Carbon and Its Compounds

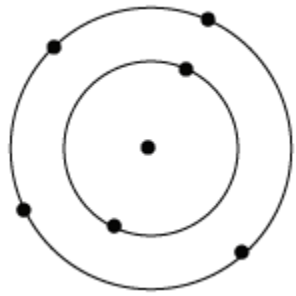
Why Carbon forms Covalent Bonds

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:

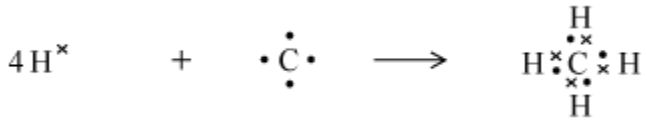
- Either lose four electrons to form $\mathbf{C^{4+}}$ or gain four electrons to form $\mathbf{C^{4-}}$. This, however, requires a lot of energy and would make the system unstable.

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.

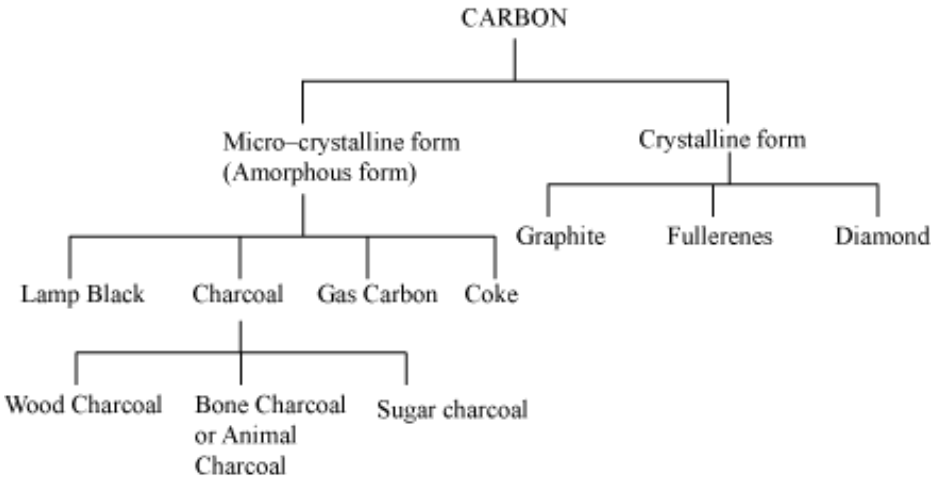
Allotropy: The phenomenon due to which an element exhibits different physical forms is called allotropy.

Reasons for allotropy are different arrangement of atoms in each allotrope, different methods by which each allotrope is prepared, and different amount of energy associated in the formation of each allotrope.

Let us study about the different allotropes of carbon.

Carbon is considered to have two main kinds of allotropes
i.e., **crystalline** and **amorphous**.

Following is a classification of the crystalline and amorphous forms of carbon:



Well known allotropes of carbon are:

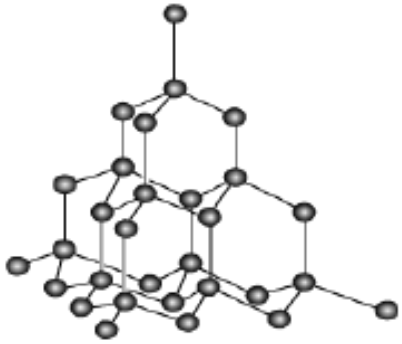
1. **Diamond**
2. **Graphite**
3. **Buckminsterfullerene**

Among these, diamond and graphite have been known for a very long time and are quite common. Buckminsterfullerene, on the other hand, was discovered just recently. Thus, not much is known about it.

Crystalline forms of carbon

Diamond

Crystal structure: In diamond, each atom of carbon of the given crystal unit is surrounded by four other carbon atoms, which are joined by covalent bonds, such that they form a regular tetrahedron. The diamond crystal is a compact structure in which atoms of a single unit lie in different planes. Thus, the atoms cannot slip because of their different positions in different planes and hence, diamond is the hardest naturally occurring substance.



Physical properties: The physical properties of diamond are:

- It is the hardest naturally occurring substance.
- Pure diamond is colourless, transparent, but brittle solid.
- It is chemically inert under ordinary conditions as there are no free electrons available.
- It is a good conductor of heat but is does not conduct electricity.
- Its refractive index is 2.42.
- Its specific gravity is 3.52.
- It is the densest form of carbon, its density being 3.5.
- It is transparent to X-rays, ultraviolet rays, and visible light rays.

Chemical properties: The chemical properties of diamond are:

- Action of air or oxygen: When diamond is heated in air, it catches fire at 800ºC. It does not leave behind any ash and therefore, it is the purest form of carbon.

$$C\,(s) + O_2\,(g) \xrightarrow{800\ ^\circ C} CO_2\,(g)$$

- Action of sodium carbonate: When diamond is heated very strongly with solid sodium carbonate, it reacts to form sodium oxide and carbon monoxide.

$$Na_2CO_3\,(s) + C\,(s) \xrightarrow{heat} Na_2O\,(s) + 2CO\,(g)$$

Uses: The various uses of diamonds are:

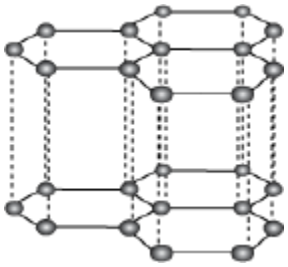
- They are generally used for making ornaments.
- They are used for cutting glass as well as diamonds.
- They are used for making dies for drawing wires.
- They are used as bearings in watches.
- They are used in making laser beam in electronics.
- Diamond is a poor conductor of electricity.

Can you tell why?

All 4 valence electrons in diamond are involved in bonding. Therefore, these are immobile and do not conduct.

Graphite

Crystal structure: In graphite, atoms of a single crystal are arranged in a hexagonal ring in a single plane. The bonds between the carbon atoms of two single crystals in the parallel planes are weak. Thus, one plane can easily slide over another plane by applying pressure. This is why graphite is soft and can be used as a lubricant.



Physical properties: The physical properties of graphite are:

- It is dark grey solid, having lustre.
- It is a very good conductor of heat and electricity.
- It is opaque to light.
- Its specific gravity is 2.2.
- It is opaque to X-rays, ultraviolet rays, and visible light rays.

