Carbon and Its Compounds

OCCURRENCE

Carbon occurs in both free state and combined state

FREE STATE

Carbon exists as the native element in the form of coal in the earth's crusts. It occurs in a very small amount in its allotropic forms like diamond and graphite. Another form of carbon, fullerene, has been discovered by geologist in a crater made by a meteorite in Germany and in ancient rocks in New Zealand.

COMBINED STATE

Carbon exists in the combined state in all the three physical states, namely solid, liquid and gaseous
states.

i. Solid state:

Carbon occurs in the solid state in the form of mineral carbonates like calcium carbonate ($CaCO_3$), magnetite ($MgCO_3$), Calamine ($ZnCO_3$) etc. In plants and animals carbon occurs in the form of fats, proteins, carbohydrates and various other complex chemical compounds.

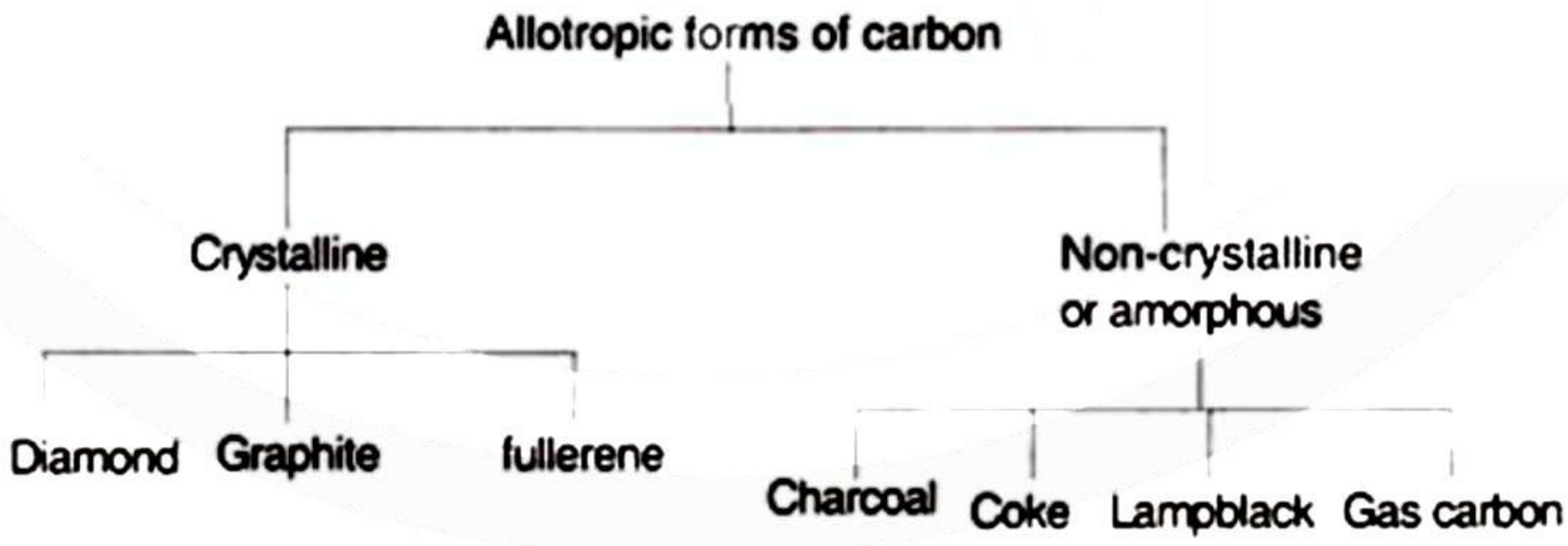
ii. Liquid state:

Carbon commonly exists in liquid state in fuels and vegetable oils. The fuels mainly comprise of petrol, diesel, kerosene, LPG etc.

iii. Gaseous State:

In gaseous state, carbon exists either in the form of oxides, hydrocarbons or in water as dissolved carbon dioxide. Carbon dioxide and carbon monoxide are the oxides of carbon. About 0.03% by volume of atmosphere is of carbon dioxide while carbon monoxide is present in volcanic gases and furnace emissions of industries.

