Carbon & its Compounds
Allotropes of Carbon

❖ ALLOTROPY

The property of an element as a result of which it exists in more than one form having different physical but same chemical properties is called **Allotropy**.

Carbon, Sulphur, phosphorus etc show allotropy.

Carbon exists in two different allotropic forms:

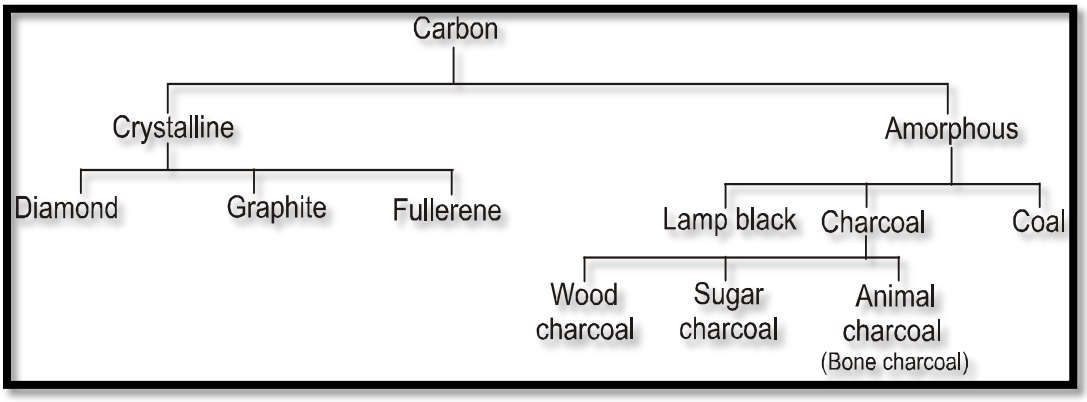
(i) Crystalline form.

Examples: diamond, graphite and fullerene.

(ii) Non - crystalline or Amorphous form.

Examples: coal, lampblack and charcoal.

Various allotropic forms of carbon are



(1) Diamond :

Diamond is a beautiful crystalline allotrope of carbon. Its atomic symbol is C. The name 'diamond' has been taken from Greek words diaphanes (which means transparent) and *adamas* (which means indomitable or invincible) with reference to its extreme hardness.

(i) Structure of Diamond :

In a crystal of diamond, each carbon atom is bonded very strongly to four other carbon atoms in *tetrahedron* manner. The valency of each carbon atom is completely satisfied in diamond and there is no free electron. This arrangement of C-atoms makes diamond very

hard, unreactive and bad conductor of electricity. The given figure depicts a portion of the diamond crystal. Smaller circles are representing
C-atoms in tetrahedtral arrangement.

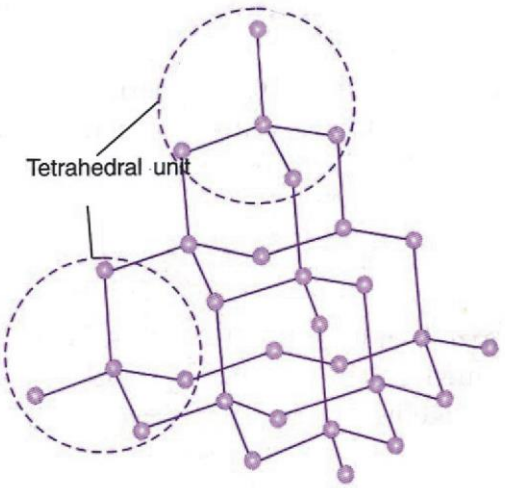


Figure : A portion of diamond structure

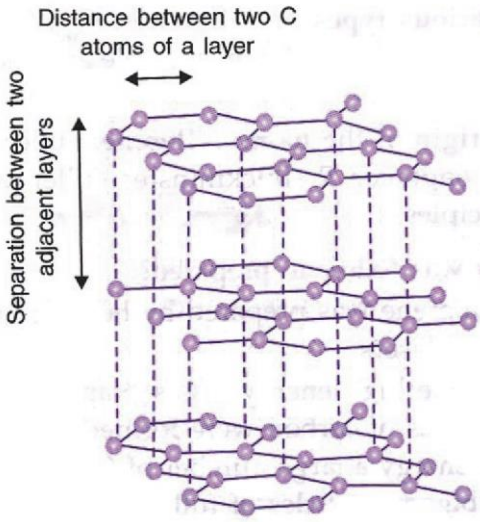


Figure : A portion of graphite crystal

(ii) Properties of Diamond :