Chemical properties: The chemical properties of graphite are:

- Action of air or oxygen: Graphite does not burn in air. However, if graphite is heated in air, then it catches fire at 700^{o}C and forms a mixture of carbon dioxide and carbon monoxide.

$$3C\ (s) + 2O_2\ (g) \xrightarrow{700\ ^{\circ}C} CO_2\ (g) + 2CO\ (g) + \Delta T$$

- Action of sodium carbonate: Like diamond, graphite also form sodium oxide and carbon monoxide when heated with solid sodium carbonate.

$$Na_2CO_3\ (s) + C\ (s) \xrightarrow{\text{fuse}} Na_2O\ (s) + 2CO\ (g)$$

Uses: The various uses of graphite are:

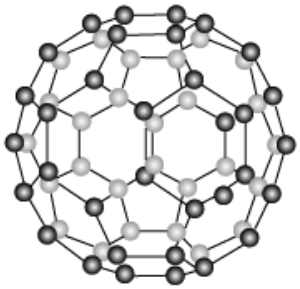
- It is used in making lead pencils.
- It is used in making electrodes.
- It is used as a dry lubricant.
- It is used as a moderator in a nuclear reactor.

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.
- **Coal**: It is formed by decomposition of dead remains of plants when they got buried in the land owing to the high temperature and pressure conditions present there. Based on the content of carbon present, normally three types of coal deposits exist and these are as follows.
- **Lignite** with 25-35% of carbon content.
- **Anthracite** with carbon content of more than 80%.
- **Bituminous coal** with 60-80% carbon
- **Peat** with less than 60% carbon content.
- Uses of Coal:

- As a fuel for cooking, in industries
- For heating of bricks
- In thermal power plants to generate electricity
- **Coke**: It is a tough, porous, black substance. It is an almost pure form of carbon obtained from coal.
- Ues of coke:
- In the manufacture of steel
- In the extraction of many metals.

Coal and Its Formation

Most of us have seen coal being used in some way or the other. It is a hard, stone-like blackish substance that releases heat and smoke on burning. It is used in traditional fireplaces. In earlier times, coal was used to run rail engines.

Coal is mainly carbon and is primarily used as a source of energy.

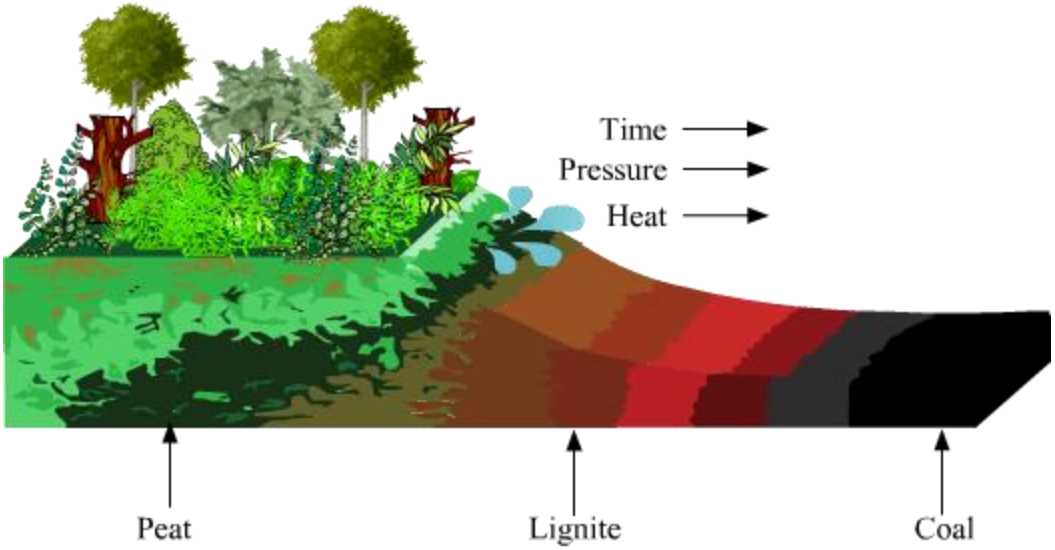
How and from where do we get coal?

Millions of years ago, the remainings of plants and animals got buried under the earth's crust.

They were subjected to very high temperature and pressure, and micro-organisms acted on them. Due to this, the gaseous substances were released from these remainings into the atmosphere.

The left-behind was mainly composed of carbon compounds, which was again subjected to tremendous pressure in the earth's crust.

Due to this high pressure, the liquid substances drained away and the remaining mineral got solidified into compact rock. This solid compound is termed coal.



First, peat coal is formed. It is again compressed between layers of sediment and forms lignite coal. This lignite coal gets converted into anthracite coal due to high pressure and temperature.

It takes millions of years for coal to form. It cannot be renewed or regenerated again in a short span of time. Also, it cannot be reused.

Coal reserves are limited and are expected to vanish in the near future. Because of this, coal is regarded as a non-renewable resource of energy.

How can we define coal into many categories?

80% of the energy that we require are obtained from organic fuels. Coal is graded on the basis of the heat that can be obtained from it.

Types of coal

1.Anthracite coal − It contains 80% carbon. It is the most widely used form of coal.

2.Bituminous coal − It contains 60% carbon. It is a relatively soft form of coal.

3.Lignite coal − The percentage of carbon in this coal is 22%. It is also referred to as brown coal.

4. Peat− It is a geologically young coal and has the lowest carbon percentage, 11%.

Products of Coal and Their Characteristics

Coal is a hard and black substance that is used for burning to generate heat

The uses of coal are

- As a fuel for cooking
- For heating of bricks
- As an industrial fuel
- In railway engines to produce steam

- In thermal power plants to generate electricity

The products that are obtained after processing coal are:

- Coke
- Coal tar
- Coal gas

Let us watch how these substances are obtained from coal:

The following table summarises the characteristics and uses of the products that are obtained from coal

Product	Characteristics	Uses of the product
Coke	A tough, porous, black substance. It is almost pure form of carbon.	It is used in the manufacture of steel and in the extraction of many metals.
Coal tar	A black, thick liquid with an unpleasant odour. It is a mixture of about 200 substances.	It is used in the manufacture of synthetic dyes, drugs, naphthalene balls, explosives, plastics, perfumes, paints, photographic and roofing materials etc. Now, bitumen is used instead of coal-tar for making of roads.
Coal gas	It is a gas that is formed during the process of obtaining coke from coal.	Coal gas was first used to illuminate street lights! Now it is used in industries as a fuel for generating heat.

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 are:

- Charcoal
- Lampblack or soot
- Coal

Here, we will study about coal and charcoal.

