Graphite and Fullerene

Allotropy → The phenomenon by which an element can exist in more than one physical state or form and having different physical properties is called allotropy.

Carbon exist in two allotropic forms:

1. Crystalline
2. Amorphous

Crystalline allotropic forms of carbon

a. Graphite b. Fullerene

Amorphous allotropic forms of carbon

(a) Coal (b) Coke (c) Wood Charcoal

Graphite

Graphite is a pure form of carbon.

Pure graphite contains only carbon atoms and atoms are arranged in layers.

Graphite itself ~~cor~~ has two allotropic forms.

a) Naturally occurring graphite is called β-graphite and it exist in hexagonal form.

b) Synthetically produced graphite is called α-graphite and it exist in a rhombohedral form.

Preparation →

Graphite is obtained by Acheson's process which consists of heating a mixture of sand (SiO_2) and coke in presence of iron oxide as catalyst at temperature of 3000°C in an electric furnace.

Reaction between SiO_2 and coke:

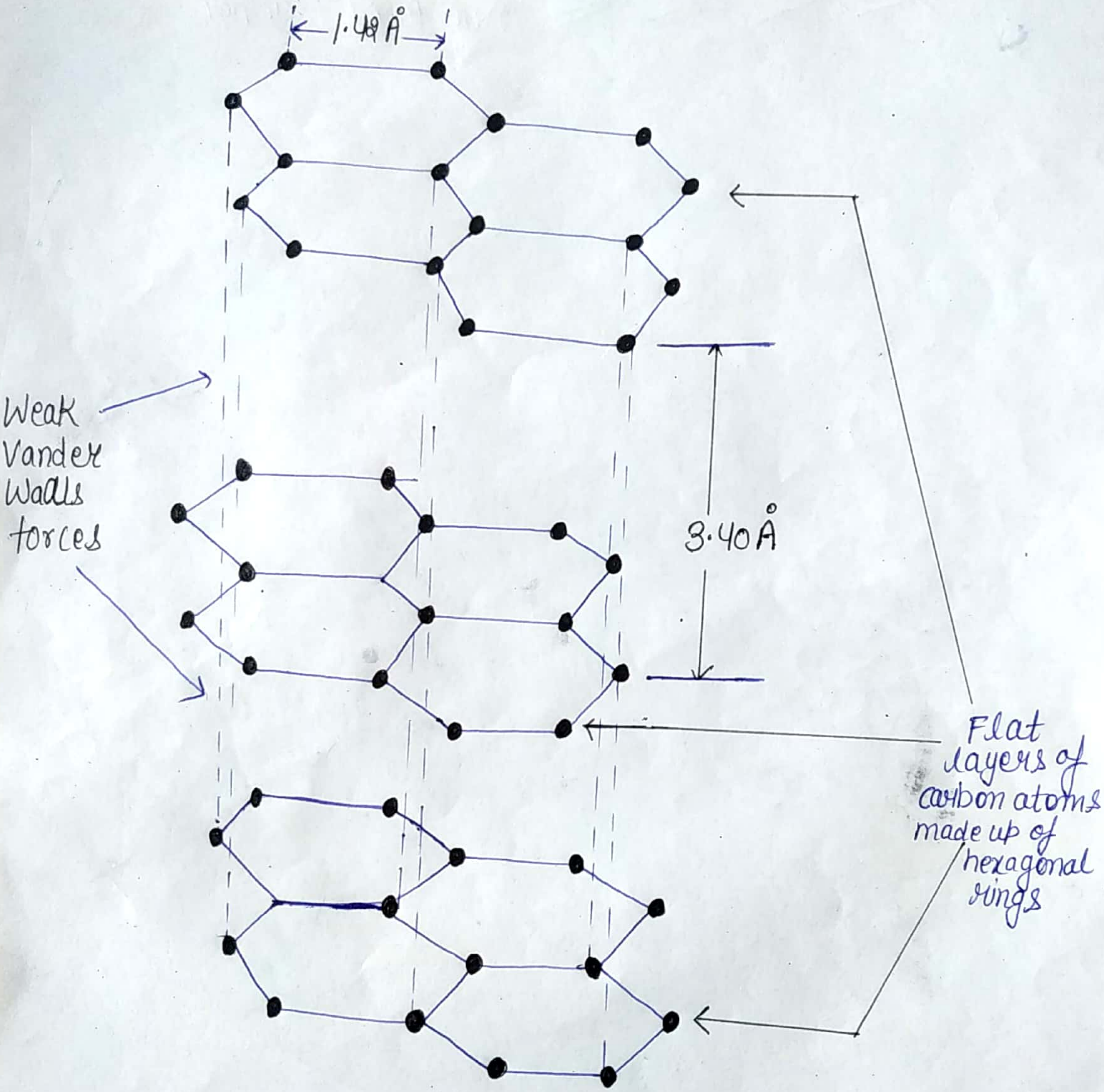
$$SiO_2 + 3C \xrightarrow{\text{Iron oxide}} SiC + 2CO$$