(A) Diamond is a transparent and colourless solid.

(B) Suitably cut and polished diamond sparkles brightly because it reflects most of the light (Refractive index of diamond is 2.45).

(C) The density of diamond is 3.51 g per cm^3 at 20°C.

(D) Diamond is the hardest natural substance known. Only a diamond can cut another diamond.

(E) It is a bad conductor of electricity.

(F) Melting point of dimond is 3550 ºC.

(G) Diamonds are not attacked by acids, alkalis and solvents like water, ether, benzene or carbon tetrachloride. But diamond is attacked by fluorine when heated to 750°C. The reaction results in the formation of carbon tetrafluoride.

$$C\ (diamond) + 2F_2 \xrightarrow{750\,^\circ C} CF_4$$

Carbon Fluorine Carbon tetrafluoride

(iii) Uses of Diamond :

(A) They are used in jewellery because of their ability to reflect and refract light.

(B) Diamonds are used in cutting glass and drilling rocks.

(C) Diamond has an extraordinary sensitivity to heat rays and due to this reason, it is used for making high precision thermometers.

(D) Diamond has the ability to cut out harmful radiations and due to this reason it is used for making protective windows for space probes.

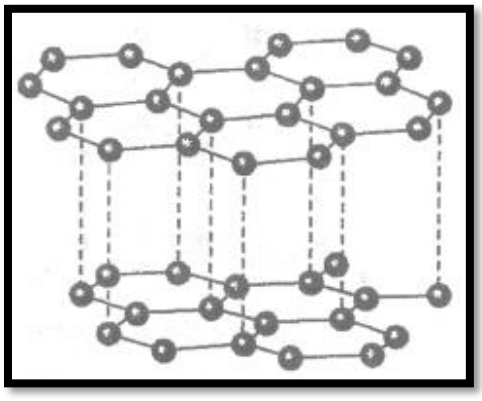
(E) Diamond dies are used for drawing thin wires. Very thin tungsten wires of diameter less than one-sixth of the diameter of human hair have been drawn using diamond dies.

(F) Surgeons use diamond knives for performing delicate operations.

(2) GRAPHITE :

Graphite is the other crystalline allotropic form of carbon and occurs in free state in nature. It can also be prepared artificially by heating a mixture of sand and coke in electric furnance at about 3300 K.

•**Occurence of graphite:** Graphite occurs in free state in nature. It can be prepared artificially by heating a mixture of sand and coke in electric furnance at about 3300 K temperature.



← weak vanderwaal's forces The Structure of Graphite

- **Structure:** In graphite each carbon atoms is linked to three other carbon atoms by single covalent bond resulting in hexagonal ring which are arranged in a layer. The C-C bond length is 1.42 Å. C-C bond angle is 120°. These layer are bonded together by weak Vander Waals force of attraction shown in figure by dotted lines. Distance between two layers is 3.35 Å.

- **Properties of Graphite :**

(i) Relatively soft and is greasy because of its hexagonal layer structure.

(ii) Has metallic lusture.

(iii) Colour varies from grey to black depends upon the origin.

(iv) Is opaque.

(v) Density varies from 2.0 to 2.25 gms/cm^3.

(vi) Melting point 3730ºC.

- **Uses of Graphite:**

(i) Graphite is used to make electrodes for electrolytic cells.

(ii) Being soft and greasy, it is used to lubricate the parts of machines.