Charcoal

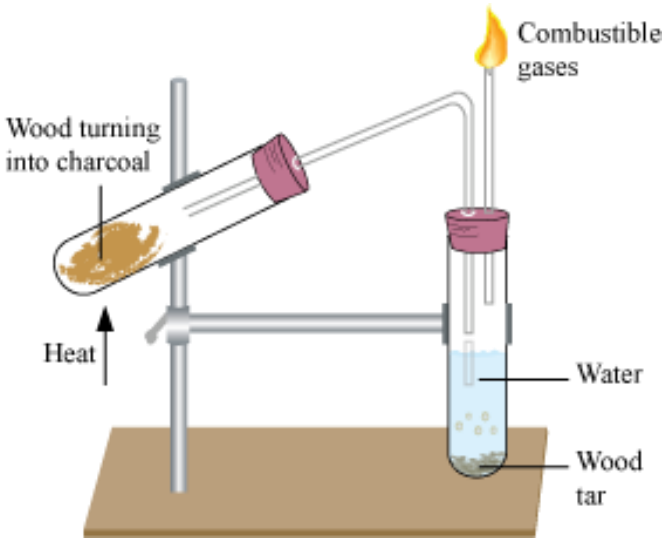
Charcoal is the grey porous substance formed when a carbon-containing compound is heated in a limited supply of air. The following are some kinds of charcoal.

- Wood charcoal
- Sugar charcoal
- Animal or bone charcoal

Wood charcoal

Preparation

The destructive distillation of dry wood results in the formation of wood charcoal.



Physical properties

- It is grey, porous, and brittle solid.

- It floats on water. This is because a large amount of air is trapped in its pores.
- It is a bad conductor of heat and electricity.
- It adsorbs gases, liquids, and solids, which can be released by heating.
- It has specific gravity between 1.5 and 1.9.

> **Curiosity Corner**
>
> Adsorption is the physical phenomenon of accumulation of atoms or molecules on the surface of a material.

Chemical properties

- Reaction with oxygen

  On heating in a free supply of oxygen, it catches fire at 400°C and combines to form carbon dioxide, liberating a large amount of heat.

  $C + O_2 \rightarrow CO_2 + Heat$

  In an insufficient supply of oxygen, it forms carbon monoxide, which is very poisonous in nature.

  $2C + O_2 \rightarrow 2CO$

- Reaction with sulphur

  It reacts with vapours of sulphur to form carbon disulphide.

  $C + 2S \rightarrow CS_2$

- Reaction with hydrogen

  It combines with hydrogen at high temperature to form methane.

  $C + 2H_2 \rightarrow CH_4$

- Reducing nature

When super-heated steam is passed through while hot charcoal, it reduces steam to **water gases** (a mixture of carbon monoxide and hydrogen).

$$C + H_2O_{(Steam)} \longrightarrow \underset{\text{Water gas}}{CO + H_2}$$

It reduces metal oxides to the corresponding metals.

$$CuO + C \longrightarrow Cu + CO$$
$$ZnO + C \longrightarrow Zn + CO$$
$$FeO_3 + 3C \longrightarrow 2Fe + 3CO$$

Oxides of calcium and silicon are reduced to corresponding carbides.

$$CaO + 3C \xrightarrow{1000^\circ C} CaC_2 + CO$$
$$SiO_2 + 3C \longrightarrow SiC_2 + 2CO$$

Uses

- It is an excellent household fuel because of its high calorific value, low ignition temperature, and less polluting nature. It is generally used to keep room warm in winter.
- It is widely used in production of metals due to its reducing nature.
- It is used in gas marks, water filters, antacid tablets, in ayurvedic dental powders due to its adsorption capacity.
- It is used in gun powder, which is a mixture of charcoal, potassium nitrate, and sulphur.

Sugar Charcoal

Preparation

It is prepared by destructive distillation of sugar.

It is the purest form of amorphous carbon.

Uses

- It is mainly used in manufacturing of artificial diamonds.
- It is also used in decolourising sugarcane juice during the manufacture of sugar.

Animal or Bone Charcoal

Preparation

It is prepared by destructive distillation of bones.

Physical properties

- It contains 10% carbon and 90% impurities such as calcium phosphate and carbonate.
- It is porous in nature.
- It adsorbs colouring matter.

Uses

- It is used in decolourising sugarcane juice during the manufacture of sugar.
- It is used to purify organic liquids.
- It is used in paint.

Lampblack or Soot

Preparation

When hydrocarbons such as petrol, kerosene, paraffin, naphthalene, which contain a large amount of carbon, are burnt in a limited supply of air or oxygen, they burn giving off smoke containing large amounts of free carbon. When the smoke is allowed to cool, carbon settles down as black powder. This black powder is called lampblack or soot.

Physical Properties

- Lamp black is light black, soft powder.
- It has an oily feel as it contains a small amount of liquefied vapours of hydrocarbon.

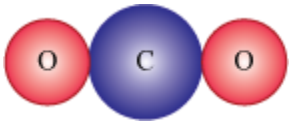
Uses

- In making printing ink and carbon paper.
- As a filter in types to increase their durability
- In shoe polish and kajal

Occurrence and Preparation of Carbon Dioxide

Carbon dioxide (chemical formula: CO_2) is a chemical compound composed of two atoms of oxygen, which are covalently bonded to a carbon atom.

It was first described as **carbonium** by **Van Helomont**. He noticed when charcoal is burned in air, it produces this gas. It was first prepared by **Joseph Black** by heating magnesium carbonate. He called it fixed air.



Occurrence

Carbon dioxide occurs in free as well as in combined state.

It is found in air in free state. A large amount of carbon dioxide is found dissolved in water bodies such as oceans, lakes, etc. It accumulates in dry wells, mines, or caves near lime kilns.

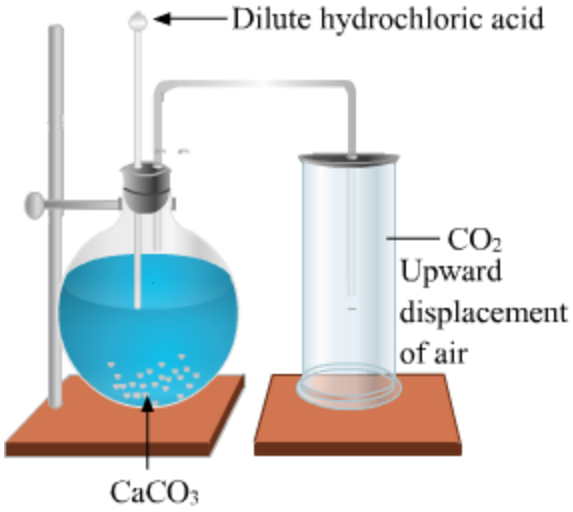
In combined state, it is found on the surface of earth, locked up in the form of mineral carbonates. For example, limestone and magnesite

Preparation of carbon dioxide

Carbon dioxide can be prepared by a number of methods. Some of them are discussed below.