$$SiC \xrightarrow{\Delta} Si + C \text{ (graphite)}$$

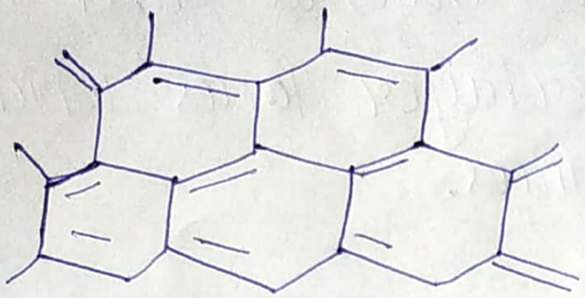
Structure :–

- Structure of graphite consists of large number of flat parallel layers of carbon atoms.
- Each layer is composed of flat hexagonal rings of C atoms.
- In each layer, each carbon atom is joined ~~by~~ to only three carbon atoms by C–C covalent bonds.
- Thus each C-atom is sp^2 hybridised.
- C–C distance in each hexagonal ring is 1.42 Å and distance between two adjacent layers of C-atoms is 3.40 Å.
- Such a large distance between two layers suggests that these layers are joined together by weak vander waal forces.

Hence graphite has two dimensional sheet like structure with weak interlayer forces which make graphite very soft substances.



Structure of Graphite



Two dimensional sheet like structure consisting of no. of benzene ring fused together.

Properties of Graphite

1. Lubricating properties → Since carbon atom in graphite forms a layer like structure with hexagonal arrangement of carbon atoms.
These layers in graphite, are held together by weak van der waal forces. that's why these layers can easily slide over one another and hence graphite is a soft, slippery substance and has <u>lubricating properties.</u>
Thus graphite is used as lubricant for fast moving part of machinery.

2. Conductivity
Since in each layer, each carbon atom is linked to other three C-atoms only. one electron on each carbon atom is free to move. And the electrons are carriers of heat and electricity in graphite. Thus graphite is a <u>good conductor of electricity and heat.</u>

3. Bond length → Because of sp^2 hybridisation C-C bond lengths in graphite are 1.40Å.

4. Opaqueness → Graphite is a black substance and possess a metallic lustre.

5. Purity → Graphite is the purest form of carbon.

6. High melting point → Melting point of graphite is very high ~ 3700°C.
In graphite, each C-atom is joined to other C-atom through strong sigma bonding. Since sigma bonds are known to be strong and they require large amount of energy to break. That's why graphite has high melting point.

Applications of Graphite

1. Writing materials
   Since graphite is soft and black in colour, it is used in making lead pencils.

2. Lubricants →
   Graphite is used as a lubricant for fast moving part of machinery. It is a greasy substance.

3. Repellents
   Graphite is used in paints. Since graphite by nature is water repellent. So it offers a protective coating on wood and other surfaces.

4. Refractories
   Due to high melting point of graphite, it is used in refractory material (these are resistant to high temperature) It is also used in production of glass & steel.

5. Nuclear reactors
   Graphite is used as moderator i.e for reducing the speed of fast moving neutrons in atomic reactors to stabilize nuclear reactions.

6. Electrical industry
   Graphite is used in making electrodes of electric furnaces. It is also useful in lithium ion batteries.

7. Graphene sheets
   Graphite can be used to make graphene sheets. These sheets are ~~solid~~ 100 times stronger and 10 times lighter than steel. Also used in making lightweight and strong sports equibment.

Fullerenes

- In 1985, a new form of carbon i.e. C_{60} or fullerene molecule was discovered.
- Fulleren was discovered by Robert Curl, Harold Kroto and Richard Smalley.
- This discovery later led to award of 1996 Nobel prize in Chemistry.