(iii) Graphite crucibles can withstand very high temperature and can be used for melting substances with high melting points.

(iv) Graphite is also used to moderate the speed of the fast moving neutrons in nuclear reactors.

(v) Mixture with wax and clay, graphite is used for making cores of lead pencils as it can mark paper black. It is therefore, often called black lead or plumbago.

Differences between Diamond and Graphite

Property	Diamond	Graphite
1. Appearance	Transparent and colourless when pure	Dark grey and opaque
2. Crystal form	Tetrahedral giant structure	Hexagonal plates
3. Hardness	Hardest natural substance known	Soft and slippery
4. Impression	Does not mark paper	Leaves impression on paper
5. Conductivity (a) Electrical (b) Thermal	 Bad conductor Very high	 Good conductor Moderate
6. Density at 20 ºC	3.51 g per cm^3	2.26 g per cm^3
7. Combustion	Burns in air above 900 ºC and gives CO_2	Burns in air at about 700 ºC and gives CO_2

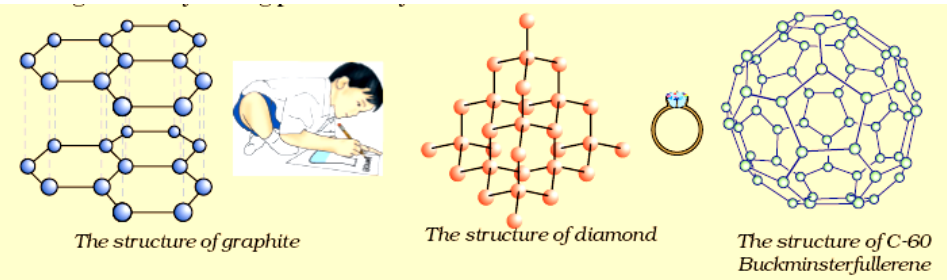
(3) FULLERENE:

Fullerenes form another class of carbon allotropes. The first one to be identified was C-60 which has carbon atoms arranged in the shape of a football. Since this looked like the geodesic dome designed by the US architect Buckminster Fuller, the molecule was named fullerene. Buckminster fullerenes contain 60 carbon atoms arranged in round molecule resembling a soccer ball C_{60} molecule has marvelously symmetrical structure.

- It has spherical tomb like structure.
- The fullerene was named after the famous American architect Buckminster Fuller.
- In one molecule of fullerene there are 60, 70 or more carbon atoms present.
- C_{60} is the most stable fullerene which is also known as Buckminster fullerene.
- The structure of C_{60} has 32 faces in which 20 faces are hexagonal and 12 faces are pentagonal. Its structure is similar to football, therefore it is also known as bucky ball.
- C_{60} is a poor conductor of electricity. The C–C bond length is 1.40A.

◆ **Uses of Fullerene**

(i) Fullerenes in pure state act as insulators but can be converted to semi-conductors and super conductors under suitable conditions.



(ii) Bucky ball's ability of fullerenes to trap different atoms or molecules make them useful in the medical field. For example, radioactive C_{60} can be used in cancer as well as AIDS therapy.

(iii) Fullerenes help in improving antiwar and antifriction properties of lubricating oils.

(iv) Fullerenes in small amounts can catalyse the photochemical refining in industry.

Differences between graphite and Fullerene

Graphite	Fullerene
1. Graphite has extended crystal structure in which C-atoms are bonded in hexagonal layers. These layers are held by weak **Vander Waals forces**	1. Fullerene is a spherical molecule like a cage in which the C atoms are arranged in mixed hexagons and pentagons. In solid state these molecules are attached to each other by weak **Vander Waals forces**.
2. Graphite is insoluble in water, acids and any other solvent.	2. Fullerene is soluble in benzene and forms deep violet colour solution.
3. Graphite is a good conductor of electricity.	3.Crystalline fullerene has semi conducting properties.
4. The compounds of graphite with metals are called carbides. They are hard materials.	4. Compounds of fullerene with alkali metals are called fullerides and they are superconductors.