- Carbon dioxide is formed by treating any metallic carbonate with dilute mineral acids. Let us perform an experiment for this.

  Take a round bottom flask, a stand, gas delivery tubes, gas jars and thistle funnel. Assemble them as shown in the figure.



Preparation of carbon dioxide

Take calcium carbonate ($CaCO_3$) in the flask and start adding dilute HCl through the thistle funnel. When the reaction between $CaCO_3$ and HCl takes place, CO_2 is produced which is collected in the jar by upward displacement of air. The reaction involved is shown below:

$$CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

Sulphuric acid can also be used in place of hydrochloric acid for the production of carbon dioxide.

$$CaCO_{3(s)} + H_2SO_{4(aq)} \longrightarrow CaSO_{4(aq)} + CO_{2(g)} + H_2O_{(l)}$$

- Carbon dioxide is also formed on heating carbonates of metals other than alkali metals.

$$MgCO_{3(s)} \xrightarrow{\Delta} MgO_{(s)} + CO_{2(g)}$$
$$CuCO_{3(s)} \xrightarrow{\Delta} CuO_{(s)} + CO_{2(g)}$$

- Carbon dioxide is also formed when charcoal or hydrocarbons are burnt in the air.

$$C_{(s)} + O_{2(g)} \xrightarrow{\Delta} CO_{2(g)}$$
$$CH_{4(g)} + O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(l)}$$
$$C_2H_5OH_{(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$$
$$C_2H_{4(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 2H_2O_{(l)}$$

- Carbon dioxide is also formed when metal hydrogen carbonates are treated with dilute acids.

$$Ca(HCO_3)_{2(s)} + 2HNO_{3(aq)} \xrightarrow{\Delta} Ca(NO_3)_{2(aq)} + 2H_2O_{(l)} + 2CO_{2(g)}$$

Properties and Uses of Carbon Dioxide

Carbon has an atomic number 6 and an atomic mass of 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. Let us now discuss the physical properties of carbon dioxide.

Physical Properties

- Carbon dioxide exists as a colourless and odourless gas with a sour taste.
- It is heavier than air as the vapour density of carbon dioxide is higher than water.
- It is a non-poisonous gas.
- It is soluble in water, ethanol, and acetone.
- Carbon dioxide can be solidified at room temp (20°C) and pressure of 70 times the atmospheric pressure to form solid carbon dioxide.
- The melting point of carbon dioxide is 55.6ºC and it has a density of 1.977 g/L.

Chemical Properties of Carbon Dioxide

Carbon dioxide is not a very reactive gas and does not react easily. However, it does react with some of the substances. Here, we will study some chemical properties of carbon dioxide.

- Reaction of carbon dioxide with calcium oxide

Carbon dioxide reacts with calcium oxide, i.e. quicklime, to form calcium carbonate. The reaction is endothermic and reversible.

$$CaO + CO_2 \xleftrightarrow{\text{Heat}} CaCO_3$$

- Reaction with lime water

Limewater is used in the laboratories for detecting the presence of carbon dioxide gas. It is also used in the preparation of sweets such as *petha* and skin lotions.

When limewater is exposed to the air, a white crust is seen floating on the surface, which is calcium carbonate. Since the surface tension of the water is sufficient to support its weight, it floats.

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O$$

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

- Carbon dioxide is acidic in nature. Therefore, it turns blue litmus paper red.
- Action with water

  Carbon dioxide dissolves in water to form carbonic acid (H_2CO_3).

  $$CO_2 + H_2O \longrightarrow H_2CO_3$$

- Action with alkali

  It combines with alkali to form metal carbonates.

  $$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

- Carbon dioxide gas is neither combustible nor does it support combustion.
- Action with metals
  When carbon dioxide burns with metals, it forms respective oxides and free carbon.

  $$4Na + 3CO_2 \longrightarrow Na_2CO_3 + C$$
  $$4K + 3CO_2 \longrightarrow 2K_2CO_3 + C$$

- Action with non-metals

  Carbon reacts with carbon dioxide to form carbon monoxide.

  $$CO_2 + C(s) \xrightarrow{Heat} 2CO(g)$$

Do You Know?

Carbon dioxide is used as a compressed gas in combat robots.

Uses of carbon dioxide

- Soft drinks

  When carbon dioxide under a pressure of 20 atm is passed through water, it dissolves to give plain soda.

> **Curiosity corner**
>
> The earliest soft drinks prepared (sherbets) were juiced soft drinks made of crushed fruit, herbs, or flowers.

- It is also used for preservation of foodstuff from insects.
- Fertiliser

  Urea prepared from ammonia and carbon dioxide is used as fertiliser.

- As fire extinguisher

  Fire extinguishers, especially those designed for electrical fires, use liquid carbon dioxide kept under pressure to extinguish flames.

  CO_2 has an added advantage. It does not conduct electricity and can be effectively used to extinguish fires caused due to electrical reasons.

  There are different types of fire extinguisher used:

  Soda-acid fire extinguisher: In this, sodium bicarbonate and sulphuric acid are filled in separate chambers. The sulphuric acid is kept inside a sealed bottle and hanged inside

the cylinder. When the knob is opened, the sulphuric acid falls on sodium bicarbonate and reacts with it to produce carbon dioxide. CO_2 spreads over the fire and cuts the supply of oxygen to it.

The reaction that occurs is:

$2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2$ (g)

Foam-type fire extinguisher: In this, sodium carbonate and aluminium sulphate are filled in two separate chambers and are mixed together whenever required. They both react to form carbon dioxide and aluminium hydroxide.

$6NaHCO_3 + Al_2(SO_4)_3 \rightarrow 3Na_2SO_4 + 2Al(OH)_3 \downarrow + 6CO_2 \uparrow$

Aluminium hydroxide comes out in the form of foam and covers the oil thereby cutting the supply of oxygen to the fire.

