Chemistry

Chemical Bond

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a/ Bond

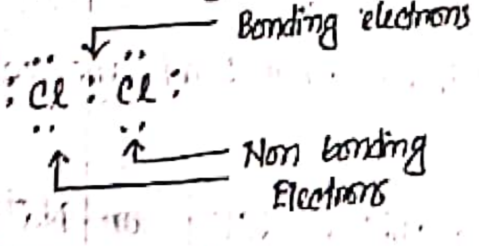
A chemical bond is defined as a force that acts between two or more atoms to hold them together as a stable molecule.

Different Types of Bond

① Ionic or Electrovalent Bond
(II) Covalent Bond
(III) Coordinate covalent Bond
(IV) Metallic Bond

Valence is the number of bonds formed by an atom in a molecule.

Bonding and Non bonding electrons: The valence electrons actually involved in bond formation are called bonding electrons. The remaining electrons are called non-bonding electrons.



Electronic Theory of valence

In chemical bonding, atoms interact by losing, gaining or sharing of electrons so as to acquire a stable noble gas configuration.

Octet theory of Valence

Atoms interact by electron-transfer or electron-sharing, so as to achieve the stable outer shell of eight electrons.

Ionic Bond

The electrostatic attraction between the cation(+) and anion(-) produced by electron transfer constitutes an Ionic or Electrovalent Bond. This type of chemical bonding which is established by transfer of an electrons from one atom to another is called "Ionic Bond" or "Electrovalent Bond".

Formation of Ionic Bond

Elements which have tendency to lose one or more electrons are called electropositive while the compounds which have tendency to gain electrons are called electronegative compounds. When a compound give its electron, it becomes positively charged and we call it cation. On the other hand when a compound gains electrons it becomes negatively charged and is called anion. The electrostatic attraction between the cation(+) and anion(-) produced by electron transfer constitutes an ionic or Electrovalent Bond.

i.e. compound containing ionic bond are called an Ionic or Electrovalent Compound.

Example $Na^{\times} \; \cdot\ddot{\underset{..}{Cl}}: \longrightarrow Na^{+} + [\times\ddot{\underset{..}{Cl}}:]^{-}$ or $Na^{+}Cl^{-}$

$\boxed{\text{Sodium Chloride}}$

$Mg + 2Cl \longrightarrow \boxed{Mg^{2+} + 2Cl^{-}}$

$\boxed{Mg^{2+}Cl_2^{-}}$

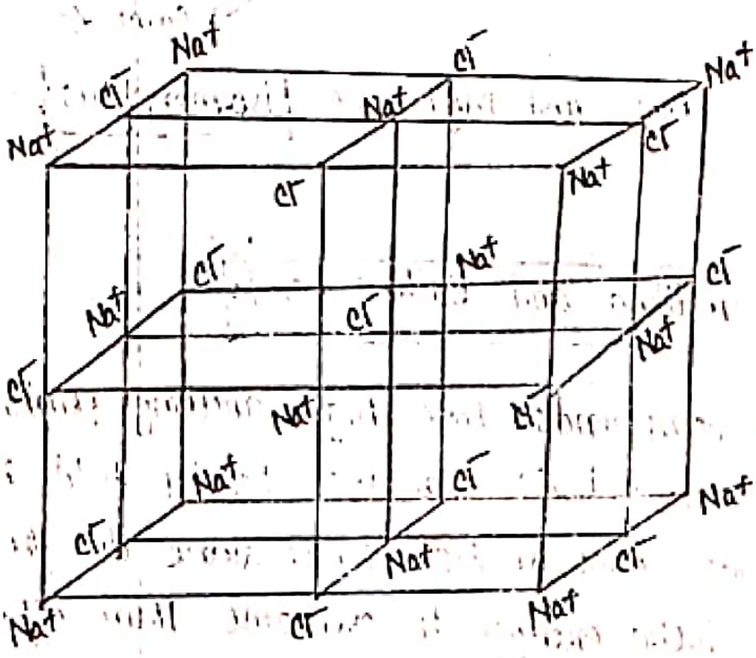
Condition for formation of Ionic Bond

(i) Number of valence electron Ⓐ- 1,2,3 ; Ⓑ- 5,6,7
(ii) Net lowering of energy
(iii) Electronegativity difference between two atom.

