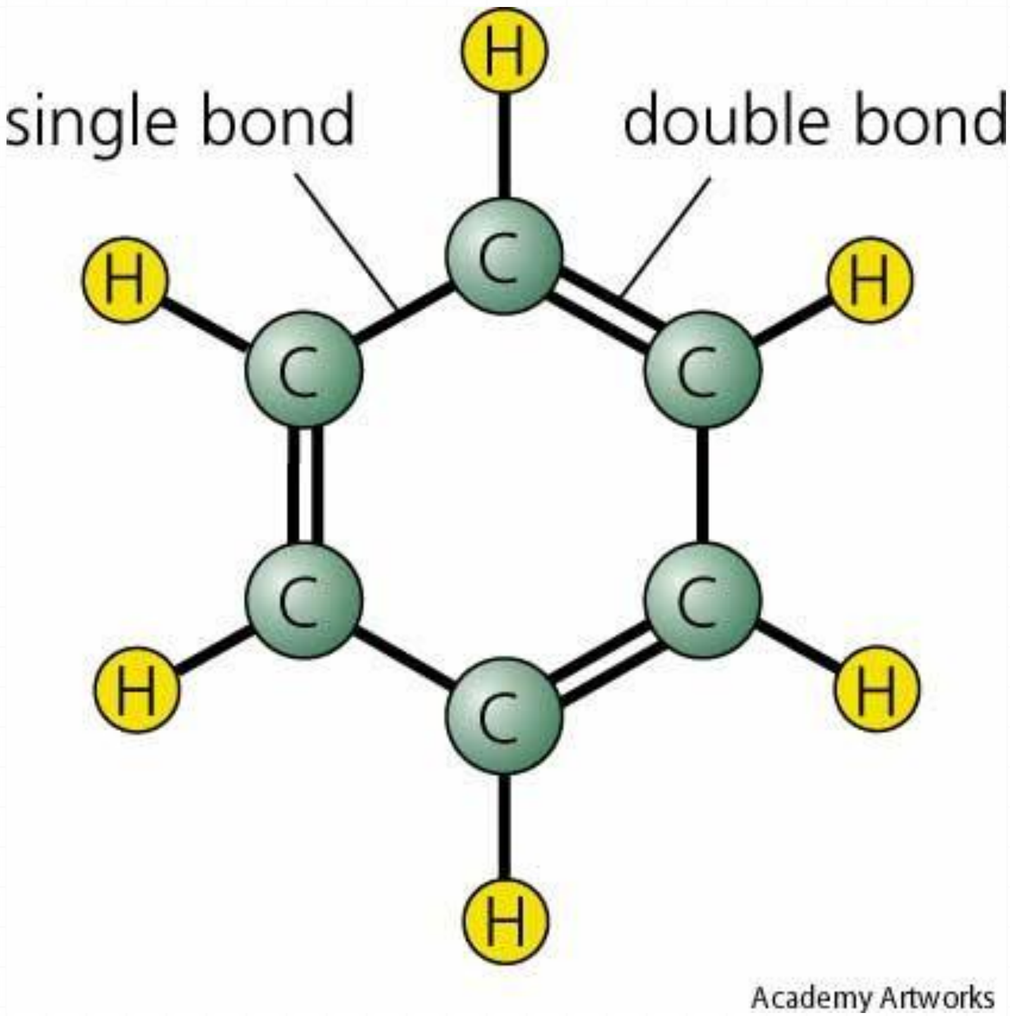
Ring

- Compounds having carbon atoms arranged in the form of a ring.
- Ex: Cyclohexane



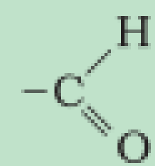
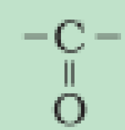
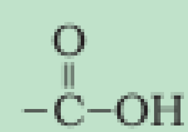
Unsaturated rings