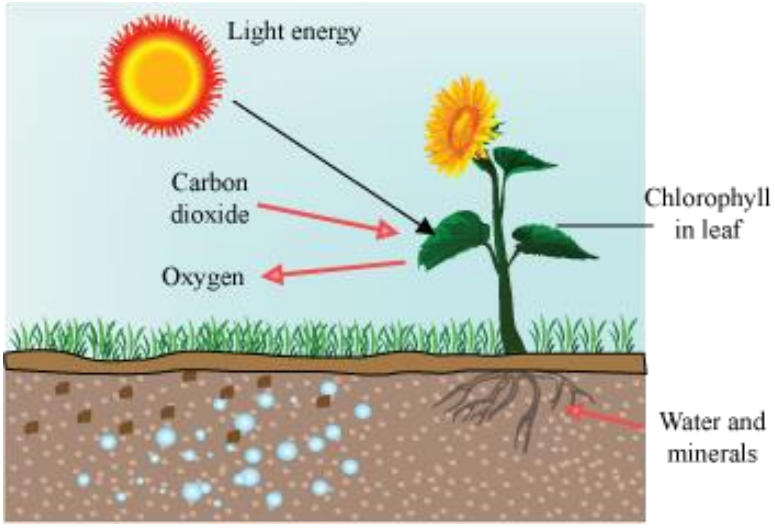
Liquid carbon dioxide fire extinguisher: It is the most popular fire extinguisher in which carbon dioxide is stored in the liquid form. When released from the extinguisher, liquid carbon dioxide turns into dry ice neutralising the oxygen supply to the fire. It is highly effective for both oil-fed and electrical fires.

Sand can also be used to extinguish the fire involving electrical appliances as it does not conduct electricity.

- **CO_2 is required in the process of photosynthesis.**

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{h\nu} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

In this process, carbon dioxide and water are converted to oxygen and glucose by plants in the presence of chlorophyll and sunlight.



- It is used as a refrigerant.

  Solid carbon dioxide is called "dry ice". It is used as a refrigerant for ice-cream and frozen food. Also, it is used for small shipments where refrigeration equipment is not practical.

- It is also used in pharmaceutical and chemical industries to manufacture chemicals such as washing soda, baking soda, etc.

  Greenhouse effect

  What is the greenhouse effect?

  The radiations from the sun enter the earth’s atmosphere but are unable to escape. This increases the temperature of the earth. This is called the greenhouse effect. It happens due to the presence of gases that absorb and emit infrared radiation.

  The gases that cause the greenhouse effect are:

- Carbon dioxide

- Vapour
- Methane

These gases that cause the greenhouse effect are responsible for increasing the temperature of the earth and thus contribute to the phenomenon called **global warming**.

Carbon Cycle

The diversity of carbon compounds is vital for sustaining life on earth. The process of changing of carbon from inorganic to organic compounds is defined as carbon cycle.

The carbon cycle

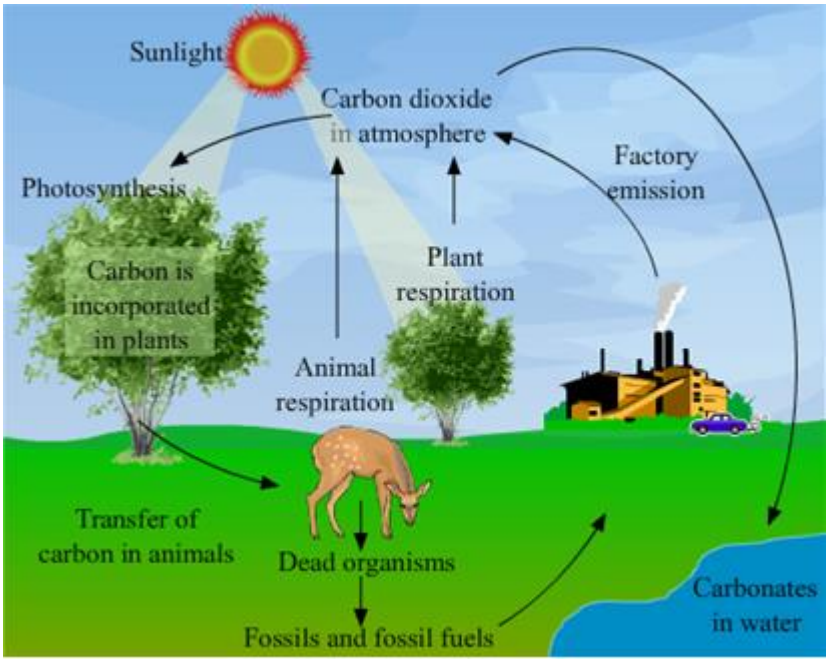
To understand the carbon cycle, we should know

• where carbon is present in the environment

• how carbon is utilised

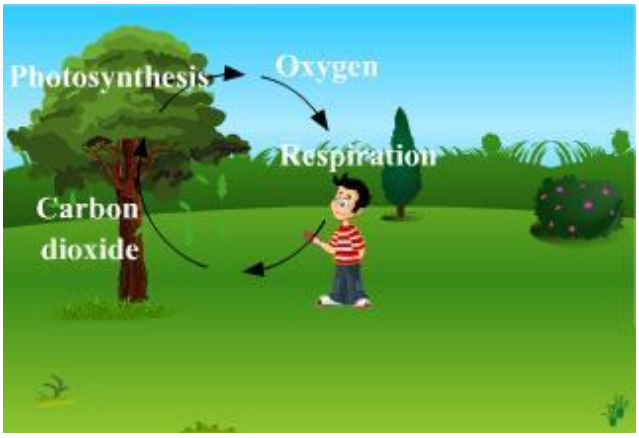
• how the utilised carbon returns to the environment

Carbon is present in the environment in many forms. In the elemental form, it is present as graphite and diamond. In the atmosphere, it is present as carbon dioxide. Mineral forms of carbon include carbonates or hydrogen carbonates.



