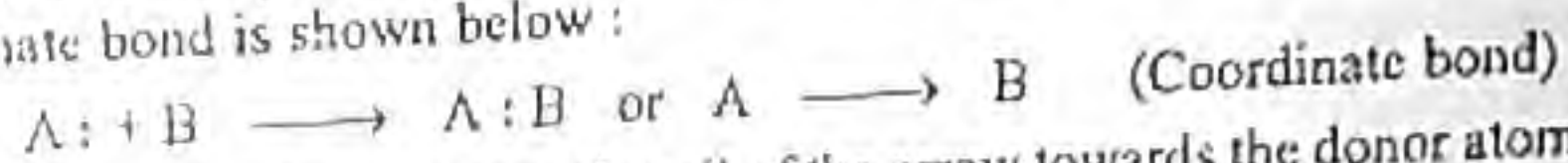


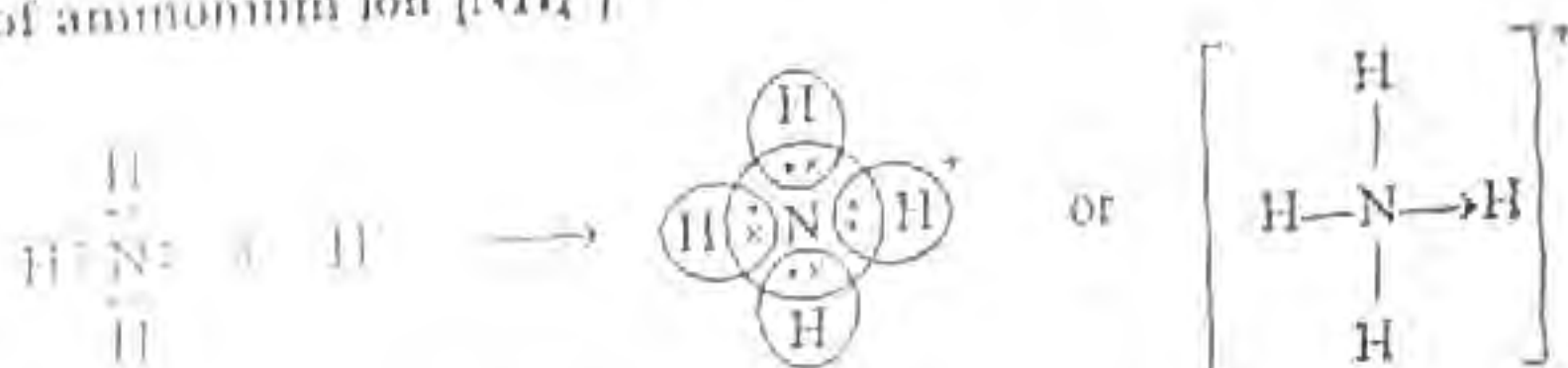
## 1.4 Coordinate Bond

When an atom having a complete octet donates a lone pair of electrons to another atom which is short of two electrons, the resulting bond is known as **coordinate bond**. The coordinate bond is similar to that of covalent bond except that both the shared electrons are donated by only one atom. The formation of coordinate bond is shown below :



The coordinate bond is shown by an arrow, the tail of the arrow towards the donor atom, and head towards the acceptor atom. Since one atom donates an electron pair and the other accepts, the molecule acquires polarity. The extent of polarity is larger than that of covalent bonds although less than electrovalent bonds. These bonds are also called **dative bond**. Examples of coordinate bonds are :

Formation of ammonium ion  $[NH_4^+]$



### Characteristics of Coordinate Compounds

Generally coordinate compounds resemble covalent compounds.

- (i) **Solubility** : These are generally insoluble in water but are soluble in organic solvents.
- (ii) **Melting and Boiling Points** : The M.P. and B.P. of coordinate compounds have intermediate value between electrovalent and covalent compounds.
- (iii) **Conductivity** : This type of compounds are not ionized in solution or in the fused state. Hence, they do not conduct electricity.
- (iv) **Space isomerism** : Coordinate compounds show space isomerism due to directional nature of bond.

## 1.5 Molecular Orbital Theory

This theory was put forward by Hund and Mulliken in 1932. It assumes that in molecules atomic orbitals lose their identity and the electrons in molecules are present in new orbitals called **molecular orbitals** which are not associated with a particular atom but belong to the molecule as a whole.

### Characteristics

1. In molecules, electrons are present in new orbitals called **molecular orbitals**. These orbitals are characterized by a set of quantum numbers like atomic orbitals.
2. These (molecular) orbitals are formed by the **linear combination of atomic orbitals (LCAO)** of nearly same energies.

- Molecular orbitals are not localised with a particular atom but belong to nuclei of all the constituting atoms of a molecule. Nuclei of various atoms in the molecule act as a polycentric nucleus.
- The shapes of the molecular orbitals depend upon the shapes of combining atomic orbitals.
- The new molecular orbitals formed are of two types; Bonding Molecular Orbital (BMO) at a lower energy than the original atomic orbital and Antibonding Molecular Orbital (AMO) at a higher energy.

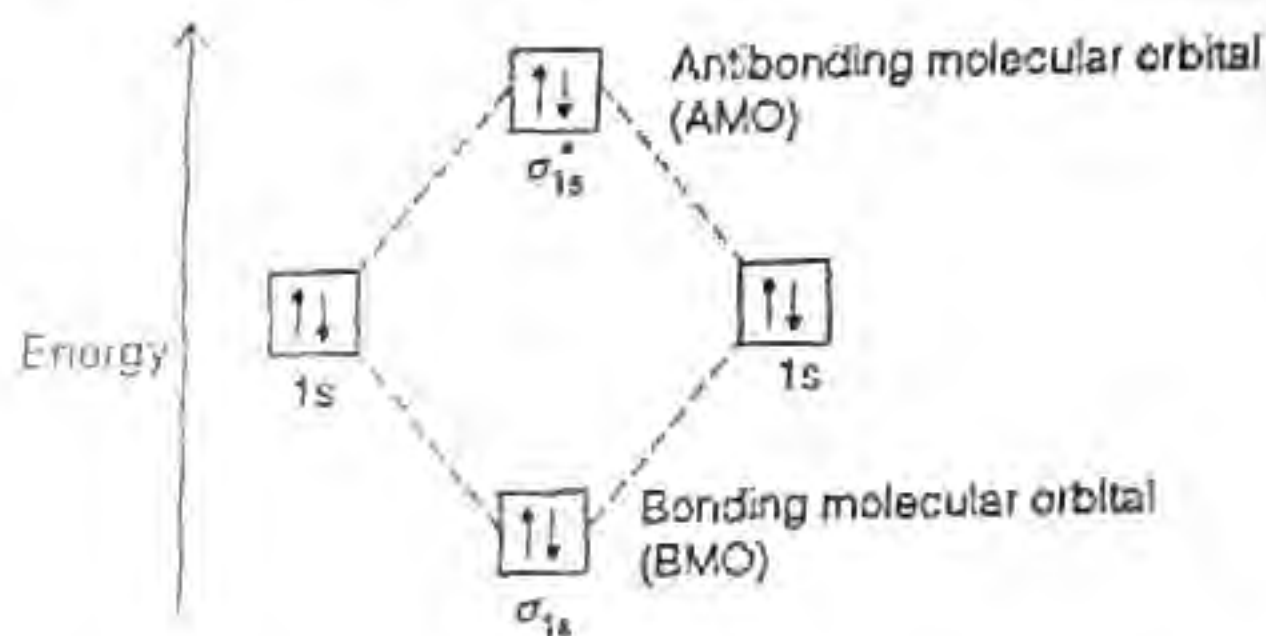


Fig. 1.1

- The number of molecular orbital produced is equal to the number of atomic orbitals that are combined.
- Electrons are filled in the increasing order of energy of the molecular orbital. (Aufbau rule).
- The maximum number of electrons that can be accommodated by the given molecular orbital is two (Pauli's exclusion principle).
- Electrons enter in molecular orbital of identical energies (degenerate orbitals) singly before they pair up (Hund's rule).
- Number of bonds between two atoms is called bond order and is given by