- Benzene



- All those carbon compounds which contain just carbon and hydrogen are called **hydrocarbons.**
- Saturated hydrocarbons are called **ALKANES**
- Unsaturated hydrocarbons which contain one or more double bods are called **ALKENES**
- Those containing one or more triple bonds are called **ALKYNES**

Other groups that bond with carbon [Heterogroups]

Hetero atom	*Functional group*	*Formula of functional group*
Cl/Br	Halo- (Chloro/bromo)	—Cl, —Br (substitutes for hydrogen atom)
Oxygen	1. Alcohol	—OH
	2. Aldehyde	
	3. Ketone	
	4. Carboxylic acid	

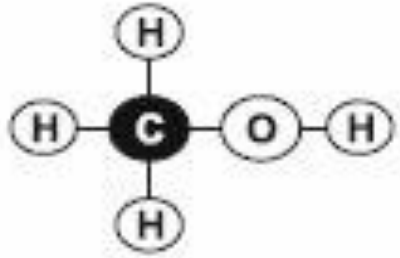
Homologous series

- Series of compounds in which the same functional group substitutes for hydrogen in a carbon chain is called a homologous series.

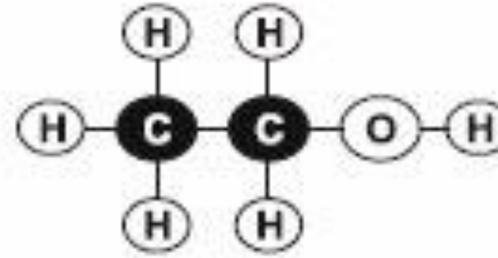
- Compounds of a homologous series have same chemical properties [Determined by functional groups not by the carbon chain]