ALLOTROPY



DIAMOND

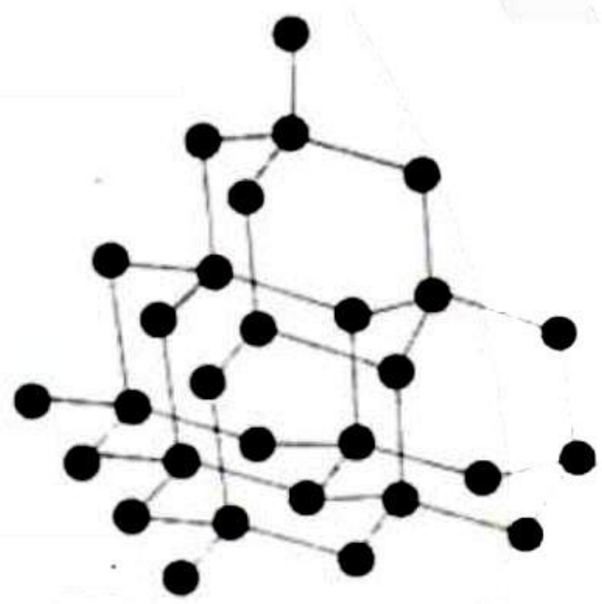
FORMATION OF DIAMOND

Diamonds are formed in nature by the crystallization of carbon. The carbon present beneath the surface of the earth under specific conditions dissolves in the molten rock material present there. The liquid so formed is commonly called magma. When the magma containing carbon is pushed up to the surface of the earth due to the volcanic eruption, it gets solidified. The iron present in the magma expands on solidification, exerting a great pressure on carbon, which, in turn, crystallizes to form diamonds.

Diamond is also synthesized artificially for specific application. In the synthesis of diamond, carbon is prepared from sugar and molten iron is obtained by melting iron in an electric furnace by raising its temperature to the range of 3000^0C-3500^0C. On sudden cooling, the molten iron on outer surface suddenly cools whereas the inner surface remains at high temperature. On further cooling, the expansion of iron takes place which exerts a great pressure on carbon, producing diamonds.

STRUCTURE OF DIAMOND

Diamond has a regular tetrahedral arrangement. Carbon has a valency of four and each carbon is bonded to four other carbon atoms forming tetrahedral units lying in different planes, forming units of crystals. These crystal units lying in different planes account for a rigid three dimensional structure.



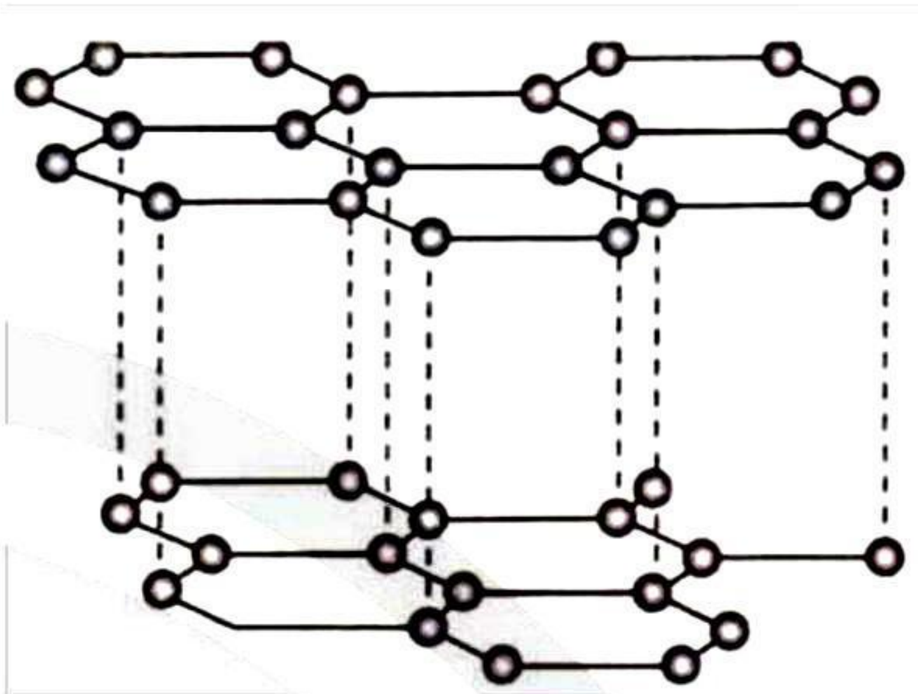
PHYSICAL PROPERTIES OF DIAMOND

1. Apure diamond is a colourless, transparent crystal. It is the hardest substance among naturally occurring solids.
2. Diamond is a good conductor of heat and bad conductor of electricity.
3. It has a high refractive index of 2.5.
4. It is the only known substance to be insoluble in any solvents.
5. Diamond is the densest form of carbon with a density of $3.5 gm/cm^3$.
6. The melting point of diamond is about 3700^oC.
7. Presence of impurities impart colour to diamonds.