$$\text{Bond order} = \frac{1}{2} [N_b - N_a]$$

where  $N_b$  = number of electrons in bonding molecular orbital

$N_a$  = number of electrons in antibonding molecular orbital

- For a stable molecule or molecular ion,  $N_b > N_a$ .
- If all the electrons in a molecule or molecular ion are paired, the molecule/ion is diamagnetic and in case there are unpaired electrons in a molecule/ion, the substance is Paramagnetic in nature.

### Conditions for the Combination of Atomic Orbitals

- The combining atomic orbitals should have almost same energies.
- The extent of overlap between the atomic orbitals of the two atoms should be large.
- The combining atomic orbitals should have the same symmetry about the molecule axis.

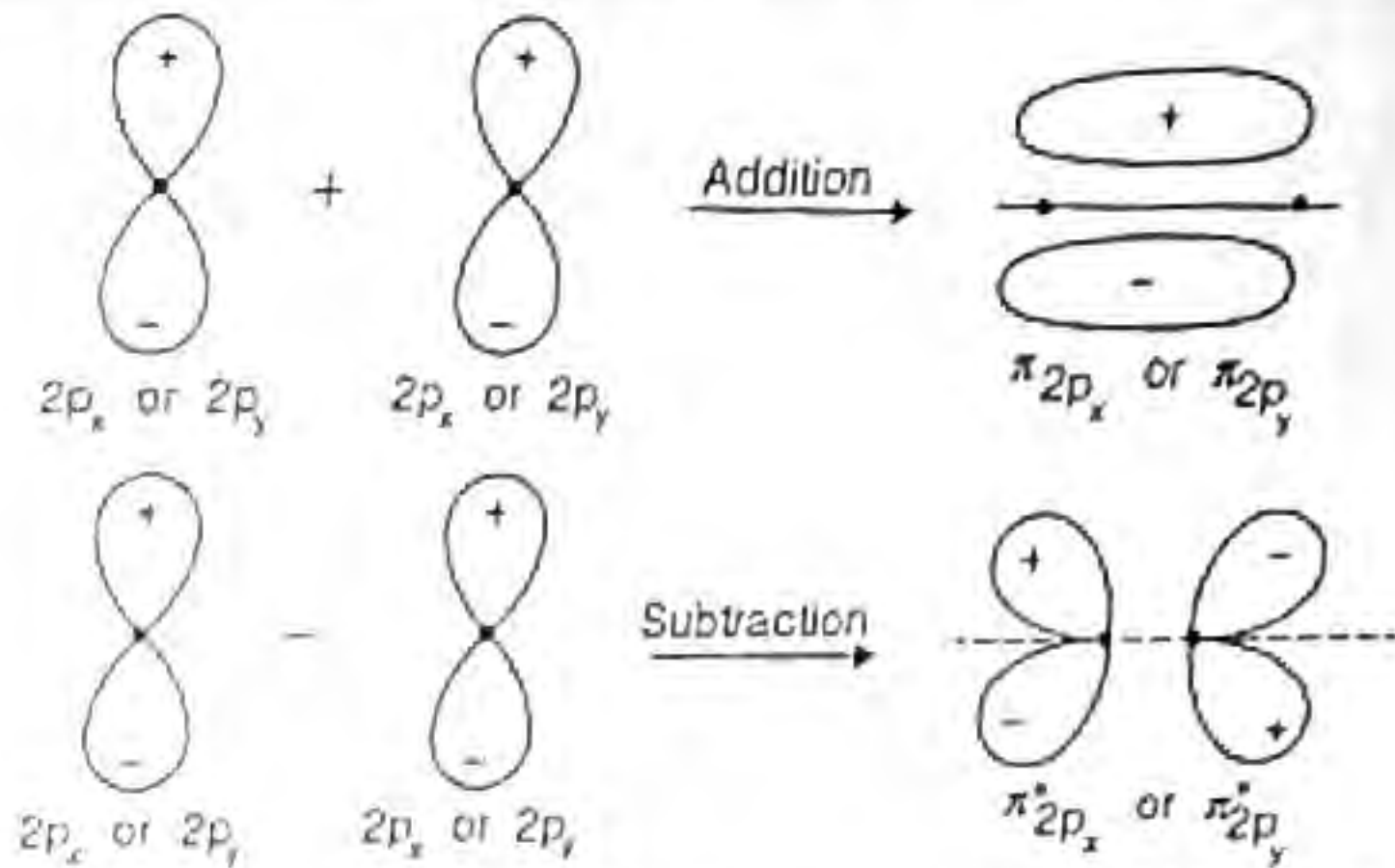


Fig. 1.3 : Formation of  $\pi$  BMO and AMO by overlapping of  $p_x/p_y$  atomic orbitals

The energies of these molecular orbitals increases in the order as shown below :

- (i)  $\sigma 1s, \sigma^* 1s, \sigma 2s, \sigma^* 2s, \sigma 2p_z, \pi 2p_x, \pi 2p_y, \pi^* 2p_x, \pi^* 2p_y, \sigma^* 2p_z$   
 increasing energy (for electrons > 14)

- (ii)  $\sigma 1s, \sigma^* 1s, \sigma 2s, \sigma^* 2s, \pi 2p_x, \pi 2p_y, \sigma 2p_z, \pi^* 2p_x, \pi^* 2p_y, \sigma^* 2p_z$   
 increasing energy (for electrons < 14)

Molecular orbitals electronic configuration is written similar to atomic orbitals. As for example  $\text{He}_2^+$ ,

$\sigma 1s^2 \sigma^* 1s^1$  or  $K^2 K^{*1}$  (K indicates first BMO and  $K^*$  AMO)  
 and for  $\text{O}_2$  molecule,

$KK^* \sigma 2s^2 \sigma^* 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \pi 2p_y^2, \pi^* 2p_x^1 \pi^* 2p_y^1$

### Electronic Configurations of Some Homonuclear Diatomic Molecules

- Hydrogen Molecule ( $\text{H}_2$ )** : It is formed by the union of two H-atoms. Each H atom has one electron in 1s orbital. Thus, electronic configuration of  $\text{H}_2$  molecule is :  $\sigma 1s^2$