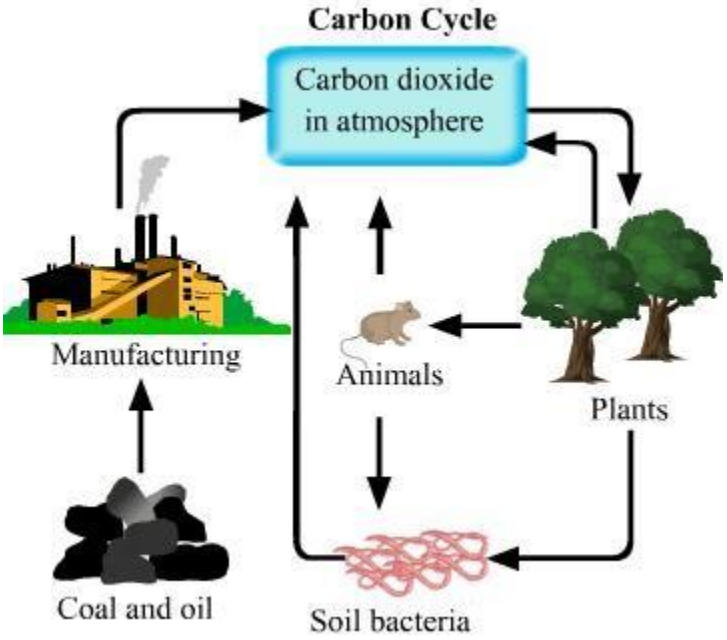
All organic substances are made up of carbon. Fats, vitamins, nucleic acids, carbohydrates and proteins contain carbon as a structural component. Carbonate salts form **endoskeletons** and **exoskeletons** of many animals.

Carbon enters the life forms through the process of photosynthesis. It is the process by which plants prepare food in the presence of sunlight and chlorophyll. **During photosynthesis, carbon dioxide and water combine to produce glucose and oxygen.** This changes the atmospheric carbon into glucose molecules.



Glucose, which is a source of food, is utilised by organisms to produce energy during **respiration**. **During this process, glucose is broken down in the presence of oxygen to produce carbon dioxide and energy**.

Thus, through the processes of photosynthesis and respiration, carbon is utilised and then returned to the environment.



All organisms do not require oxygen to break down glucose and produce energy. The organisms which respire in the absence of oxygen are called anaerobes.

Another process that releases carbon dioxide is called **combustion**. It is the process of burning of substances. Many substances release carbon dioxide on burning. Vehicular

emissions, industrial fumes and the gases released during the process of cooking are some instances during which carbon dioxide is released.

Analysis of carbon cycle:

Have you ever wondered which compound plays a major role in the cyclic changes of carbon?

Carbon dioxide plays the major role in the cyclic transformation of carbon. During respiration, oxygen gas is inhaled while carbon dioxide is exhaled. This carbon dioxide gas is utilised by plants to produce food through photosynthesis.

But there are many processes which increase the amount of CO_2 in the atmosphere. For example, coal is obtained through decaying of plants, which on decomposition liberates carbon dioxide gas in the environment.

Carbon dioxide gas constitutes 0.03% of the atmosphere, which is about 260 ppm to 360 ppm.

Do You Know?

The terms ppm (parts per million) and ppb (parts per billion) are used to assess the presence of a substance in a very minute quantity. One ppm means one in a million and one ppb means one in a thousand million. These are used to denote the proportion of pollution.

About a hundred years ago, the proportion of carbon dioxide in air was about 0.029%. Today it is about 0.035%. There has been a rise of 0.006% in the last hundred years because of the following reasons:

a. The increasing number of fuel burning industries has produced tons of carbon dioxide.

b. Growing number of automobiles has increased the amount of carbon dioxide gas in the atmosphere.

c. Due to large scale deforestation, conversion of carbon dioxide into oxygen gas has decreased.

d. Increase in human population also led to an increase in the usage of fuels, which causes liberation of more carbon dioxide gas into the atmosphere.

All these activities have caused an increase in the amount of carbon dioxide gas in the atmosphere.

What are the effects of rising level of carbon dioxide gas in the atmosphere?

The level of carbon dioxide gas is rising at the rate of about one part per million per year. Carbon dioxide molecules absorb the heat from the sun but do not emit the absorbed heat completely. This increases the temperature of the earth's surface. Hence, the green house effect is also rising.

The level of carbon dioxide gas is rising at the rate of about one part per million per year. Carbon dioxide molecules absorb the heat from the sun but do not emit the absorbed heat completely. This increases the temperature of the earth's surface. Hence, the green house effect is also rising.

Curiosity Corner

Greenhouse effect is an atmospheric phenomenon named after the heat-trapping transparent structures. Sunlight passes through the earth’s atmosphere to warm the surface of the earth but the heat radiated back from the warmed surface is absorbed by certain gases present in the atmosphere. This trapping of heat increases the temperature on the earth in the same way as the temperature inside a greenhouse rises. This is called the greenhouse effect and the gases responsible for this phenomenon are called **greenhouse gases**.

The amount of greenhouse gases in the atmosphere has been on the rise for centuries. This has in turn increased the earth’s average temperature and has resulted in the phenomenon known as **global warming**.

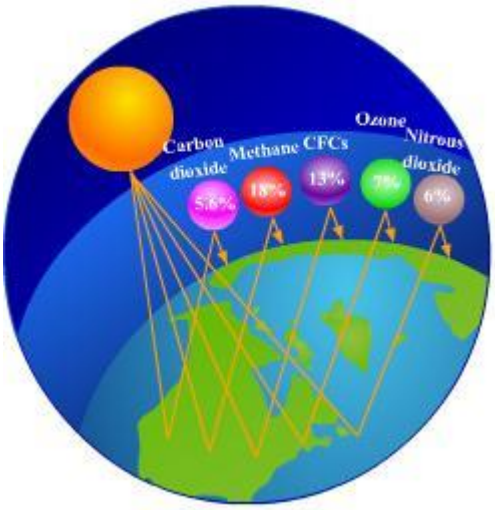
Some green house gases and their composition present in the atmosphere are:

Water vapour: 36–70%

Carbon dioxide: 9–26%

Methane: 4–9%

Ozone: 3–7%



Effects of global warming:

• Rise in sea level and ocean acidification

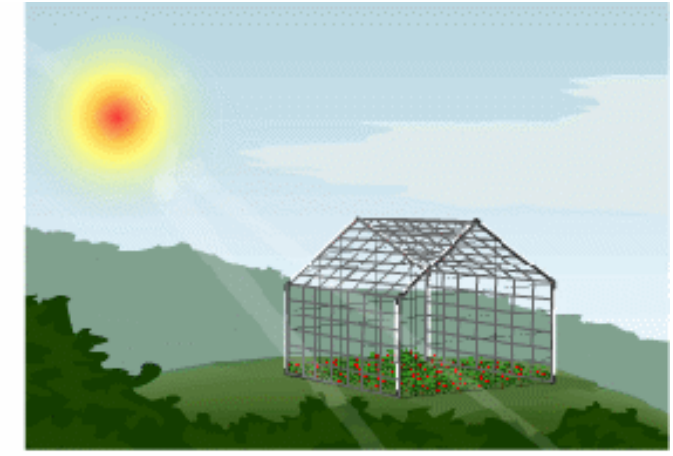
• More and more species at the risk of extinction

• Deglaciation of Greenland and west Antarctic ice sheets

Greenhouse Effect and Global Warming

Greenhouse Effect

What is a greenhouse?