GRAPHITE

'CTURE OF GRAPHITE

In graphite each carbon atom is bonded covalently to three other carbon atoms resulting in the arrangement of hexagonal rings in a single plane. The bonds between the atoms of two single layers in the parallel planes are weak. Each carbon is bonded to three carbon atoms only leaving behind one free valency.



three dimensional arrangement of hexagonal rings is resulted. These rings lie on a single plane. The entire structure is such that the layers of hexagonal rings are arranged parallel to each other.

PHYSICAL PROPERTIES OF GRAPHITE

1. Graphite is a dark grey, very soft solid with metallic lustre.
2. It is a good conductor of heat and electricity.
3. It is opaque.
4. It is insoluble in ordinary solvents.
5. Density is 2.25gm/cm^3.
6. It has a melting point of about 3600°C

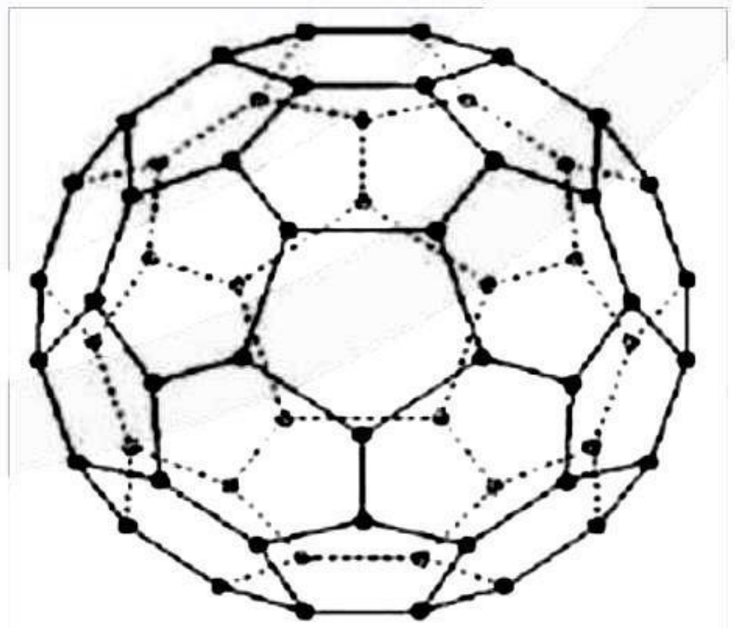
FULLERENES

SYNTHESIS OF FULLERENE

The first step in the synthesis of fullerene is the evaporation of graphite using laser radiation and subsequent condensation of carbon vapour. When these vapours are cooled in the atmosphere of noble gases, fullerene molecules consists of mainly C_{60} with smaller amount of C_{70} and traces of other fullerene molecules consisting of even number of carbon atoms upto 350 are formed. From these, C_{60} and C_{70} are separated through chromatographic separation.

STRUCTURE OF FULLERENE

Fullerenes are large spherical carbon cage molecules and were named Buckminister fullerenes in honour of American architect Robert Buckminister Fuller.



The name Fullerene originated from the structure that resembled the geodesic dome structures designed by the architect

L PROPERTIES OF FULLERENE

1. Brown or black powder
2. It becomes super conductor when it forms compounds with noble gases.
3. Refractive index of fullerene is 2.2.
4. Soluble in common solvents such as benzene, toluene or chloroform.

5. Density is 1.65gm/cm^3
6. It undergoes sublimation at about 527°C.

AMORPHOUS ALLOTROPES OF CARBON

Charcoal, Coke, lamp black and gas carbon are amorphous forms of carbon. In these forms of carbon, the carbon atoms are not arranged in an orderly manner. Recently studies reveal that these allotropic forms are tiny graphite crystals cemented together by impurities.

CHARCOAL

Charcoal is one of the man-made amorphous forms of carbon. It is used as a fuel. Depending on the source from which charcoal is obtained, it is of three types.

BONE CHARCOAL

Bone charcoal is also known as animal charcoal or bone ash or ivory black. Animal bones contain organic matter and calcium phosphate. The crushed fine powder of the animal bones if subjected to destructive distillation produces residue. This residue is called bone charcoal.