- Gradation in physical properties is seen [Because of chain length increase

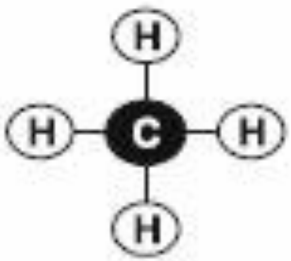
H_2 - Hydrogen



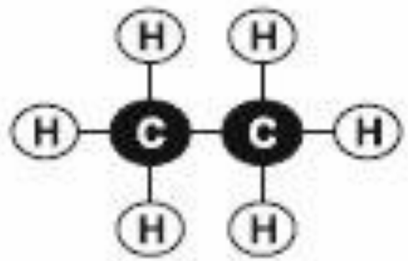
CH_3OH - Methanol



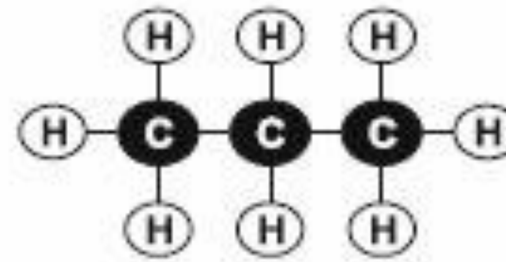
C_2H_5OH - Ethanol



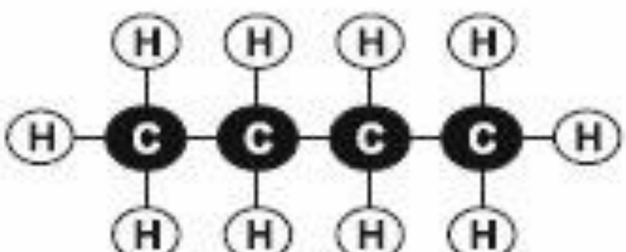
CH_4 - Methane



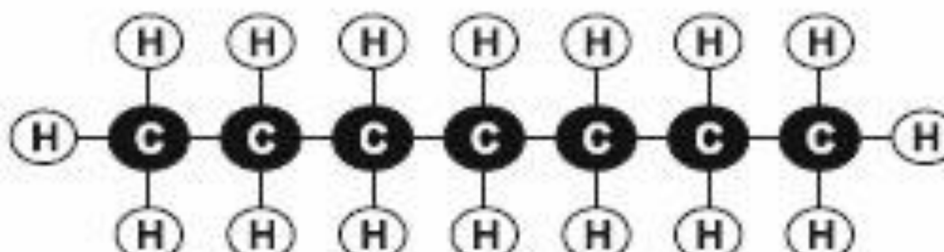
C_2H_6 - Ethane



C_3H_8 - Propane

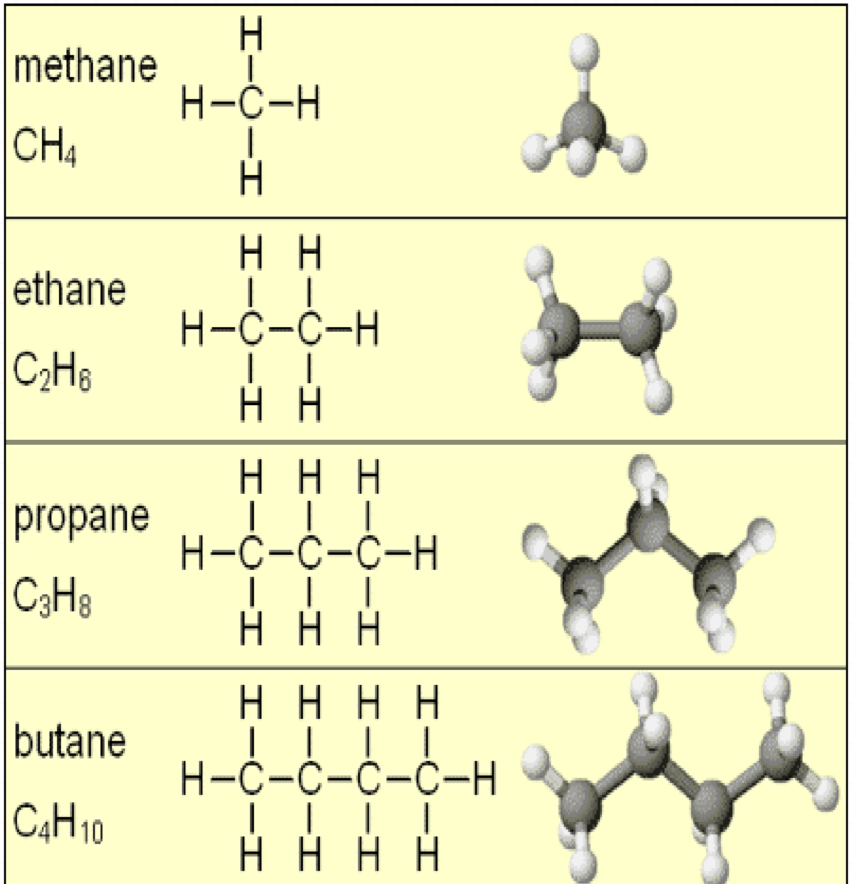


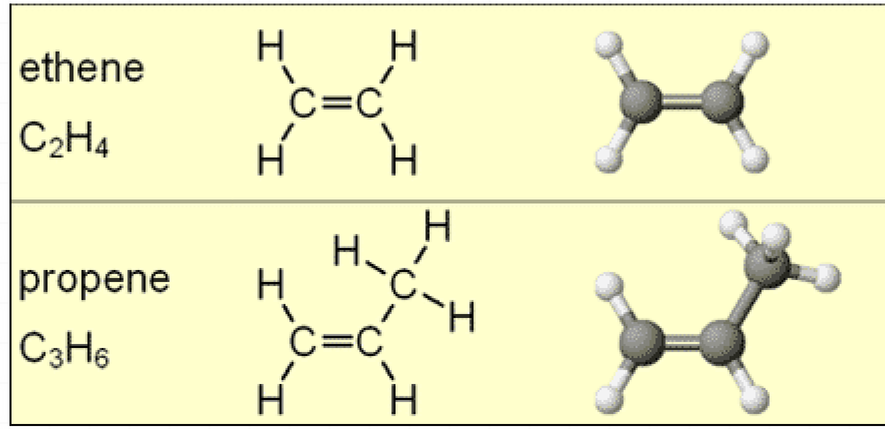
C_4H_{10} - Butane (Normal)