You may have seen **transparent structures made of plastic or glass that house small plants**. These transparent structures are called greenhouses.

A greenhouse allows sunlight to enter, but prevents the heat from escaping. This results in an increase in the temperature inside the greenhouse.

Greenhouses help maintain climatic conditions such as temperature and humidity at the levels that are conducive for the optimum growth of plants. Specially designed greenhouses keep tropical plants warm during the winters in colder climates.

Apart from this, greenhouses also provide protection to plants against factors that are adverse to their growth, for example, pests and strong winds.

Greenhouse effect

Greenhouse effect is an atmospheric phenomenon named after the heat-trapping transparent structures. Sunlight passes through Earth's atmosphere to warm Earth's surface, but the heat radiated back from the warmed surface is absorbed by certain gases present in the atmosphere.

This trapping of heat increases Earth's temperature, much the same way as the temperature inside a greenhouse rises. This is called greenhouse effect and the gases responsible for this phenomenon are called **greenhouse gases**.

Greenhouse Effect: Causes

The amount of greenhouse gases in the atmosphere has been on the rise for centuries. This has in turn increased Earth's average temperature and resulted in the phenomenon known as **global warming**.

Some of the factors responsible for this increase in greenhouse gases in the atmosphere.

- **Deforestation**: The cutting down of trees on a large scale negatively affects the amount of carbon dioxide getting converted into oxygen. This increases the concentration of carbon dioxide in the atmosphere.
- **Burning of fossil fuels**: The burning of fossil fuels such as coal and petroleum releases greenhouse gases such as carbon dioxide and methane into the atmosphere.
- **Industrial emissions**: Gases released by various industries also contribute to the rise in the amount of greenhouse gases in the atmosphere.

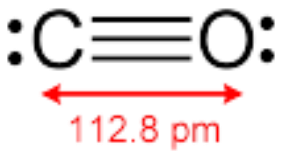
Carbon Monoxide

Carbon monoxide was first prepared by Lasson in 1776 by heating zinc oxide with wood charcoal. It was first mistaken for hydrogen.

Carbon monoxide was established as a compound of carbon and oxygen in 1880 by Cruik Shank.

Structure

Carbon monoxide has the chemical formula:



It is colourless, odourless, and tasteless, but a highly toxic gas. Its molecules consist of one carbon atom and one oxygen atom, connected by a covalent double bond and a dative covalent bond.

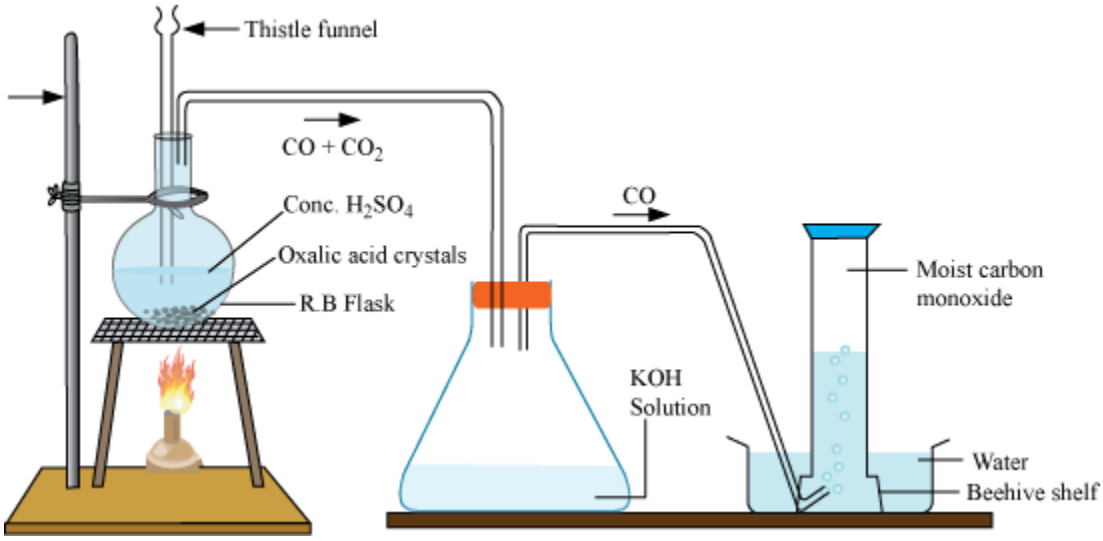
Occurrence

- Normally, air does not contain any appreciable amount of carbon monoxide. However, small amount of carbon monoxide is present in urban and industrial areas due to incomplete combustion of fuels in industry as well as in automobiles.
- It may be present in air around volcanic regions.
- When organic matter decays in swamps in the absence of air, carbon monoxide gas is formed.

Preparation

- **Preparation of carbon monoxide from oxalic acid**

  Take 20 g of oxalic acid in dry round bottomed flask and set the apparatus as shown below.



  Pour concentrated sulphuric acid from thistle funnel so that the lower end of thistle funnel is completely immersed in acid. Heat the mixture.

$$(COOH)_2 + 2H_2SO_4 \xrightarrow{Heat} H_2SO_4.H_2O + CO_2 + CO$$

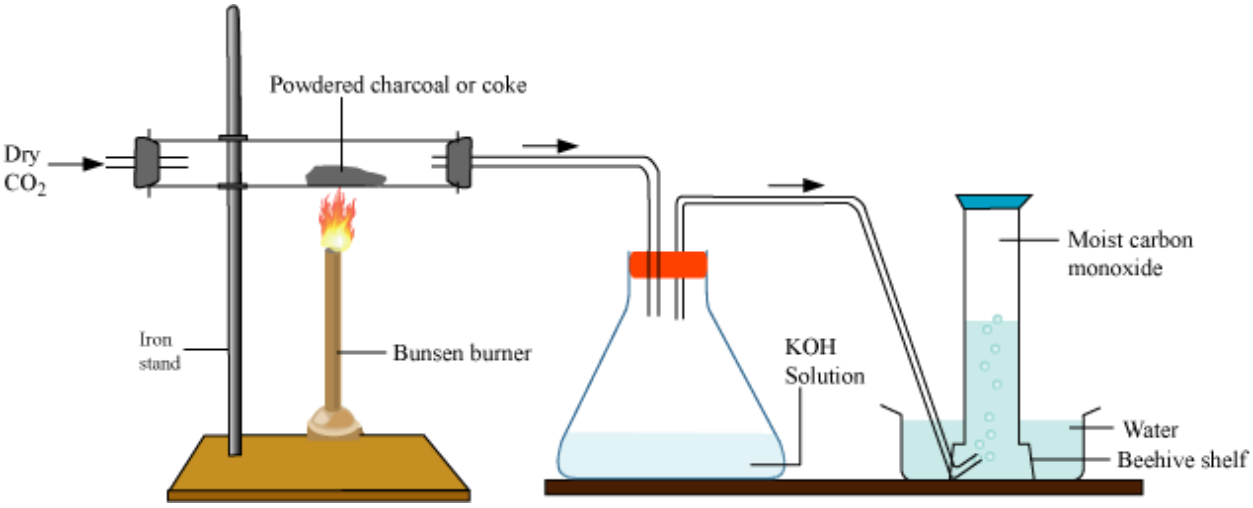
  The mixture of gases obtained is then passed through caustic potash solution so as to remove carbon dioxide and sulphur dioxide gas, which are present as impurities.