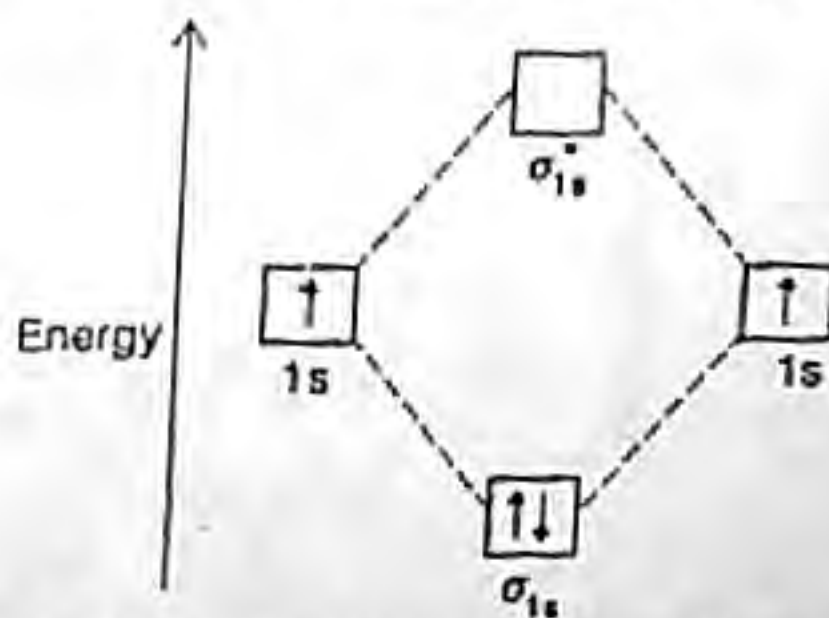


Fig. 1.5 : Molecular orbital diagram of  $\text{H}_2$  molecule

**Helium molecule ion ( $\text{He}_2^+$ ):** This is formed by combination of He atom and  $\text{He}^+$  ion.

The configuration of the ion is:

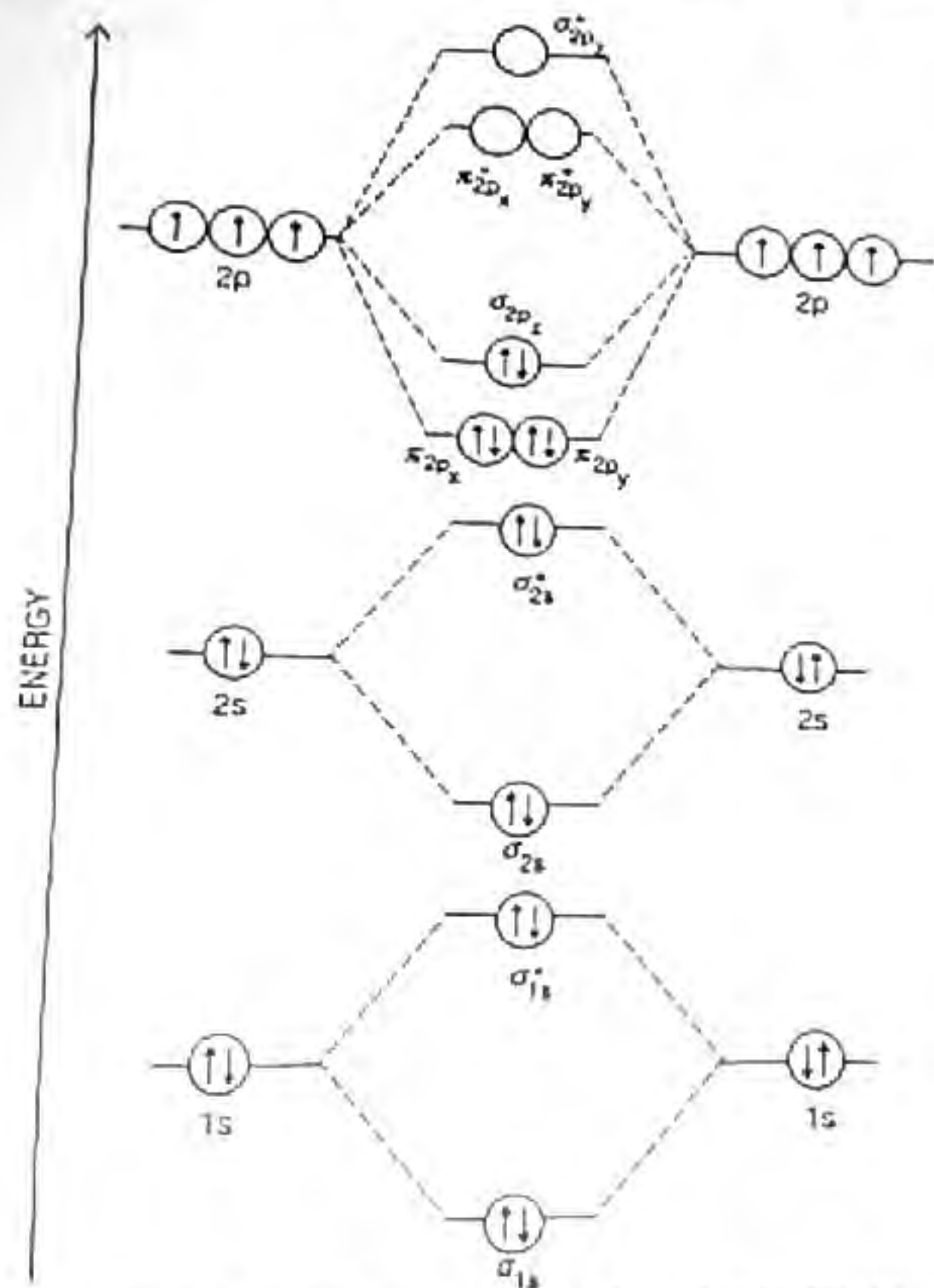
$$\sigma 1s^2, \sigma^* 1s^1$$

$$\text{Bond order} = \frac{1}{2} [N_b - N_a]$$

$$= \frac{1}{2} [2 - 1] = 0.5$$

Unpaired electron = 1, Paramagnetic nature.

**Hydrogen molecule ( $\text{H}_2$ ):** Each H atom has one electron. Thus, Hydrogen molecule has two electrons.



Atomic orbitals Molecular orbitals Atomic orbitals  
Fig. 1.8 : Molecular orbital diagram of  $\text{N}_2$  molecule

The molecular orbital configuration of  $\text{N}_2$  molecule is:

$$\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2, \pi 2p_y^2, \sigma 2p_z^2$$

$$\text{Bond order} = \frac{1}{2} [N_b - N_a]$$

$$= \frac{1}{2} [10 - 4] = 3$$

Unpaired electron = zero, diamagnetic in nature.

