# Carbon & Its Compounds

Carbon is the $15^{th}$ most abundant element found on earth and the second most abundant element in the human body since it easily merges with different elements and forms compounds.

**Occurrence of Carbon**

Carbon occurs in free and combined states:

- Free state: coal, diamond, graphite
- Combined state:
    - As $CO_2$ in the atmosphere, water bodies (in dissolved form)
    - As hydrocarbons in petroleum, natural gas and their derivatives (wax, soap, detergents, plastics, paper and perfumes)
    - In plants and animals as carbohydrates, fats, proteins, vitamins
    - In inorganic compounds as carbonates and bicarbonates of metals
    - In natural and artificial fibers like silk, jute, cotton, polyester, rayon and nylon

The study of carbon its derivatives compounds is called organic chemistry

**Allotropy of Carbon:** The occurrence of an element in more than one form with same chemical properties but different physical properties are called allotropy and the different forms are called allotropes.

The allotropes of carbon are classified in three states:

Crystalline form, Amorphous form and Fullerene

**Crystalline Forms of Carbon**

| Property | Graphite | Diamond |
|---|---|---|
| Natural formation | | Action of high pressure and temperature on carbon in the earth at depths of 150 km and brought to surface by volcanic eruptions. |
| Nature | Greyish black, opaque, metallic luster | Transparent, colourless (impurities impart color) |
| Density | 2.39 $g/cm^3$ | 3.5 $g/cm^3$ |
| Hardness | Soft and greasy | Hardest substance known |
| Conduction | Good conductor of heat and electricity | Bad conductor of heat and electricity |
| Melting point | High melting point (3700°C), stable to heat | Stable to heat, but prolonged heating can change diamond into graphite |
| Refractive index | Low | High refractive index of 2.5 makes diamond spark |
| Solubility | Insoluble, but makes black mark on paper | Insoluble in any solvent |

**Uses of graphite**

- As lubricant
- As electrodes in electric furnaces
- To make crucibles for melting metals and carbon brushes for electric motors
- Pencil leads are made by mixing graphite with clay

- As moderator in nuclear reactors

**Uses of diamonds**

- As a gem in jewels
- Cutting and drilling rocks, glass or other diamonds
- Tips of drills in boring machines and needles in microsurgery and in LP record players
- Radiation proof windows in space satellites

**Amorphous form of carbon**

- **Charcoal**

The three main types of charcoal are wood charcoal, bone charcoal and sugar charcoal.

Wood Charcoal

- Preparation: Wood is heated in a limited supply of air
- Physical properties:
    - Soft, black, porous (porosity helps it to float on water even though it is heavier)
    - Brittle
    - Tasteless
    - Bad conductor of heat and electricity
    - Allows surface absorption (adsorption) of gases, liquids and solids
    - Adsorption of charcoal can be increased by heating it up to 900°C to increase porosity and the holding capacity of the gas. This is activated charcoal.

Chemical Properties:

- Action of non-metals:
    - $C + O_2 \rightarrow CO_2$ + Heat (Burns without flame)
    - $C + O_2 \rightarrow CO$ (Limited supply of air)
    - $C + 2H_2 \rightarrow CH_4$
    - $C + 2S \rightarrow CS_2$
- Action of metals:
    - $Ca + 2C \rightarrow CaC_2$ (Occurs at high temperatures)
- Reducing action of charcoal: Charcoal has a high affinity for oxygen which makes it a good reducing agent

- $ZnO + C \rightarrow Zn + CO$
- $PbO + C \rightarrow Pb + CO$
- $C + H_2O \rightarrow (CO + H_2)$. This mixture is called water gas
- $C + 2H_2SO_4 \rightarrow CO_2 + 2SO_2 + 2H_2O$
- $C + 4HNO_3 \rightarrow CO_2 + 4NO_2 + 2H_2O$
- $SiO_2 + 3C \xrightarrow{\text{Electric spark}} SiC + 2CO_2$

Uses of wood charcoal

- Smokeless fuel
- Reducing agent in metallurgy
- Making explosives like gun powder
- As adsorbing agent in gas masks, digestive tablets, filters and sieves, and sugar syrup (to decolorize it)

<u>Sugar Charcoal</u>

- It is the purest form of charcoal
- $C_{12}H_{22}O_{11} \xrightarrow{Heat} 12C\ (sugar\ charcoal) + 11H_2O$

Uses of Sugar Charcoal

- As reducing agent to extract metals from their oxides
- To decolourise coloured solutions
- To make artificial diamonds

<u>Bone Charcoal</u>

- Bone charcoal is obtained by destructive distillation of bones
  - Products created: Bone charcoal (containing calcium phosphate), bone oil and pyridine
- Bone black is obtained when bone charcoal and hydrochloric acid (HCl) are mixed
  - Products created: Particulate carbon and calcium phosphate in solution
  - When this solution is filtered, bone black/ivory black is obtained

Uses of Bone Charcoal

Bone charcoal is used:

- To decolourise sugar syrup

- In making phosphorus compounds
- To filter aquarium water
- To remove excess fluoride from water
- As black pigment in painting

**Lamp Black (Soot)**

Preparation:

- Carbon-rich compounds like turpentine or kerosene oil are heated in a limited supply of air
- A smoky flame with free carbon is created
- Damp blankets collect the free carbon
- Collected powder is lamp black

Uses

- Shoe polish
- Carbon paper
- Printing ink
- Black paint
- Cosmetics – eye shadow, eye liner
- Tyres
- Gunpowder etc.