operties of Ionic compounds

① **Crystal structure**: All ionic compounds are remain crystal lattice in solid state. The ⊕ and ⊖ ions attract each other with electrostatic force that extends in all directions. This means that ions will be bonded to a number of oppositely charged ions around them. Therefore in solid state, single ionic molecules do not exist as such. Rather many (+) and (–) ions are arranged systematically in an alternating cation-anion pattern called the crystal lattice.

The crystal lattice of **NaCl** is shown as follows:



(ii) **Solid at room temperature:** On account of strong electrostatic forces between the opposite ions, these ions are locked in their alloted positions in the crystal lattice. Since they lack the freedom of movement characteristics of the liquid state, they are solids at room temperature.

(III) **Isomorphism**

When the electronic configuration of different ionic compounds are same in solid state then their crystal structure also be same. The crystal structure between two compounds are the same, then it called as isomorphous crystal. The property to make isomorphous crystal is known as isomorphism.

Example:

same

NaF : $Na^+ \rightarrow \boxed{1s^2 2s^2 2p^6}$: $F^- \rightarrow \boxed{1s^2 2s^2 2p^6}$

MgO : $Mg^{2+} \rightarrow \boxed{1s^2 2s^2 2p^6}$: $O^{2-} \rightarrow \boxed{1s^2 2s^2 2p^6}$

Same

Here, NaF and MgO are **isomorphous**

(IV) **High melting and Boiling point:**

Ionic compounds have high melting point's (or boiling point) since the (+) and (−) ions are tightly held in their positions in the lattice, only at high temperature do the ions acquire sufficient kinetic energy to overcome their attractive forces and attain the freedom of movement. Thus ionic compounds need heating to high temperatures before melting.

(V) **Hard and brittle:**

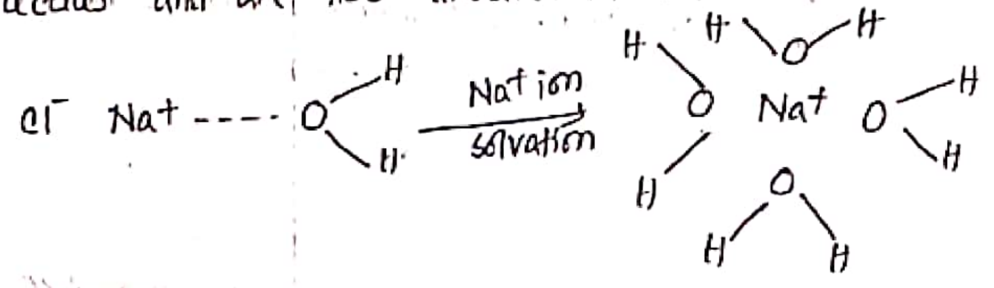
The crystals of ionic substances are hard and brittle. Their hardness is due to the strong electrostatic forces which hold each ion in its allotted position.

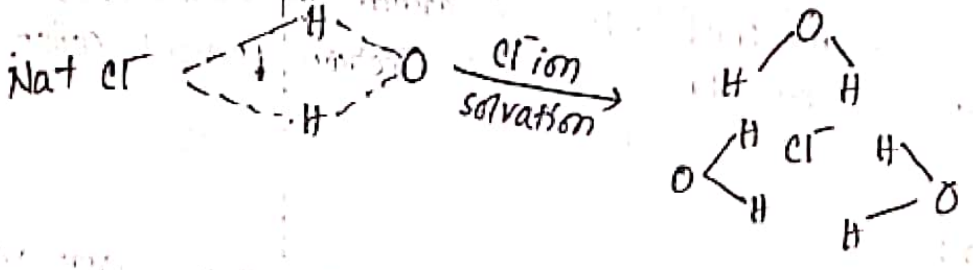
(VI) Ionic reactions are fast

Ionic compounds give reaction between ions and these are very fast.