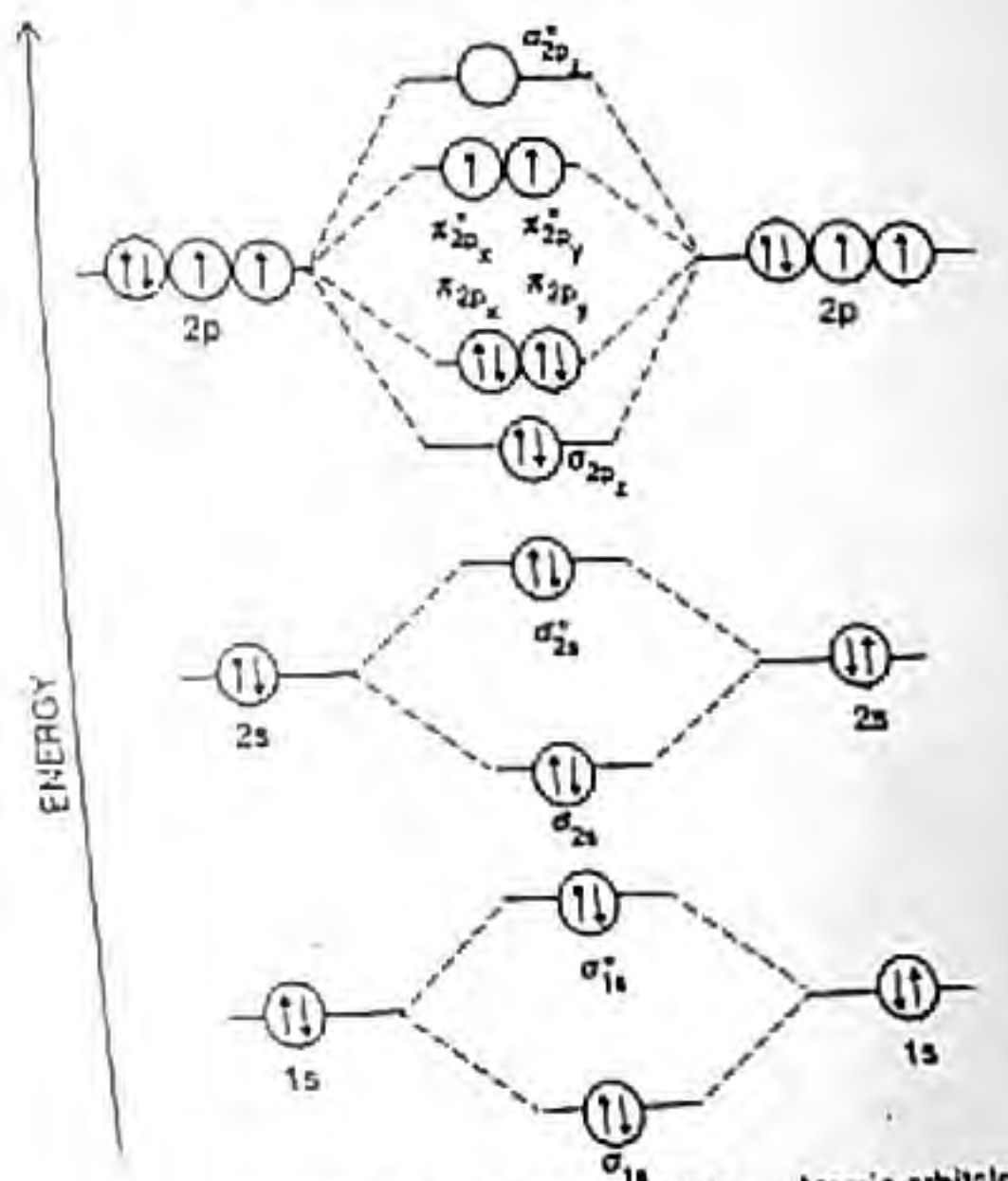
6. **Oxygen molecule ( $\text{O}_2$ ):** The electronic configuration of oxygen atom is  $1s^2, 2s^2, 2p^4$ . The electronic configuration of  $\text{O}_2$  molecule is:

$$\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, \pi 2p_x^2, \pi 2p_y^2, \pi^* 2p_x^1, \pi^* 2p_y^1$$

$$\text{Bond order} = \frac{1}{2} [N_b - N_a]$$

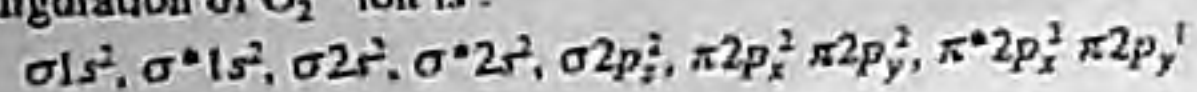
$$= \frac{1}{2} [10 - 6] = 2$$

Unpaired electrons = 2, Paramagnetic nature



Atomic orbitals Molecular orbitals Atomic orbitals  
Fig. 1.9 : Molecular orbital diagram of  $\text{O}_2$  molecule

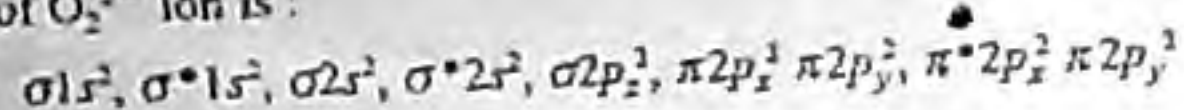
**oxide ion ( $O_2^-$ ):** This ion is formed by the combination of O atom and  $O^-$  ion. The electronic configuration of  $O_2^-$  ion is:



$$\text{Bond order} = \frac{1}{2}(N_b - N_a) = \frac{1}{2}(10 - 7) = 1.5$$

Unpaired electron = 1, Paramagnetic nature

**peroxide ion ( $O_2^{2-}$ ):** Peroxide ion is formed by the combination of two  $O^-$  ions. The electronic configuration of  $O_2^{2-}$  ion is:



$$\text{Bond order} = \frac{10 - 8}{2} = 1$$

Unpaired electron = zero, diamagnetic nature

**fluorine molecule ( $F_2$ ):** Each F-atom has electronic configuration  $1s^2, 2s^2, 2p^5$ . The molecular orbital configuration of  $F_2$  molecule is:

