

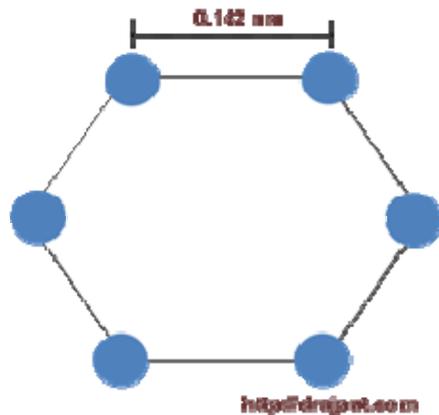
- Name the allotropes of carbon?

Carbon exists in many different forms. Its allotropes are: **diamond**, **graphite**, **lonsdaleite**, **fullerenes** (C_X , where $X = 60, 70, 72, 76, 78, 80, 84, 540$, etc., and carbon nanotubes), and **amorphous carbon**. It should be noted that C_{60} , C_{70} , C_{72} , and so forth constitute a single allotrope of carbon called as fullerenes. The spherical form of fullerenes is called as buckminsterfullerenes. It should also be noted that carbon nanotubes (single wall and multi wall) are also types of fullerenes. So, broadly speaking, carbon has five allotropes.

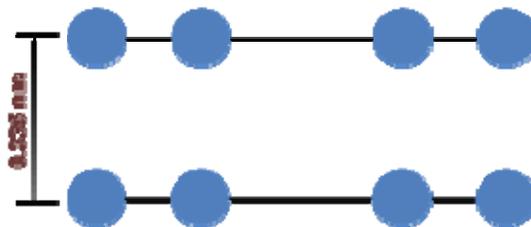
- What is graphite and what are its crystallographic forms?

Graphite is one of the allotropes of carbon, which consists of layers of carbon atoms arranged in a hexagonal lattice. Each carbon layer in graphite is bonded to a carbon layer above and a carbon layer below through van der Waals interactions. Each carbon atom in graphite is sp^2 hybridized. Graphite exists in two crystallographic forms: **hexagonal**(alpha) and **rhombohedral** (beta). The difference in the "stacking" of the layers of hexagonally-linked carbon atoms in graphite gives rise to hexagonal and rhombohedral crystallographic forms.

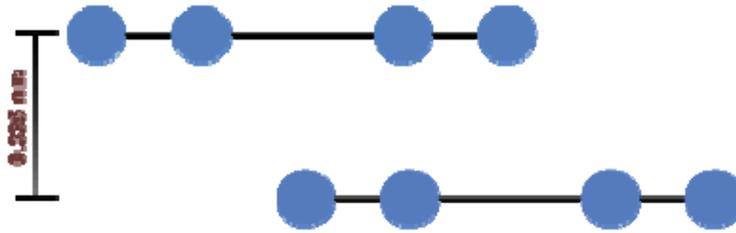
- Draw and explain the structure of graphite.



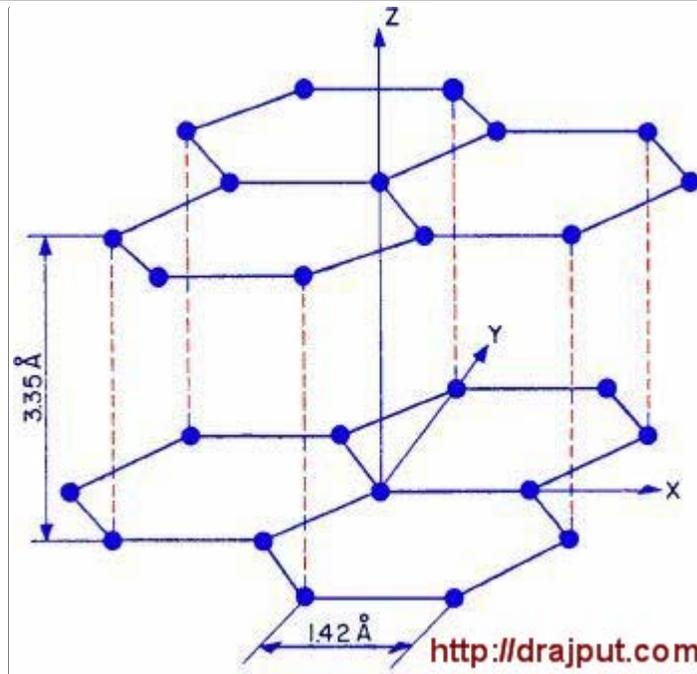
This figure shows the hexagonally-bonded carbon atoms in a layer of graphite. Each atom is 0.142 nm apart.



This figure shows two layers of hexagonally-bonded carbon atoms in graphite that are 0.335 nm apart. This arrangement forms the hexagonal crystallographic form (alpha) of graphite.



This figure shows two layers of hexagonally-bonded carbon atoms in graphite that are 0.335 nm apart. This arrangement forms the rhombohedral crystallographic form (beta) of graphite.



Three-dimensional pictorial description of graphite (alpha).

- What are the three naturally occurring types of graphite?

Flake graphite (often referred to as crystalline flake graphite), **amorphous** graphite, and **vein** (or **lump**) graphite are the three naturally occurring types of graphite.

- What is HOPG?

HOPG stands for Highly Ordered (or Oriented) Pyrolytic Graphite, where the stacked planes of carbon atoms are strongly aligned with very low angular spread (called as mosaic angular spread or simply mosaic spread). The lower the mosaic spread, the stronger the orientation, the better the quality of HOPG. It is used as a probe for the calibration of scanning tunneling microscopes.

- **Explain the lubricity of graphite.**

Graphite is a good lubricant in open atmosphere (i.e., in the presence of moisture and air), whereas it is a very poor lubricant in vacuum (i.e., in the absence of moisture and air). The lubricity of graphite depends solely on the environment. In open atmosphere (that has moisture and air), graphite adsorbs moisture and air between the layers that aid them to slide on each other with ease, and hence obtains the self-lubricity property. In vacuum it is not the case, hence it is a poor lubricant in vacuum.

- **What is graphene?**

Graphene is a single atomic layer of sp^2 hybridized hexagonally-bonded carbon atoms. It has very high electron and hole mobilities. Graphene is very strong and its ultimate tensile strength is around 200 times that of steel [Lee *et al* (2008), *Science* **321** (5887)].

- **What is intercalated graphite?**

Intercalated graphite (often referred to as graphite intercalation compound) is a compound of graphite formed by intentionally bonding atoms of different elements between the layers of graphite. Chemically, intercalated graphite is represented as XC_Y , where X is a different element or a molecule and Y is a stoichiometric constant. Some examples of intercalated graphite are calcium graphite (CaC_6), potassium graphite (KC_8), and ytterbium graphite (YbC_6).

- **What is expanded graphite and what are its uses?**

Expanded graphite (also referred to as Expandable or Intumescent flake graphite) is a form of intercalated graphite in which the crystal planes of carbon atoms are moved apart resulting in the expansion (or swelling) of graphite. As a result of this event, the chemical and physical properties change. The most common of all expanded graphites is graphite bisulfate. It is prepared by soaking natural graphite flakes in chromic acid followed by concentrated sulfuric acid. Expanded graphite(s) is used as fire retardant, electromagnetic radiation shield, conductive filler material, etc.

- **What is xGnP?**

xGnP stands for **Exfoliated Graphite Nanoplatelets**. It consists of several graphene sheets stacked together to a total thickness between 1 and 15 nanometers (average 5 nanometers), whereas the platelet diameter ranges from sub-micron to over 100 microns.