Preparation

- These were first prepared by evaporation of graphite using powerful laser.
- Practical method of prodution of fullerene involves heating of graphite in an electric arc in an inert gas such as helium or argon, then sooty material is formed by condensation of C_n small molecules.
- The sooty material so formed mainly consist of C_{60} fullerene

The complete process of formation and separation of C_{60} and C_{70} fullerene from graphite as follows

$$\text{Graphite} \xrightarrow[\text{He or Ar}]{\text{Electric arc}} \text{vapourised carbon}$$

$$\downarrow \text{Condensation}$$

$$\underset{\text{Fullerene}}{C_{60} + C_{70}} \xleftarrow{\text{Chromatography}} \underset{(C_{60} + C_{70}\,\text{little})}{\text{Fullerene soot}}$$

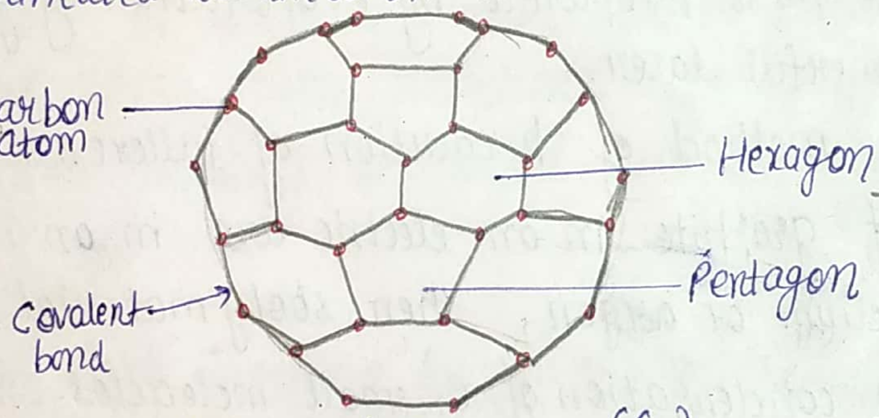
Structure

(1) It looks like a soccerball and is also called buckyball.

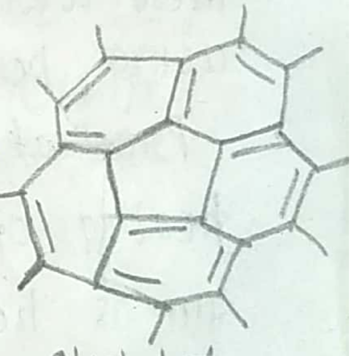
(3) It contains 20 six membered ring or hexagonal rings. and 12 five membered rings or pentagonal rings.

(4) Each hexagonal rings are fused both to other hexagonal rings and pentagonal rings but pentagonal rings are connected only to hexagonal rings. C-C bond length in hexagonal rings is 1.4A° and for pentagonal rings is 1.44A°

(2) The structure of fullerene is Truncated icosahedron. The truncated icosahedron is an Archimedean solid.



Structure of fullerene (C_{60})



Skeletal formula for part of Buckminster fullerene

(5) All the carbon atoms ~~are~~ undergo sp^2 hybridisation. Each carbon atom forms three σ bonds with other three carbon atoms. The remaining electrons of each carbon is delocalized in molecular orbitals.

(6) Fullerene consist of spherical arrangement of C-atoms.

(7) Fullerene molecule consist of 60 carbon atoms which are arranged in pentagons and hexagons similar to soccer ball.

(8) ~~Due~~ It is also known as Buckminster Fullerene due to resemblance of this shape to geodesic domes (having hexagonal & pentagonal patterns) designed and built by architect, R. Buckminster Fullerene.

Properties of (Fullerene

1. Fullerenes being covalent are soluble in organic solvents such as toluene, chlorobenzene etc.

2. It acts as an electron-accepting group and is characterised as an oxidising agent.

3. It can react with group 1 alkalimetals, forming solids such as K_3C_{60}. This compound behaves as a superconductor which means that it carries electric current with zero resistance.

4. In chemical reactions, fullerene can acts as an electrophile.

Types of fullerene

1. Spherical fullerene → These are also called buckyballs.
2. Cylinderical fullerene → These are called carbon nanotube.
3. Planar fullerene → Graphene is an example of planar fullerene sheet.

Applications of Fullerenes

1. Buckminster fullerene is used in drug delivery systems, in lubricant and as a catalyst.

2. It is also used as conductor.

3. Fullerene acts as electron accepting group and is characterised as an oxidising agent.

4. Fullerenes are used in biomedical applications including design of high performance MRI contrast agents, X-ray imaging contrast agents.

5. C_{60} based films are used for photovoltaic applications such as in solar cells, diode and semiconductors.

6. Fullerene are used in making carbon nanotubes based fabrics and fibres.

7. Fullerene C_{60} and its derivatives have potential antiviral activity and are of great significance for the treatment of HIV infection.