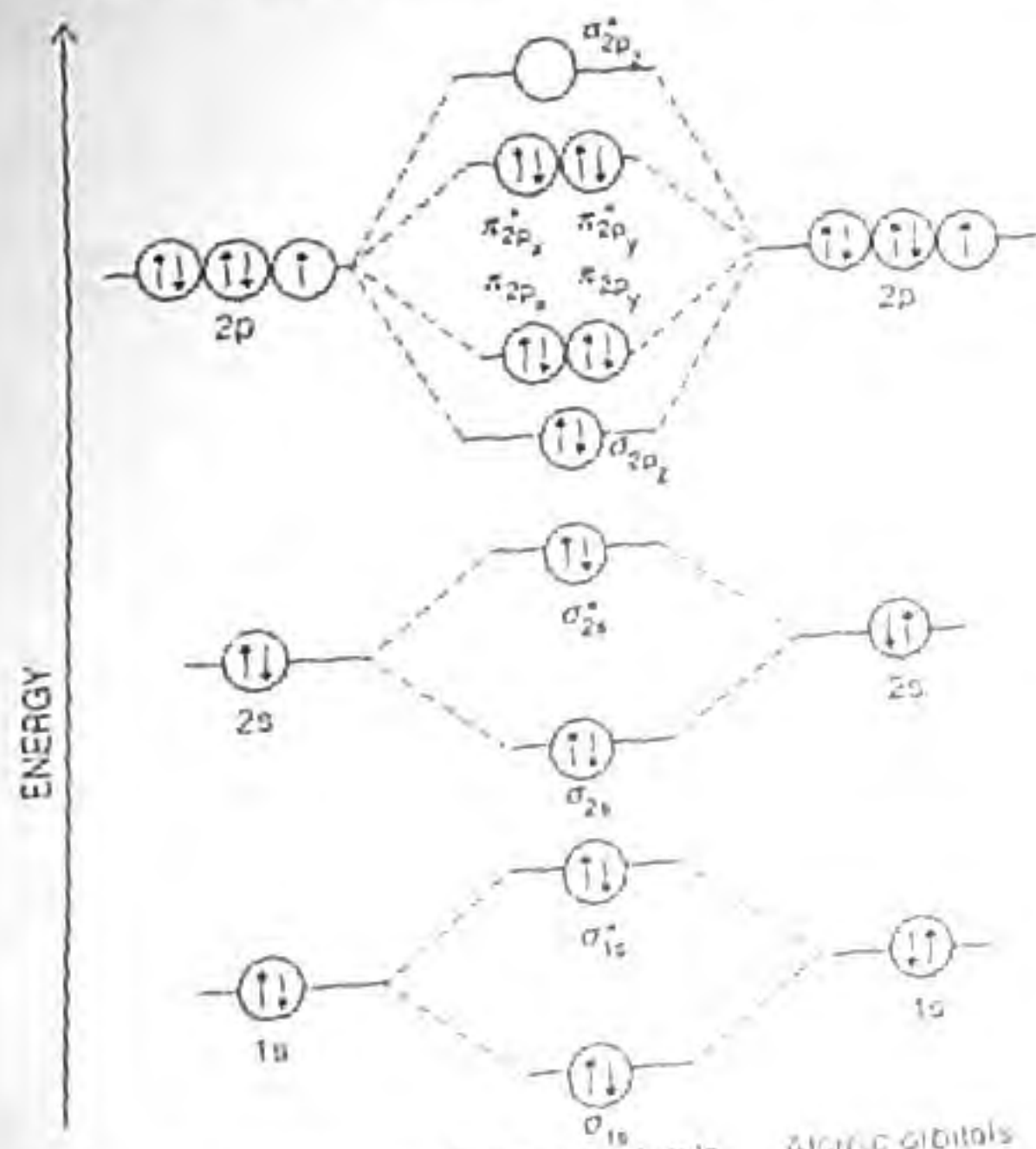
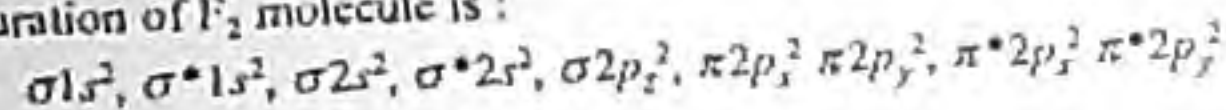
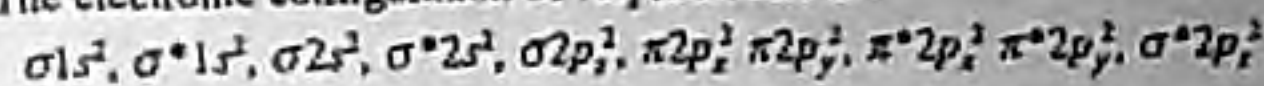


Fig. 1.10 : Molecular orbital diagram of  $F_2$  molecule

$$\text{Bond order} = \frac{10 - 8}{2} = 1$$

Unpaired electron = zero, diamagnetic nature

**10. Neon ( $Ne_2$ ):** The electronic configuration of  $Ne_2$  molecule is:

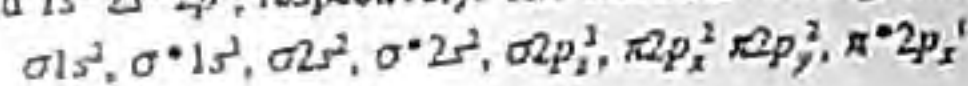


$$\text{Bond order} = \frac{10 - 10}{2} = \text{zero}$$

Since bond order for  $Ne_2$  molecule is zero, the molecule is unstable and does not exist.

**Molecular Orbital Energy Level Diagrams of Some Heteronuclear Diatomic Molecules**

**1. Nitric oxide molecule NO:** The electronic configuration of N and O atoms have been  $1s^2, 2s^2, 2p^3$  and  $1s^2, 2s^2, 2p^4$ , respectively. The electronic configuration of NO molecule is:



