Carbon and its Compounds

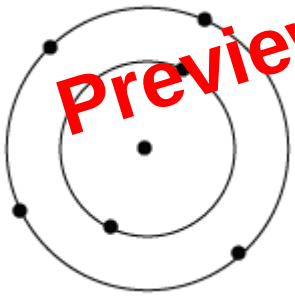
Why Carbon forms Covalent Bonds

We know that a majority of substances used by us daily, from paper and plastics to coal and petrol, are all made up of carbon. Food grains, pulses, medicines, cotton, synthetic fibres, wood etc. are all made up of carbon. Carbon is also a major part of all living things. In air, it is present as carbon dioxide and comprises around 0.03% of the total air.

Let us study about carbon and its bonding in its compound in more detail.

Carbon is a non-metal having the symbol '**C**' and atomic number **six**. Since the atomic number of carbon is six, its electronic configuration is 2, 4. This means that carbon contains two electrons in K shell and 4 electrons in L shell (outermost shell). Hence, it has four electrons in its valence shell.

Since carbon has four electrons in its valence shell, it needs four more electrons to complete its octet. Therefore, it is a tetravalent element.



In order to complete its octet i.e., to attain its noble gas configuration and to stabilize itself, carbon can:

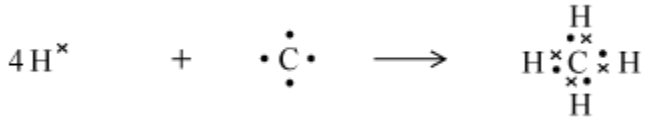
- Either lose four electrons to form C^{4+} or gain four electrons to form C^{4-}. This, however, requires a lot of energy and would make the system unstable.

Therefore, carbon completes its octet by sharing its four electrons with the other carbon atoms or with atoms of other elements.

The bonds that are formed by sharing electrons are known as covalent bonds. Covalently bonded molecules have weak intermolecular forces, but intramolecular forces are strong.

Carbon has four valence electrons and needs four more electrons to complete its octet. Therefore, it is capable of bonding with four other atoms of carbon or atoms of other elements having a valency of 1.

For example, the molecule, methane can be formed with hydrogen (H) atoms that have only one electron in its K shell. To attain the noble gas configuration, it combines with four hydrogen atoms as shown in the figure.



Now, let us study the properties of carbon compounds.

- Covalent bonds are made by atoms by sharing their electrons. Formation of ions does not take place in this process. In addition, these compounds do not have any extra electrons. Hence, covalent compounds are non- conductors of electricity.

- As all organic compounds contain covalent bonds, they also have low melting and boiling points. This becomes evident from the following data:

Compound	**Melting point (K)**	**Boiling point (K)**
Acetic acid	290	391
Chloroform	209	334
Ethanol	156-159	351
Methane	90-91	111

Also, from the above data, it can be inferred that the forces of attraction between the carbon molecules in carbon compounds is not very strong.

Because of their low melting and boiling points, these compounds mostly exist as liquids or gases at room temperature.

Allotropic Forms of Carbon

Carbon is the versatile element present in food, clothes, medicines, papers, etc. In addition, all living structures are carbon based. The earth's crust has only 0.02% carbon in the form of minerals and the atmosphere has 0.03% carbon dioxide. In spite of the small amount of carbon available in nature, the importance of carbon is immense.

Position of carbon in the periodic table

Carbon has an atomic number 6 and an atomic mass as 12 u. It contains 2 and 4 electrons in the K and L shell respectively. It belongs to the group IVA of the periodic table and has a valency of 4.

Occurrence: Carbon occurs in free as well as in combined state.

In free state, carbon occurs as diamond, graphite, and coal. Diamond and graphite are pure forms of carbon while coal is an impure form of carbon in which the percentage of carbon varies from 24% to 90%.

In combined state, carbon occurs in

- bio-molecules such as cellulose, carbohydrates, fats, proteins, etc.
- minerals in the form of carbonates
- calcium carbonate ($CaCO_3$) in lime, marble, and chalk
- magnesium carbonate ($MgCO_3$) in magnesite
- calcium and magnesium carbonate ($MgCO_3.CaCO_3$) in dolomite
- calamine ($ZnCO_3$) as zinc carbonate

Also,

- It is present in large amount in petrol, kerosene oil, diesel oil, grease, and wax.
- Natural gas, marsh gas, petroleum gas, and coal gas contain carbon in the form of its compounds.