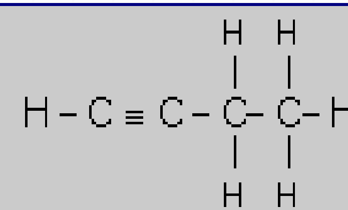
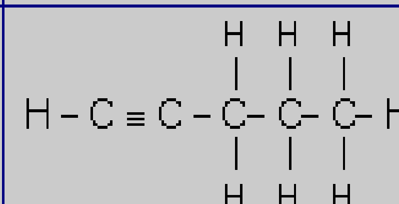


C_7H_{16} - Heptane (Normal)

General formula of hydrocarbons

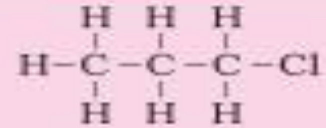
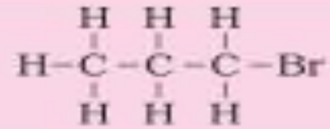
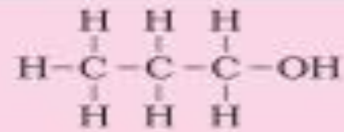
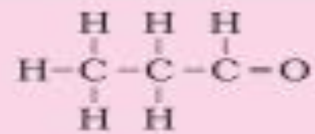
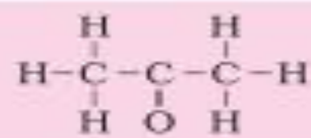
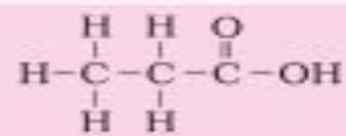
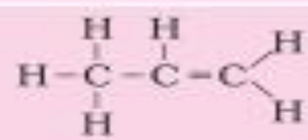
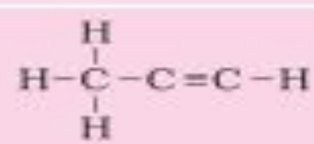




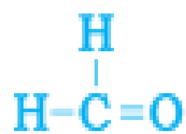
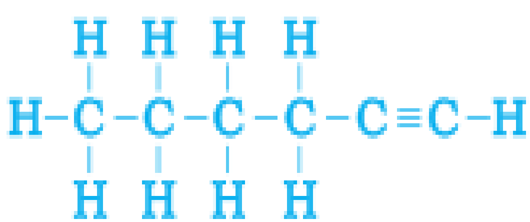
Butyne	C_4H_6	
Pentyne	C_5H_8	

Nomenclature of carbon compounds Rules

- **(i) Identify the number of carbon atoms in the compound.**
- **(ii) In case a functional group is present, it is indicated in the name of the compound with either a prefix or a suffix**
- **(iii) If the name of the functional group is to be given as a suffix, the name of the carbon chain is modified by deleting the final 'e' and adding the appropriate suffix.**
- **(iv) If the carbon chain is unsaturated, then the final 'ane' in the name of the carbon chain is substituted by 'ene' or 'yne'**

Functional group	Prefix/Suffix	Example
1. Halogen	Prefix-chloro, bromo, etc.	 Chloropropane
		 Bromopropane
2. Alcohol	Suffix - ol	 Propanol
3. Aldehyde	Suffix - al	 Propanal
4. Ketone	Suffix - one	 Propanone
5. Carboxylic acid	Suffix - oic acid	 Propanoic acid
6. Double bond (alkenes)	Suffix - ene	 Propene
7. Triple bond (alkynes)	Suffix - yne	 Propyne