$$\text{Bond order} = \frac{10 - 5}{2} = 2.5$$

Unpaired electron = 1 Paramagnetic nature

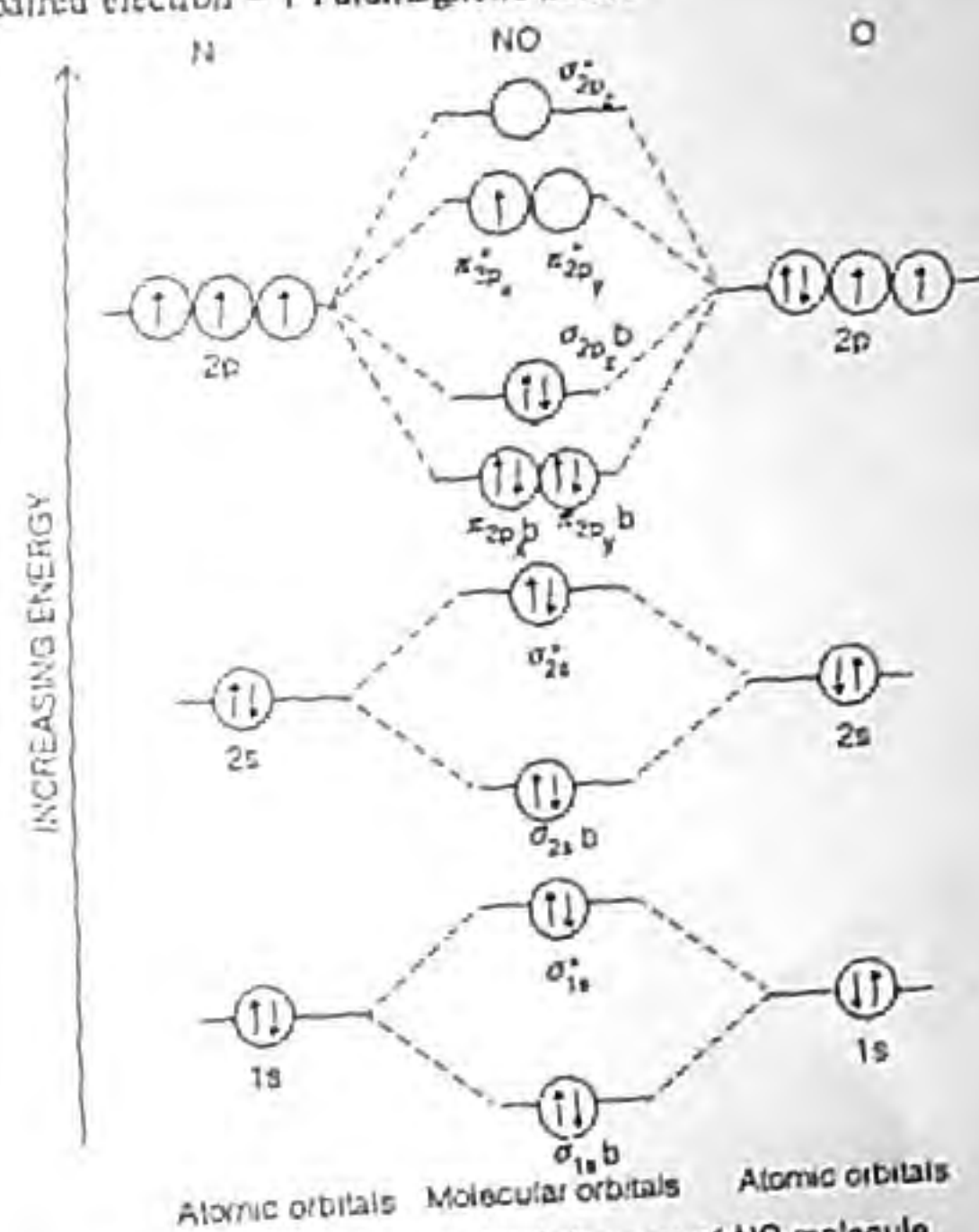


Fig. 1.11 : Molecular orbital diagram of NO molecule

## 8. Diamond

In Diamond, each carbon atom is covalently bonded to four carbon atoms involving  $sp^3$  hybrid orbitals. Thus, each carbon atom is surrounded by four other carbon atoms at the four corners of a regular tetrahedron. The crystal is, consequently, a three-dimensional giant, compact, interlocking molecule without any limit of its extension. The C-C bond distance is  $1.54\text{\AA}$  and bond angle is  $109^\circ 28'$ . Since all the bonding orbitals are fully occupied, the crystal is an insulator. The extreme hardness, brittleness and high melting point of the diamond is due to good strength of the bond and their uniformity in all directions, throughout the crystal lattice. The entire crystal is regarded as one large carbon molecule and is called a macromolecule. Silicium carbide, Zinc sulphide, Silver iodide also have diamond type structure.

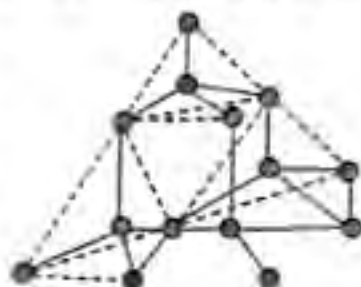


Fig. 17: Structure of diamond

## 9. Graphite

It is another polymorph of carbon. It has a crystal structure distinctly different from that of diamond and is also more stable than diamond at ambient temperature and pressure. Graphite offers a very good example of two-dimensional solid. The graphite structure is composed of layers of hexagonally arranged carbon atoms; within the layers, each carbon atom is bonded to three coplanar neighbourly atoms by covalent bonds. The fourth bonding electron participates in a weak van der Waals type of bond between the layers. As a consequence of these weak interplanar bonds, interplanar cleavage is facile, which gives rise to the excellent lubricative properties of graphite. Also, the electrical conductivity is relatively high in crystallographic directions parallel to the hexagonal sheets.



Fig. 18: Structure of graphite

Other desirable properties of graphite are

1. High strength and good chemical stability at elevated temperatures and in non-oxidizing atmospheres.
2. High thermal conductivity, low coefficient of thermal expansion and high resistance to thermal shock, high absorption of gases and good machinability.

## 9.1 Applications of Graphite

Graphite is commonly used (1) as heating elements for electric furnaces, (2) as electrodes for arc welding, (3) in metallurgical crucibles, (4) in casting moulds for metal alloys and ceramics, (5) for high-temperature refractories and insulations, (6) in rocket nozzles (7) in chemical reactor vessels (8) for electrical contacts, (9) brushes and resistors, (10) as electrodes in batteries, (11) and in air purification devices.

## 10. Fullerenes

This polymorphic form of carbon was discovered in 1985. It exists in discrete molecular form, and consists of a hollow spherical cluster of sixty carbon atoms; a single molecule is denoted by  $C_{60}$ . Each molecule is composed of groups of carbon atoms that are bonded to one another to form both hexagon (six-carbon atom) and pentagon (five-carbon atom) geometrical configurations. One such molecule, shown in fig. 19 is found to consist of 20 hexagons and 12 pentagons. Which are arrayed such that no two pentagons share a common side; the molecular surface thus, exhibits the symmetry of a soccer ball. The material composed of  $C_{60}$  molecules is known as buckminster fullerene. The term fullerenes is used to denote the class of materials that are composed of this type of molecule.

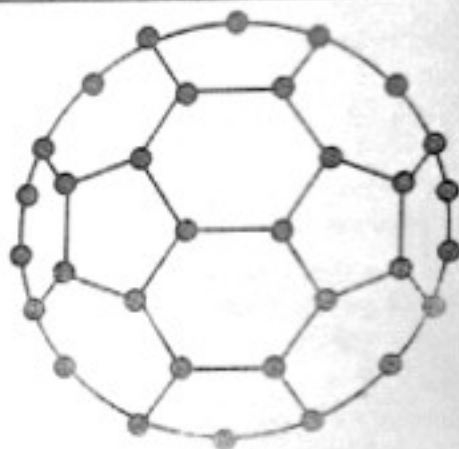


Fig. 19: Structure of  $C_{60}$  molecule

While, the carbon atoms in buckminster fullerene bond together so as to form these spherical molecules. In the solid state,  $C_{60}$  units form a crystalline structure and pack together in a face centered cubic array.

### 10.1 Preparation of Fullerenes

1. Fullerenes are prepared by vaporizing a graphite rod in the atmosphere of helium. Mixture of fullerenes are formed which are separated by solvent extraction or by sublimation. Fullerene  $C_{60}$  is isolated from the mixture by chromatographic technique using alumina-hexane.
2. Small percentage of fullerenes containing soot can be prepared from benzene-oxygen combustion flame in a carefully designed argon atmosphere.

### 10.2 Properties of Fullerenes

1. It is a mustard coloured solid.
2. The colour changes from brown to black with increasing thickness of fullerene films.
3. It gives magenta coloured solution, when dissolved in toluene.
4. On sublimation, it gives translucent magenta crystals.

- In pure form, it is an insulator but functions as super conductor by doping with alkali metals.
- Fullerenes react with a number of nucleophiles, for example, amines, phosphines, Grignard reagent, organolithium reagent to give suitable derivatives.
- It also gave adducts with anthracene, cyclopentadiene, furan and isobenzofuran.
- Many higher fullerenes are chiral, with increasing cage size, the number of chiral isomers increases rapidly, for example, of the 5 isomeric  $C_{78}$  structures, 2 are chiral, and 10 chiral isomers exist.
- It can be compressed to loss 30% of its volume without destroying its carbon cage structure. Under UV irradiation,  $C_{60}$  undergoes photodissociation via successive  $C_2$  losses down to  $C_{32}$ .
- It can form solid soft ferromagnetic with zero remanence on reaction with organic electrophiles [Tetrahedron's (Dimethyl amino) ethylene].

### 10.3 Applications of Fullerenes

- Superconductors** : It can be used as a superconductor when doped with alkali metals. When it is cooled, its resistivity begins to drop sharply at about 18°K indicative of superconductivity.
- HIV Protease inhibitor** :  $C_{60}$  and its derivatives, because of their large size, stable structure and hydrophobic character, may prove to have value as diagnostic agents in medicine, for example,  $C_{60}$  derivatives are currently being investigated as potential inhibitors of the protease enzyme specific to the Human Immuno Deficiency Virus 1 (HIV).
- Carbon nanotubes and nanowires**: One potential important application for these carbon nanotubes is in the area of composites. Carbon fibres made from organic polymers are used to strengthen light weight high-tech materials such as the carbon/epoxy resins used in golf clubs, tennis rackets and yachts. Each fibre is five times thinner than a human hair.
- Catalysis**: Fullerene  $C_{60}$  participates in catalysed processes as either a part of the catalyst and/or substrate. The complex  $\eta^2-C_{60}Pd(PPh_3)_2$  has been used as the catalyst in the homogeneous and heterogeneous hydrogenation reactions.
- Polymerization reactions**: When  $C_{60}$  fullerene pellets are exposed to a pressure of 1.2 GPa at 600 K for 5 hour, cycloaddition occurs to give polymers, including linear polymers, in which the  $C_{60}$  fragments are linked by cyclobutane rings.