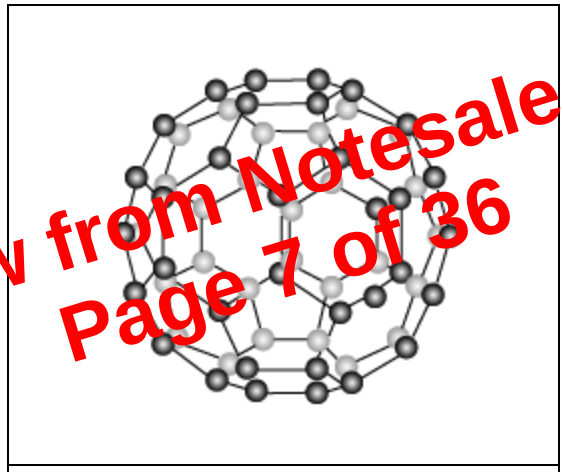
- It is used in making lead pencils.
- It is used in making electrodes.
- It is used as a dry lubricant.
- It is used as a moderator in a nuclear reactor.

Buckminsterfullerene:

It is the third and the most recently discovered allotrope of carbon**.**

Buckminsterfullerene is a cluster of sixty carbon atoms arranged in the form of a football.

It is named after the American architect **Buckminster Fuller,** as it resembled the geodesic dome designed by him. Since it contains sixty carbon atoms, its chemical formula is C_{60}.



Structure of Buckminsterfullerene

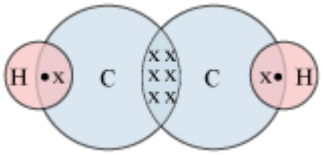
Amorphous Forms of Carbon

What is an amorphous solid?

An amorphous solid is a non-crystalline solid with no well-defined ordered structure.

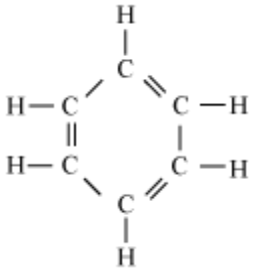
Some amorphous forms of carbon:

- **Charcoal**: It is produced from the bones of animals, combustion of wood etc.
- **Lampblack or soot**: It is produced from the incomplete combustion of hydrocarbons.



The chains, branches, and rings that carbon forms by forming bonds with it can be saturated as well as unsaturated.

For example, benzene is a six-member ring that contains three double bonds. Thus, it is an unsaturated hydrocarbon



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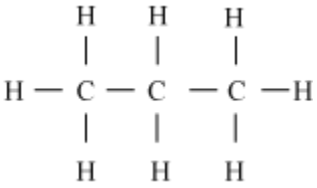
Organic compounds and Homologous Compounds

The number of carbon compounds is so vast that there is only branch of chemistry dedicated only to the study of carbon and its compounds. This branch is known as **organic chemistry**.

The compounds of carbon having only single bonds between the carbon atoms are called saturated compounds and those that contain a double or a triple bond between any two carbon atoms are known as unsaturated compounds.

For example, a molecule of propane (C_3H_8) contains two single bonds between the carbon atoms.



There are two main groups of hydrocarbons:

Aliphatic hydrocarbons:

- **Laboratory preparation**: By oxidation of ethanol or ethanal (acetaldehyde) using acidified potassium dichromate solution
  - $\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow{[O]} \underset{\text{Ethanal}}{CH_3CHO} \xrightarrow{[O]} \underset{\text{Ethanoic acid}}{CH_3COOH}$
- **Industrial preparation**:
  - From acetylene using concentrated H_2SO_4 and $HgSO_4$
    - $\underset{\text{Ethene (Acetylene)}}{C_2H_2} + H_2O \xrightarrow[60\,^\circ C]{40\%\ H_2SO_4,\ 1\%\ HgSO_4} \underset{\text{Ethanal (Acetaldehyde)}}{CH_3CHO}$

    $\underset{\text{Ethanal (Acetaldehyde)}}{2\ CH_3CHO} + O_2 \xrightarrow[\text{Manganous acetate}]{\Delta} \underset{\text{Ethanoic acid (Acetic acid)}}{2\ CH_3COOH}$
  - From catalytic oxidation of ethanol over platinum rod
    - $\underset{\text{Ethanol}}{C_2H_5OH} + O_2 \xrightarrow[Pt]{300\,^\circ C} \underset{\text{Ethanoic acid (Acetic acid)}}{CH_3COOH} + H_2O$

Physical properties

- It is a colourless, pungent smelling liquid.
- The melting point of ethanoic acid is 290 K. This is below room temperature. Thus, it freezes during winters. It looks similar to ice when it freezes. Therefore, it is also known as glacial acetic acid.
- It boils at a temperature of 118 °C.
- It is miscible with water, alcohol and ether in all proportions. It is hygroscopic in nature.

Chemical properties

- **Acidic nature**: Acetic acid is a weak acid. The following reactions prove the acidic nature of acidic acid.
- It turns blue litmus red.
- It reacts with active metals such as Zn and Mg to evolve hydrogen gas.
  - $\underset{\text{Ethanoic acid (Acetic acid)}}{2\ CH_3COOH} + Zn \longrightarrow \underset{\text{Zinc acetate}}{(CH_3COO)_2Zn} + H_2(\uparrow)$

- **Reaction with alcohol or esterification reaction**: The reaction of a carboxylic acid with an alcohol to form an ester is known as **esterification reaction**.