SUGAR CHARCOAL

One of the purest forms of amorphous allotropes of carbon is sugar charcoal and it is prepared by destructive distillation of sugar. Sugar crystals lose water and get converted to pure carbon. This pure carbon obtained from sugar is known as sugar charcoal. The chemical reaction of sugar with concentrated sulphuric acid produces sugar charcoal.

$$C_{12}H_{22}O_{11} \xrightarrow{\text{Conc. } H_2SO_4} 12C + 11H_2O$$

PHYSICAL PROPERTIES OF CHARCOAL

Charcoal is a porous black solid. It has a huge surface area due to its porosity. It has the ability to absorb specific substance like coloured impurities, poisonous substances, etc.

USES

Wood charcoal

1. It is used as an excellent household fuel for keeping rooms warm in winter.
2. It is used extensively for small scale production of metals. When wood charcoal is heated with oxides of less active metals, they get reduced to free metals.
3. It is used as a deodorant and disinfectant.
4. Charcoal is used as one of the constituents of the gunpowder.
5. It is used in gas masks.

Bone charcoal

1. Bone charcoal is used to remove colour from sugar cane juice due to adsorbing impurities.
2. It is used in the extraction of yellow phosphorous.

Sugar Charcoal

1. It is used for extracting metals from their oxides.

2. It is used as an adsorbent material in place of activated charcoal.

OTHER AMORPHOUS FORMS OF CARBON

LAMP BLACK

ration

black is prepared by burning mustard oil, turpentine oil and petroleum in the absence of oxygen. The preparation of lamp black can be done at home by placing a clean dry glass slide over the flame of mustard oil lamp. After some time a deep black powdery substance is coated on the slide, which is known as lamp black.

rties

1. Lamp black is light, powdery black substance, having a velvet touch.
2. It has an oily feel due to the presence of the vapours of some amount of oil.
3. It has a density of 1.7-1.8 gm/cm^3
4. It does not conduct electricity.

1. Lamp black is used as stabilizing filler for rubber in making tyres and plastics.
2. It is used as a black pigment in inks and paints.
3. It is used for making black shoe polishes.
4. It is used in the manufacture of black carbon papers and carbon ribbons for type writers.

COKE

ration

is prepared by heating coal in the absence of air upto a temperature of 1300°C in huge iron retorts. The products obtained by the decomposition of coal are coal gas, carbon, coal tar, liquor ammonia and coal gas.

of Coke

Hard Coke:

It is a light lustrous substance, used in metallurgical furnaces or in other industrial furnaces

Soft Coke:

It is a black and porous substance, which ignites with difficulty and is used in household furnaces.

rties

1. It is greyish black porous solid, which burns without smoke.
2. It is a good reducing agent
3. It is a bad conductor of heat and electricity

1. It is used as a household fuel.
2. It is used extensively in the extraction of metals like iron copper, lead, etc. From their oxide and sulphide ores as it is an excellent reducing agent.
3. It is used in the manufacture of graphite and calcium carbide.
4. It is used in the manufacture of water gas and producer gas.

GAS CARBON

ration

arbon can be prepared by destructive distillation of coal. The thermal vaporisation of small amounts of carbon from coal on condensation produces a grey solid. This grey solid obtained is called gas carbon.

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1. It is a dull grey solid.
2. It is a good conductor of electricity.
3. Its density is 2.068 gm/cc

ed for making electrodes for dry cell.

Oxides of carbon

Carbon monoxide and carbon dioxide are the two stable oxides formed by carbon.

CARBON MONOXIDE

PHYSICAL PROPERTIES OF CARBON MONOXIDE

Molecular Mass	:	28
Physical State	:	Gas (neutral)
Colour	:	Colourless
Taste	:	Tasteless
Odour	:	No characteristic smell
Vapour density	:	Slightly lighter than air V.D. = 14
Solubility	:	Insoluble in water
Nature	:	Neutral and does not respond to litmus test.
Boiling point	:	-192 ℃
Special feature	:	Poisonous

CHEMICAL PROPERTIES OF CARBON MONOXIDE

1. Combustibility:

Combustible Burns in air with a pale blue flame. A mixture of CO and air burns spontaneously resulting in an explosive reaction. Carbon monoxide is not a supporter of combustion.

2. Reaction with alkalis : No reaction

3. Reaction with lime water : No reaction

4. Reaction with metals:

When CO gas is passed over the finely-divided metals like nickel and chromium and iron metal carbonyls are formed.