## 11. Liquid Crystalline State

In certain liquids, new phases which resemble both liquid and solid phases appear when the liquid is cooled. These phases have a translucent or cloudy appearance and are called liquid crystals. When a solid is heated, the thermal agitation gradually overcomes the cohesive force of attraction till at its melting point the solid changes into liquid form. In some substances, the tendency towards an ordered arrangement is so great that the kinetic energy is sufficient to disrupt the binding of the ends of the molecules but is insufficient to overcome strong lateral attraction between the long chains of molecules. The crystalline form thus does not melt directly to give liquid instead it first passes through an intermediate state called the liquid crystal.



state. In this state of matter, the substance tends to take the shape of container like liquids but is more viscous and turbid and appears distinctly different from liquids. The step-wise changes that take place when a solid consisting of long chain rod like molecules melt are shown in fig 20.

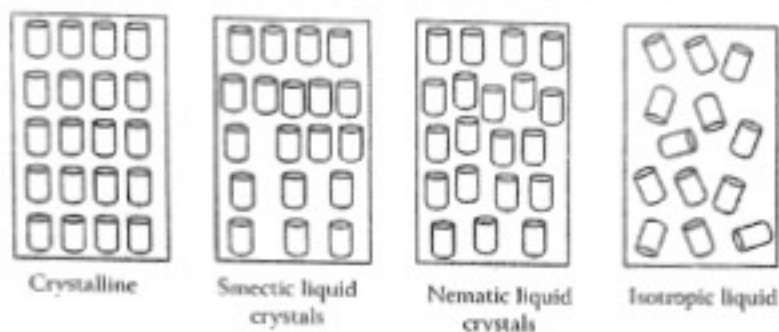


Fig. 20: Step-wise changes in conversion of crystalline solid into liquid through liquid crystalline state

## 11.1 Classification of Liquid Crystals

There are 3 types of the liquid crystals:

1. Nematic liquid crystal
  2. Cholesteric liquid crystal
  3. Smectic liquid crystal
1. **Nematic liquid crystal:** In these liquid crystals, the long axis of the molecules are lined up. The molecular axes are parallel to each other but the molecules are not arranged in layer. Nematic liquid crystals have a translucent appearance because they scatter light strongly. The mechanical, electrical and optical properties like dielectric constant, diamagnetism, elasticity, viscosity etc., depend on the direction along which these are measured. This crystal does not conduct electricity in pure form. However, they show conductance in presence of some impurities. For example, *n*-paramethoxy benzyladine-*p* butyl aniline is solid below 295 K but changes into nematic liquid crystal above this temperature.
  2. **Cholesteric liquid crystal:** In this type, the molecular axes are aligned, and the molecules are arranged in layers in which the orientation of axis shifts in a regular way in going one layer to the next. These are named cholesteric crystals because the skeleton of the substance passing through this state is similar to that of the cholesterol. These liquid crystals are characterized by their very high optical rotation. The pitch of the spiral and the reflected colour depends sensitively on the temperature.
  3. **Smectic liquid crystal:** Smectic liquid crystals are formed by certain molecules with chemically dissimilar parts. The chemically similar parts attract each other and there is tendency to form layers as well as to have the molecules aligned in one direction. Smectic phases are soap like in feel and structure and may have some relationship with the cell membrane. Cholesteryl oleyl carbonate is a typical example of the material passing through the smectic liquid crystal state between 2.3 K and 293 K.

## 11.2 Applications of Liquid Crystals

- Such crystals are used as solvent for the study of structure of anisotropic molecules spectroscopically.
- These crystals consume very little electric power hence these are used in digital displays like pocket calculators, digital wrist watches etc.  
Due to their electrical and mechanical properties lying between crystalline solids and isotropic liquids are used in gas liquid chromatography.
- The cholesteric type of crystals are used for detecting tumours in the body by the method called thermography.

## 12. Concepts of Nanomaterials and Its Applications

### 12.1 Definition of Nanotechnology

Nano is the prefix of a unit. As one nano is equal to  $10^{-9}$ , so 1 nano meter means  $10^{-9}$  m (i.e.  $1 \text{ nm} = 10^{-9} \text{ m}$ ). Any technology involving processes, operations, applications and development of devices of such small dimension is referred to as nanotechnology. Nanotechnology is undergoing a revolutionary change. It has initiated beginning of a new era in industrial revolution. Its advent in day-to-day life will soon be felt and realized.

### 12.2 Background

The word nanotechnology is originated from the Greek word 'nano', which means is extremely small. This name was evolved by Japanese scientist Norio Taniguchi in 1976. The interest of scientists in nanotechnology started increasing in 1986 when a 'scanning tunnelling microscope' was developed by noble prize winner West German scientists Gerd Binnig and Switzerland scientist Heinrich Rohrer. This is the same microscope with the help of which the scientists could easily visualize the structure of an atom and a molecule for the first time.

### 12.3 Concept

The atoms and molecules of materials are almost of the nano size. Therefore, they influence the nano region of materials, consequent upon which the newer changes appear in them. Hence under nanotechnology, the size of material is reduced to the size of nano-domain (one nano-domain generally refers to 1 to 100 nm). By doing so, the changes in different properties of material viz. mechanical, thermal, electrical, optical etc. occur at each level. For so small sized materials, the surface to volume ratio plays important role and most of the molecules make the material hyperactive by coming on the surface.

Examples of Nano structured materials are as follows:

- Nonporous materials** have nano sized pores.
- Nano crystalline materials** consist of many nano-sized crystallize domains.
- Nano composite materials** contain two or more phase separated components. They are of two types
  - Inorganic and
  - Polymer nano composite.

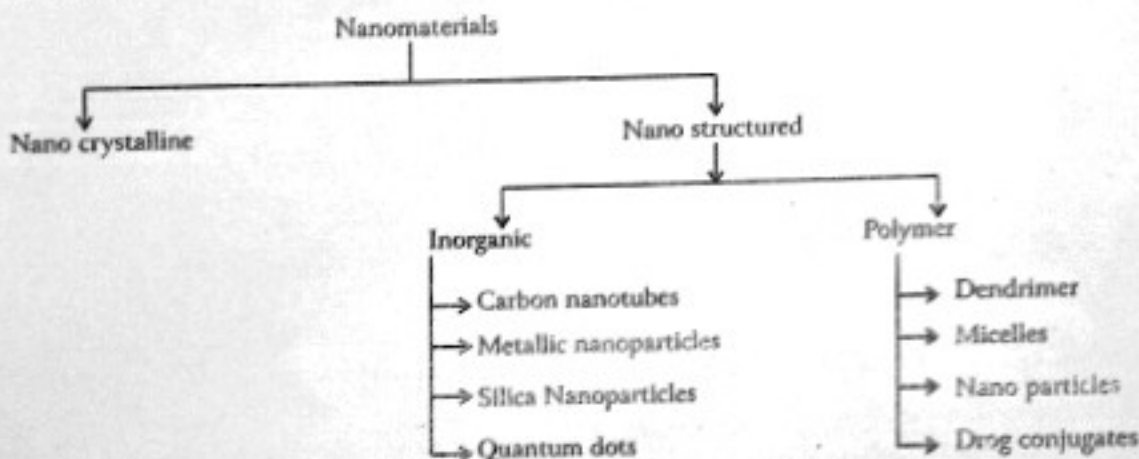
Hybrid materials are made of a combination of organic and inorganic components inter connected at a molecular level (block copolymers)

## 12.4 Classification of Nanomaterials

Nano materials have extremely small size having at least one dimension 100 nm or less.