(VII) Soluble in water

When a crystal of an ionic substances is placed in water, the polar water molecules detach the (+) and (-) ions from the crystal lattice by their electrostatic pull. These ions then get surrounded by water molecules and are thus dissolved in water.





(VIII) Individuality

In ionic compound the ion which is required opposite charges with each other but they are absorbed in strong electrometic force maintain their different parts of characters. Example:

$2Na + Cl_2 \rightarrow NaCl$

$4Na + O_2 \rightarrow 2Na_2O$

4- **Factors Governing the formation of ionic bond**

① Ionisation Energy (amount of energy which is required to remove the most loosely bound electron). Lower the ionisation energy greater the tendency to form ionic bond.

(ii) Electron Affinity (amount of energy which is released to add an electron)

(iii) Lattice energy (amount of energy released when one mole of an ionic compound is formed from its cations and anions. Greater the lattice energy, greater the strength of ionic bond)

Covalent Bond

The chemical Bond which is caused by the attractive force between atoms created by sharing of an electron pair is called covalent Bond.

Formation:

Let, the two atoms A and B have one and seven valence electrons respectively. When they form a covalent bond they share the valence electron and resulting electron pair fills the outer shell of both the atoms and thus A acquires 2 electrons and B acquires 8 electrons which is stable.

$$A\times + \cdot B \longrightarrow \overset{\text{shared electron pair}}{(A)\!\times\!\cdot\!(B)} \longrightarrow A-B$$

The shared pair is indicated by dash (–) between the two bonded atoms.

Properties of covalent Bond / Characteristics of covalent compound

(i) Gases, liquids or solids at room temperature

(ii) Low melting and boiling points

(iii) Covalent compound are soft, much readily broken.

(iv) Insoluble in water but soluble in organic solvents

(v) Non-conductors of electricity

(vi) Exhibit isomerism.

(vii) Undergo molecular reaction which are slow.

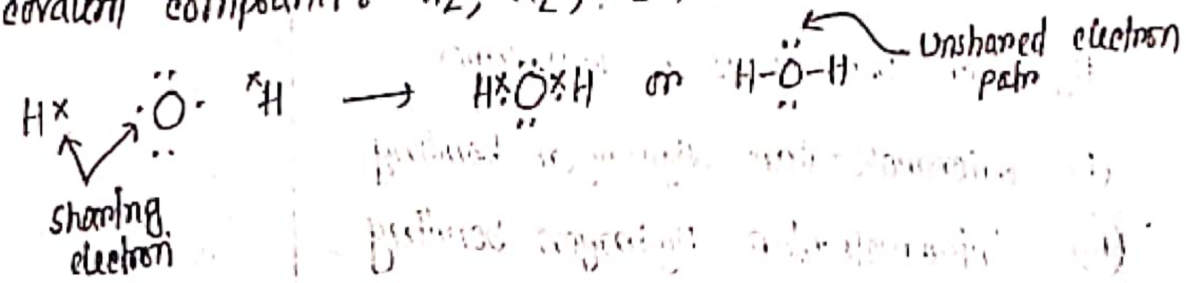
Condition for formation of covalent bond

(i) Number of valence electron Both Ⓐ and Ⓑ - 5, 6, 7

(ii) Equal electronegativity

(iii) Equal sharing of electron.

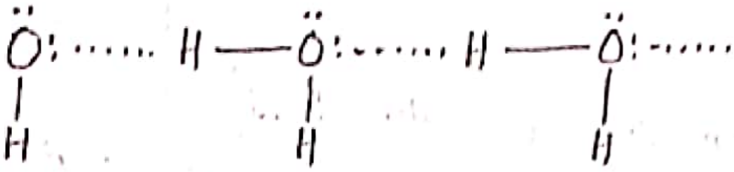
Example of covalent compound: H_2, Cl_2, H_2O, NH_3, CH_4



Hydrogen bonding:

The electrostatic attraction between an H atom covalently bonded to a highly electronegative atom X and a lone pair of electrons on X in another molecule; is called hydrogen bonding.