$$CO_2 + KOH \rightarrow KHCO_3$$

  Carbon monoxide, being insoluble, bubbles out of caustic potash and is collected by downward disp lacement of water.

- **Preparation of carbon monoxide from carbon dioxide**

  Take powdered charcoal in hard glass test tube and set the apparatus as shown below.



The charcoal is heated to a dull red heat and then carbon dioxide is passed over it.

$$C + CO_2 \rightarrow 2CO$$

The mixture of gases obtained is then passed through caustic potash solution so as to remove carbon dioxide and sulphur dioxide gas, which are present as impurities.

$$CO_2 + KOH \longrightarrow KHCO_3$$

Carbon monoxide, being insoluble, bubbles out of caustic potash and is collected by downward displacement of water.

- Carbon, when heated in limited supply of air or oxygen, yields carbon monoxide gas as the main product

$$2C_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2CO_{(g)}$$

- Dehydration of formic acid with concentrated H_2SO_4 at 373 K gives pure carbon monoxide gas as the main product.

$$HCOOH \xrightarrow[\text{conc. } H_2SO_4]{373K} H_2O + CO$$

The gas evolved contains carbon dioxide as impurity, which can be removed by the method discussed above.

- The passage of steam over hot coke gives carbon monoxide.

$$C_{(s)} + H_2O_{(g)} \xrightarrow{473-1273K} CO_{(g)} + H_{2(g)}$$

Mixture of $CO_{(g)}$ and $H_{2(g)}$ → Water gas

- A mixture of CO and N_2 (called producer gas) is produced when air is used instead of steam.

$$2\,C_{(s)} + O_{2(g)} + 4\,N_{2(g)} \xrightarrow{1273\,K} 2\,CO_{(g)} + 4\,N_{2(g)}$$

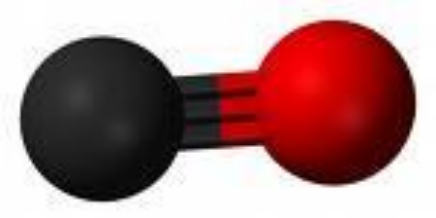
(Producer gas)

To test your knowledge of **this concept**, solve the following puzzle.

Properties of Carbon Monoxide

Some physical properties of carbon monoxide are discussed below.

- Carbon monoxide is a colourless, odourless, and almost water insoluble gas. It has nearly the same density as air.



- The molecular mass of carbon monoxide is 28.
- **Carbon monoxide is highly poisonous in nature**. Its poisonous action is explained below.

  During respiration, oxygen molecule enters the lung and is then carried by red blood cells where it binds to haemoglobin forming a complex known as oxyhaemoglobin.

  If carbon monoxide enters the lung, then it reacts with haemoglobin to form a very stable complex carboxyhaemoglobin (which is 300 times more stable than oxyhaemoglobin complex). It prevents haemoglobin from carrying blood, which results in suffocation leading to death.

- Vapour density of carbon monoxide is 14. It is slightly lighter than air.
- Carbon monoxide can be liquefied under high pressure and low temperature. It has a boiling point of −192°C.

Chemical properties of carbon monoxide

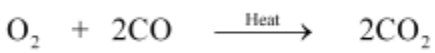
Some chemical properties of carbon monoxide are given below.

- Carbon monoxide is a combustible gas, but does not support combustion. As it burns without any smoke and produces a large amount of heat energy, it serves as an excellent fuel.

- **Action with litmus**: It is neutral to litmus and thus has no acidic or basic properties.

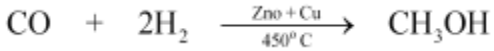
- **Action with non-metals**

- **Action with oxygen:** It burns producing carbon dioxide gas and a lot of heat energy.



$$O_2 + 2CO \xrightarrow{\text{Heat}} 2CO_2$$

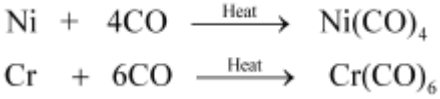
- **Action with hydrogen**: It reacts with hydrogen to produce methyl alcohol in the presence of zinc oxide and finely divided copper at 450°C.



$$CO + 2H_2 \xrightarrow[450^\circ C]{Zno + Cu} CH_3OH$$

- **Action with metals**

- Carbon monoxide reacts with heated metals such as nickel, chromium, and iron to form their respective carbonyls.

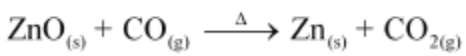


$$Ni + 4CO \xrightarrow{\text{Heat}} Ni(CO)_4$$

$$Cr + 6CO \xrightarrow{\text{Heat}} Cr(CO)_6$$

- **Reducing property of carbon monoxide:** Carbon monoxide is a powerful reducing agent. It can reduce almost all metal oxides (exceptions − alkali and alkaline earth metals, aluminium). This is why it is used in the extraction of many metals from their oxide ores.

$$Fe_2O_{3(s)} + 3\,CO_{(g)} \xrightarrow{\Delta} 2\,Fe_{(s)} + 3\,CO_{2(g)}$$

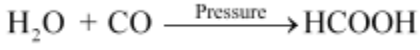


$$ZnO_{(s)} + CO_{(g)} \xrightarrow{\Delta} Zn_{(s)} + CO_{2(g)}$$

- **Action with compounds**

Action with water

Carbon monoxide reacts with water to form formic acid.



$$H_2O + CO \xrightarrow{\text{Pressure}} HCOOH$$