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

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

$$Fe + 5CO \xrightarrow{\Delta} Fe(CO)_5$$

5. Reaction with non metals:

Reaction with oxygen gives CO_2 gas and reaction with Cl_2 gas gives phosgene.

$$2CO + O_2 \longrightarrow 2CO_2$$

$$CO + 2H_2 \longrightarrow CH_3OH \text{ Methyl Alchol}$$

$$CO + Cl_2 \longrightarrow COCl_2 \text{ Carbonyl Chloride (phosgene)}$$

$$CO + S \longrightarrow \mathbf{COS} \text{ Carbonyl Sulphide}$$

6. As reducing agent/oxidizing agent:

CO reduces oxides of less active metals.

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

$$CuO + 3CO \longrightarrow Cu + CO_2$$

$$ZnO + 3CO \longrightarrow Zn + CO_2$$

7. Biochemical process:

Combine with haemoglobin of blood to form carboxyhaemoglobin. This makes CO gas poisonous.

USE OF CARBON MONOXIDE

1. Carbon monoxide can be used as a fuel as it produces a large amount of heat on combustion. The fuels like coal gas, water gas and producer gas contain carbon monoxide as an important constituent.
2. Carbon monoxide is used in the extraction of metals like nickel from the mixture of other metals.
3. In the manufacture of chemicals.
4. It behaves as a reducing agent in the extraction of metals.
5. In the preparation of war gas like phosgene.

CARBON DIOXIDE

PHYSICAL PROPERTIES OF CARBON DIOXIDE

Colour	:	Colourless
Odour	:	No characteristic smell
Taste	:	Slightly sour in taste
Vapour density	:	Heavier than air V.D. = 22
Solubility	:	Highly soluble in water
Nature	:	Acidic. Changes blue litmus to red.
Boiling point	:	-32 ℃
Special feature	:	Not Poisonous. Its solid form is called dry ice which sublimes.

It can also be easily liquefied at 70 atm pressure at room temperature.

CHEMICAL PROPERTIES OF CARBON DIOXIDE

1. **Combustibility:**

Non-combustible and does not support combustion

2. **Reaction with alkalis**:

Neutralization takes place with the formation of salt and water.

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

3. **Reaction with lime water:**

Turn milky due to the formation of insoluble $CaCO_3$.

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

4. **Reaction with metals**:

Na, K, Ca combine with CO_2 to form their respective carbonates along with carbon whereas Mg, Al gives their respective oxides and carbon

$$4Na + 3CO_2 \qquad 2Na_2CO_3 + C$$

$$2Mg + CO_2 \rightarrow 2MgO + C$$

5. **Reaction with non metals**: No reaction with O_2 and Cl_2

6. **As reducing agent/oxidizing agent:**

Green plants synthesize carbohydrates by the combination of CO_2 and water in the presence of sunlight. The process is called photosynthesis.

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2.$$

7. Action of CO_2 when it is passed through lime water

Limited amount of CO_2

When limited amount of CO_2 is passed through lime water, it turns milky due to the formation of insoluble $CaCO_3$.

$$Ca(OH)_{2(aq)} + CO_{2(g)} \rightarrow CaCO_3 + H_2O$$

Excess amount of CO_2

When an excess amount of CO_2 is passed through lime water, it first turns milky, and then the milkiness disappears due to the formation of soluble $Ca(HCO_3)_2$.

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

$$CaCO_3 + CO_2 + H_2O \qquad Ca(HCO_3)_2$$

USES OF CARBON DIOXIDE

Apart from being the natural and indispensible raw material for photosynthesis, CO_2 finds many important applications in various fields.

1. Carbon dioxide is used for the hardening of mortars (mixture of $Ca(OH)_2$, sand and water). Thus, the mortar applied to join bricks slowly hardens due to the absorption of carbon dioxide from the atmosphere forming calcium carbonate.
2. Carbogen, a mixture of 95% of oxygen and 5% of carbon dioxide is used to stimulate respiratory system.
3. It is used in soft drinks or aerated drinks to give them a tangy taste.

4. Solid carbon dioxide called dry ice is used as a refrigerant.
5. Carbon dioxide is extensively used in the production of industrial compounds such as washing soda, baking soda, White lead, etc.
6. Atmosphere of carbon dioxide can be used in the preservation of food grains, fruits etc.
7. Carbon dioxide is used in fire extinguishers to put off fires since it is a non- combustible gas and does not support combustion.
8. Baking powder which contains sodium bicarbonate produces carbon dioxide gas on heating; This gas helps in the aeration of dough.