According to Siegel, nanostructured materials are classified as zero dimensional, one dimensional, two dimensional and three dimensional nanostructures on basis of structure.

Nanomaterials are classified as:



## 12.5 Processes to Prepare Nanomaterials

Nanomaterials are prepared by following two methods.

1. Larger to smaller doing method
2. Smaller to larger doing method

Since each and every object on earth is constructed of molecules, the prepared object obeys the characteristics of its chemical nature. This nature can be changed again and again. The nanomaterials thus prepared are much lighter, strong, transparent and completely different from their parent materials.

## 12.6 Carbon Nanotubes

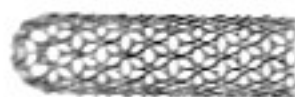
Carbon nanotubes are allotropes of carbon with a nano structure that can have a length to diameter ratio greater than 10,00,000. These cylindrical carbon molecules have unusual properties which are valuable for nanotechnology, electronics, optics and other fields of material science and technology.

Carbon nanotubes is a sheet of graphite rolled into a cylindrical structure in which one carbon atom is covalently bonded to three other carbon-atoms.

### Types of Nanotubes

1. Single Walled carbon Nanotube (SWNT)
2. Multi Walled carbon Nanotube (MWNT)

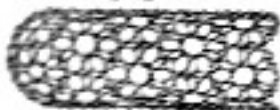
**Construction of Different Structures of Carbon Nanotubes:** Construction of some possible structures of carbon nanotubes are shown in fig. 21. These configurations are following.



(a) Armchair structure



(b) Zig-zig structure



(c) Chiral structure

**Fig. 21 :** Illustration of some possible structures of carbon nanotubes (a) Armchair, (b) Zig-zag, and (c) Chiral structures

#### Application of Nanotubes

1. Nanotubes can be used to produce clothes, sports wear to combat, bullet proof jackets and spacemuits.
2. In developing nanoscale electric motors.
3. In detection of chemical vapours.
4. For transportation of drugs into the body. (in treatment of cancer).
5. Wires from nanotubes can conduct large amount of current with less power wastage.
6. In production of transistors and memory devices.

### 12.7 Carbon Nanocones

Carbon Nanocones were discovered in 1994. They are conical structures which are made from carbon. Nanocones have height and base diameter of the same order of magnitude. They occur on the surface of natural graphite.

#### Applications of Nanocones

Their application areas are:

1. Sensors
2. Hydrogen storage
3. Electronics (as electron field emitter)
4. Manufacture of nanostructured materials with desired mechanical properties.
5. To cap ultra fine gold needles used in scanning probe microscopy.

## 12.8 Dendrimers

Dendrimers are highly branched polymers with controlled composition and nanoscale dimensions. The term dendrimer is derived from the Greek word 'dendri' meaning 'tree like' and 'meros' means 'part of'. Poly (amidoamine) or PAMAM is the most well known dendrimer.

Dendrimers are fabricated from monomers using step growth polymerization by:

1. **Convergent methods**
2. **Divergent methods**

### Applications of Dendrimers

Some important applications are as follows:

1. In bio medical field
2. Transdermal drug delivery
3. In gene delivery
4. In gene therapy
5. Anticancer drugs
6. In chemotherapy
7. For enhancing solubility
8. As magnetic resonance imaging (MRI) contrast against
9. As dendritic sensors
10. In crop protection and agrochemicals
11. In photodynamic therapy

## 12.9 Uses of Nanotechnology

The scope of unique and peculiar products made from nanotechnology is expanding very fast. It ranges from clothes to cosmetics, hard disc of computer to industries, and medical sciences to water purification etc. In this regard, different major fields of application of nanotechnology are enumerated as follows:

1. **Computer stream:**
  - (i) **In Supercomputer:** Development of supercomputer is the outcome of nanotechnology. For that a 'nanowire' is used instead of a computer 'connector'. Consequently, the memory and speed of computer enhances many times. Increase in memory may be as high as 1 million.
  - (ii) **In Chips and ICs:** Computer chips, circuits, transistors and resistors etc. can be made more useful and of much improved quality as compared to existing chips.
2. **Medical sciences:** Presently the maximum use of nanotechnology is in the field of medical sciences. Main among them are the following:
  - (i) **Cancer treatment:** Bacteria tumor cells of gold particle are being developed for changing the structure of cancer. It is likely to destroy the dangerous element of tumor.
  - (ii) **Disease detecting devices:** Nanotechnology based devices such as 'wrist watch' is being developed, which is likely to predict the probable diseases/illnesses of the body. Since the disease will be detected at its original stage, an appropriate treatment can be started without delay. Therefore, there is every likelihood of an increase in human life.
3. **Industries:** The industrial products/items can be produced with excellence of quality and many other peculiarities, such as given below:

- (i) **Nanotechnology based Paints:** If titanium dioxide ( $\text{TiO}_2$ ) as nanomaterial is mixed with the paint; the hardness, shining and life of the paint thus prepared is likely to be many times more than the conventional paint.
- (ii) **Nanotechnology based Clothes:** Such clothes are being manufactured by textile industry, which absorb human sweat easily. These clothes are more durable also as compared to conventional clothes.

4. **Other uses:** Nanotechnology has many other uses. Main amongst them are as follows.

- (i) **Water purification:** Nano-mineral, nano-gold and nano-silver nitrate are useful to remove the harmful element arsenic (As) from water.
- (ii) **Nanofoster material** is used to improve the quality of brightness and contrast of pictures on television.

5. **In future:**

- (i) It will become possible to produce lighter and stronger materials.
- (ii) The nanostructured pharmaceuticals can be delivered into the body's circulatory system in a very short duration.
- (iii) The storage capacity of magnetic tapes can be increased.
- (iv) It will be possible to manufacture scratch proof glasses.

## 12.10 Nano-Electromechanical Systems (NEMS)

Progress in nanotechnology is poised for a great jump. Development of ultra-miniature systems viz. nano-electromechanical systems (NEMS) will make the maintenance, safety and updating of computers and other hardware an easy task.

1. Systems will provide almost troublefree services. The large organizations will be able to squeeze their installations/ equipments into a smaller chamber.
2. Many electronic systems may be mounted-on or housed-in the watches, shirt pockets, pens, other body parts and their belongings.

The future expectations of nanotechnology can be viewed in the light of the following development.

Japanese company 'Nippon Denso' has made an ultra-micro car of unimaginable 4.78 mm size. Made of aluminium and nickel, it contains a motor of 0.67 mm size. The 3 volt motor consists of a coil of 1000 conductors. This car will run inside the human veins for medical treatment, such as of heart etc.

Nanotechnology is undergoing a revolutionary change. Its advent in day to-day life is yet to be felt and realized.