Example: In H_2O molecule, two hydrogen atoms are covalently bonded to the highly electronegative O atom. Hence each H atom can hydrogen bond to the O atom of another molecule. Each O atom still has an unshared electron pair which leads to the hydrogen bonding with other water molecules.



$$\begin{array}{ccccc} \ddot{O}:\cdots\cdots H - & \ddot{O}:\cdots\cdots H - & \ddot{O}:\cdots\cdots \\ | & | & | \\ H & H & H \end{array}$$

Liquid Water

Types of hydrogen Bonding:

Hydrogen bonding is of two types

① Intermolecular Hydrogen bonding

⑪ Intramolecular Hydrogen bonding

Intermolecular Hydrogen Bonding:

This type of hydrogen bonding is formed between two different molecules of the same or different substances. **Example**

$H—F\cdots\cdots H—F\cdots\cdots H—F$

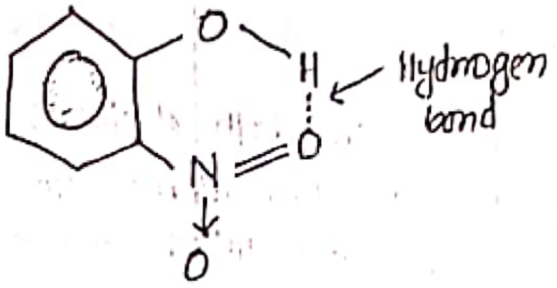
Hydrogen Fluoride
Molecule.

This type of hydrogen bonding result in the formation of associated molecules. Generally, the substance with intermolecular hydrogen bonding have high melting points, boiling points, viscosity, surface tension etc.

Intramolecular Hydrogen bonding :

This type of hydrogen bonding is formed between the hydrogen atom and the electronegative atom present within the same molecule. Molecules exist as discrete units and not in associated molecule. Molecules exist as discrete units and not in associated molecule. Intramolecular hydrogen bonding has no effect on physical form. Hence intramolecular hydrogen bonding has no effect on physical properties like melting and boiling point, viscosity, solubility etc.

Example as follows



2- Nitrophenol

Characteristics of hydrogen bond

① Abnormally high melting and boiling point
(ii) Three dimensional crystal lattice
(iii) High solubilities of some covalent compounds.

Metallic Bonding:

The peculiar type of bonding which holds the atoms together in metal crystal is called the metallic Bonding.

Example: Electron sea model

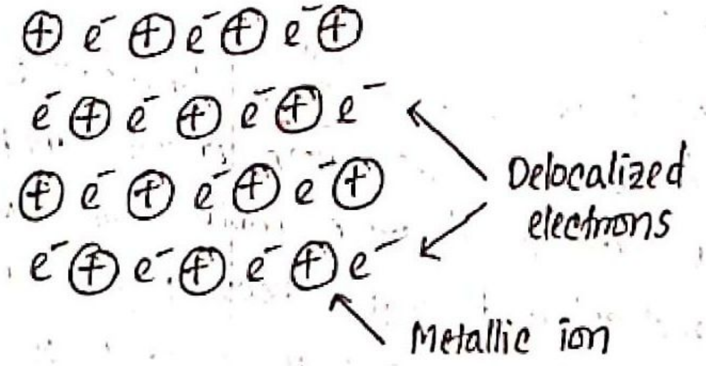
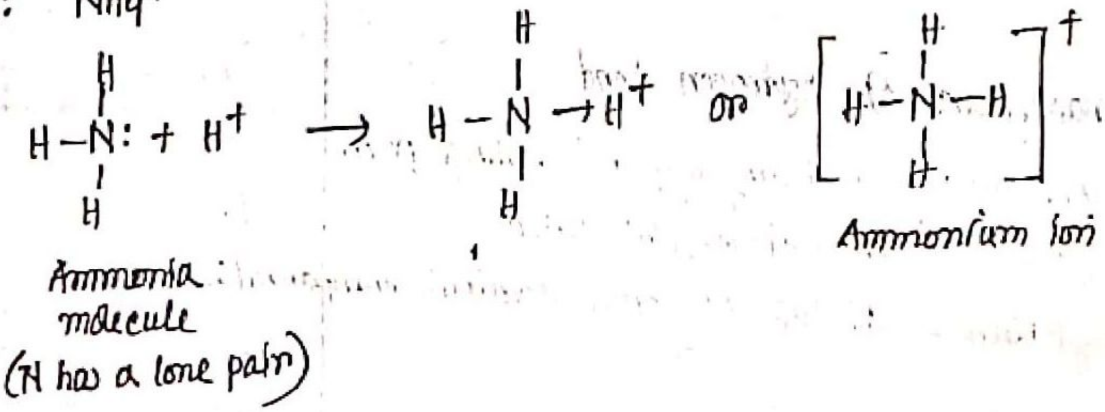