QUESTIONS

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. What will be the formula and electron dot structure of cyclopentane?
4. Draw the structures for the following compounds.
   (i) Ethanoic acid (ii) Bromopentane*
   (iii) Butanone (iv) Hexanal.
   *Are structural isomers possible for bromopentane?
5. How would you name the following compounds?
   (i) $CH_3—CH_2—Br$ (ii) 
   (iii) 

CHEMICAL PROPERTIES OF CARBON COMPOUNDS

- **Combustion**
  - Carbon burns in oxygen to give carbon dioxide along with the release of heat and light.
  - Saturated hydrocarbons will generally give a clean flame while unsaturated carbon compounds will give a yellow flame with lots of black smoke.

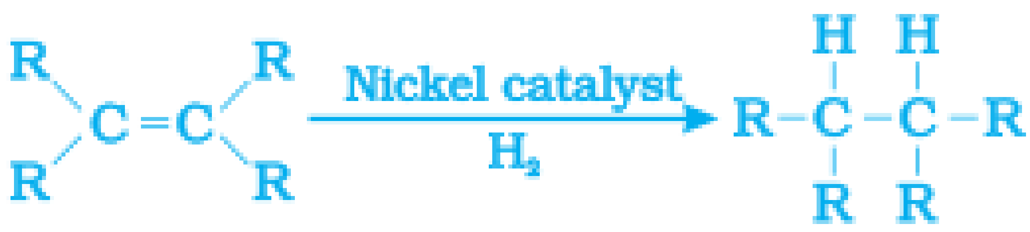
Oxidation

- Carbon compounds can also be oxidised by oxidising agents [adding oxygen to the starting material.
- Alkaline potassium permanganate or acidified potassium dichromate can oxidize alcohols to acids.

$$CH_3-CH_2OH \xrightarrow[\text{Or acidified } K_2Cr_2O_7 \text{ + Heat}]{\text{Alkaline } KMnO_4 \text{ + Heat}} CH_3COOH$$

Addition Reaction

- Unsaturated hydrocarbons add hydrogen in the presence of catalysts such as palladium or nickel to give saturated hydrocarbons.
- This reaction is commonly used in the hydrogenation of vegetable oils using a nickel catalyst.
- Vegetable oils generally have long unsaturated carbon chains while animal fats have saturated carbon chains.



Substitution Reaction

- In the presence of sunlight, chlorine is added to hydrocarbons in a very fast reaction.
- Chlorine can replace the hydrogen atoms one by one.

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

QUESTIONS

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?

SOME IMPORTANT CARBON COMPOUNDS – ETHANOL AND ETHANOIC ACID

- **Properties of Ethanol**
  - Ethanol is a liquid at room temperature
  - Ethanol is commonly called alcohol
  - Because it is a good solvent, it is also used in medicines such as tincture iodine, cough syrups, and many tonics.
  - Ethanol is also soluble in water in all proportions.
  - Consumption of small quantities of dilute ethanol causes drunkenness.
  - Pure ethanol [Absolute alcohol]

Reactions of Ethanol

- (i) Reaction with sodium

$$2Na + 2CH_3CH_2OH \rightarrow 2CH_3CH_2O^-Na^+ + H_2$$

(Sodium ethoxide)

- (ii) Reaction to give unsaturated hydrocarbon:
  - Heating ethanol at 443 K with excess concentrated sulphuric acid results in the dehydration of ethanol to give Ethene

$$CH_3{-}CH_2OH \xrightarrow[H_2SO_4]{\text{Hot conc.}} CH_2 = CH_2 + H_2O$$

Properties of Ethanoic Acid

- Ethanoic acid is commonly called acetic acid and belongs to a group of acids called carboxylic acids.
- 5-8% solution of acetic acid in water is called vinegar and is used widely as a preservative in pickles.
- The melting point of pure ethanoic acid is 290 K and hence it often freezes during winter in cold climates. This gave rise to its name glacial acetic acid.
- Carboxylic acids and mineral acids are different