**Gas Carbon:**

Gas carbon is obtained from:

- Destructive distillation of coal
- Heating petroleum products at high temperatures in closed containers
- Carbon particles deposited on walls of container (gas carbon)

Uses: Gas carbon is a good conductor of electricity and is used to make electrodes in dry cells and carbon rods for arc lamps

**Fuels:** Substances that burn in air/oxygen to release a large amount of heat energy with or without a flame are called fuels. They are generally hydrocarbons – compounds made of carbon and hydrogen only.

**Calorific value of fuel:** The amount of energy produced when 1kg of fuel is completely burnt. It is expressed in kJ/kg or cal/g.

**Types of fuels:** Fuels are classified on the basis of sources and the state they are available in.

- Classification according to sources:
    - Primary fuels: Are obtained directly from nature. Example: Coal, wood, and natural gas
    - Secondary fuels: Are obtained by processing primary fuels. Example: Petrol, kerosene, coke
- Classification according to state: Solid, liquid or a gaseous state.
    - Solid fuels: Coal, wood, coke, charcoal
    - Liquid fuels: Kerosene, diesel, petrol
    - Gaseous fuels: Methane, coal gas, LPG

Depending on the type of fuels, they are also characterised by the following:

- The ignition temperature
- Type of storage used
- Residues they produce
- Mode of transport

**Petroleum**

Petroleum or crude oil is drilled from earth's crust. It undergoes fractional distillation to yield several useful fuels including petrol, diesel, kerosene and LPG

Methane – An Ideal Gaseous Fuel

Methane is a colourless, odourless and flammable gas which is the main constituent of natural gas. Methane can be found as the main constituent of:

- Natural gas: Found along with petroleum reserves (in the upper layers)
- Coal gas: found in coal mines and also formed during destructive distillation of coal
- Marsh gas: Slow decomposition of vegetation in marshy areas leads to formation of marsh gas
- Biogas: When animal and plant matter undergo anaerobic bacterial decomposition and fermentation, biogas is obtained
    - Manure is obtained as a by-product
    - It can be produced commercially on farms using biogas plants

**Properties:**

- Methane is a gaseous fuel which burns with a bluish flame and has high calorific value
  - $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + heat
- With insufficient oxygen, it forms carbon monoxide and water
  - $2CH_4 + 3O_2 \rightarrow 2CO + 2H_2O$
- It can be easily ignited and shows complete combustion
- It can be directly supplied to households or industries by pipes
- CNG or compressed natural gas is being increasingly used as fuel because it does not cause much pollution and is cheaper than petrol and other fuels

Combustion or Burning

**Difference between Combustion and Burning**

- **Combustion:** When a substance burns in air to give out heat it is called combustion.
- **Burning:** If it is accompanied flame it is called burning.
- **Fire:** A large flame, along with heat, light and smoke constitutes a fire.
- Examples:
  - Digestion of food is a slow combustion process where food is oxidised and energy is produced.
  - Respiration in living organisms is a special type of combustion where food is burnt in the presence of oxygen to release energy in the form of ATP.
  - $(C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O)$

**Combustible and Non-combustible Substances**

- Materials or substances which undergo burning or combustion are called combustible. All fuels are combustible, but all combustible substances need not be fuels.

  Example: Paper is combustible but cannot be used as a fuel.
- Materials which cannot burn or catch fire are called non- combustible. Example: Clay

**Conditions for Combustion**

- **Combustible Substance:** A material which can undergo combustion (fuel).

- **Supporter of Combustion:** Oxygen must be present because combustion is actually oxidation of fuels. That is why a candle will be put off if burned in a closed container where air cannot enter.
- **Ignition Temperature:** The lowest temperature at which a substance catches fire.
    - For example, kerosene can catch fire at low temperatures, while wood needs to be heated to a higher temperature before it can burn. That is why kerosene is poured over wooden logs before they are burnt.
    - Kerosene burns to produce heat which in turn heats up the wood so that it attains its ignition temperature.
    - Substances like petrol, LPG and alcohol have very low ignition temperatures and are called inflammable substances.
    - Water can be boiled in a paper cup as long as the heat supplied is transferred to the water by conduction and the paper does not attain its ignition temperature.

**Types of Combustion**

The different types of combustion are:

- **Slow combustion:** Burning occurs at a moderate rate and some fuel may be left unburnt. Example, burning of coal, wood etc.
- **Spontaneous combustion:** Ignition of a substance without any external cause.

  Example, phosphorus and sodium can catch fire just by exposure to air.
- **Rapid combustion:** When a substance burns quickly, it produces heat and light. Example, burning of magnesium ribbon, burning of LPG or CNG.
- **Explosion:** A sudden reaction with production of heat, light and sound. Example, fire-crackers.