Reactions of ethanoic acid

- (i) *Esterification reaction:*
  - *Esters are most commonly* formed by reaction of an acid and an alcohol.
  - Ethanoic acid reacts with absolute ethanol in the presence of an acid catalyst to give an ester

$$\underset{\text{(Ethanoic acid)}}{CH_3-COOH} + \underset{\text{(Ethanol)}}{CH_3-CH_2OH} \xrightarrow{\text{Acid}} \underset{\text{(Ester)}}{CH_3-\underset{\underset{O}{\|}}{C}-O-CH_2-CH_3}$$

- Esters are sweet-smelling substances. These are used in making perfumes and as flavoring agents.

- Esters react in the presence of an acid or a base to give back the alcohol and carboxylic acid. This reaction is known as saponification because it is used in the preparation of soap.

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

- (ii) *Reaction with a base:*
- *Like mineral acids, ethanoic acid reacts with* a base such as sodium hydroxide to give a salt (sodium ethanoate or commonly called sodium acetate) and water

$$NaOH + CH_3COOH \rightarrow CH_3COONa + H_2O$$

- (iii) *Reaction with carbonates and hydrogen carbonates:*

$$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$$

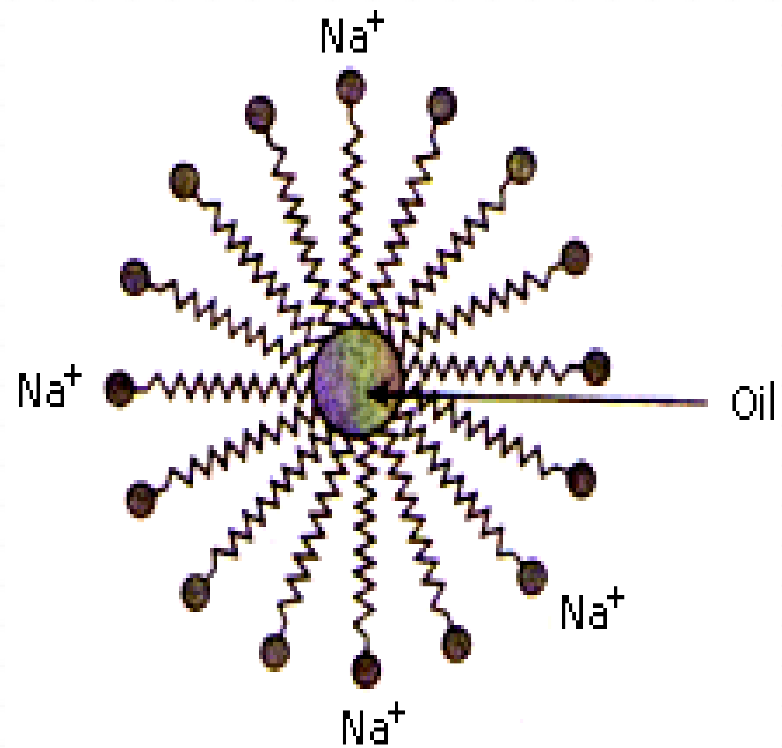
$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$$

QUESTIONS

1. How would you distinguish experimentally between an alcohol and a carboxylic acid?
2. What are oxidising agents?

SOAPS AND DETERGENTS

- The molecules of soap are sodium or potassium salts of long chain carboxylic acids.
- The ionic-end of soap dissolves in water while the carbon chain dissolves in oil.
- The soap molecules, thus form structures called micelles where one end of the molecules is towards the oil droplet while the ionic-end faces outside which forms an emulsion in water.
- The soap micelle thus helps in dissolving the dirt in water and we can wash our clothes clean



Formation of micelles