Fig: Electron sea model of metallic bonding

Co-ordinate covalent Bond:

A covalent bond in which both electrons of the shared pair come from one of the two atoms, The compound containing a co-ordinate bond are called co-ordinate compounds.

Example: NH_4^+



ybridization:

The phenomenon of mixing up or merging of orbitals of an atom of nearly equal energy, giving rise to entirely new orbitals equal in number to the mixing orbitals and having same energy contents and identical shapes is known as hybridization.

1 ## Theory of Hybridization:

① Hybridization always takes place between two or more orbitals of same energy level.

(II) Before and after hybridization no. of orbitals will be same.

(III) Only orbitals participate in hybridization, not electron.

(IV) Hybridized orbitals bear same energy.

(V) Reactivity of hybridized orbital are high and σ bond always occurs between them.

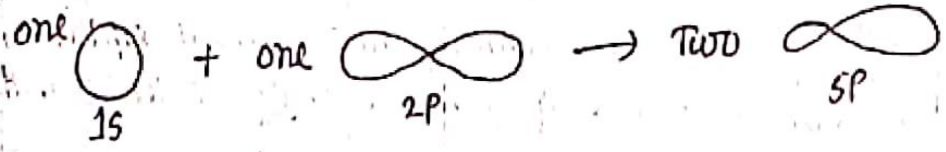
(VI) σ bond always occurs between the hybridized orbitals.

1 ## Types of hybridization

sp, sp^2, sp^3, sp^3d, sp^3d^2, sp^3d^3

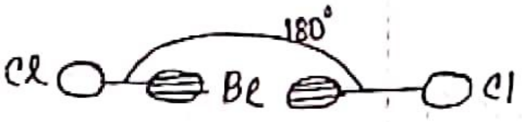
1 **SP** The process of mixing of an s and p orbital which only leads to two hybrid orbitals known as sp hybrid orbitals is called sp hybridization. Each sp orbital has 50% s character and 50% p character. Orbitals thus generated are the seat of electrons which have a tendency to repel and be farthest apart. In order to do so the new orbitals arrange themselves along a line and are therefore, often referred to as linear hybrid orbitals. This gives an angle of 180° between the axes of the two orbitals.

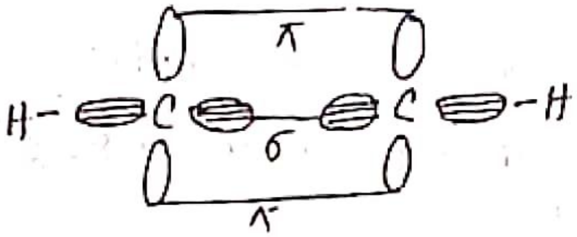
Example: BeF_2, $BeCl_2$ etc.



Be → $1s^2 \boxed{2s^1 2p_x^1} 2p_y 2p_z$

C → $1s^2 \boxed{2s^1 2p_x^1} 2p_y^1 2p_z^1$



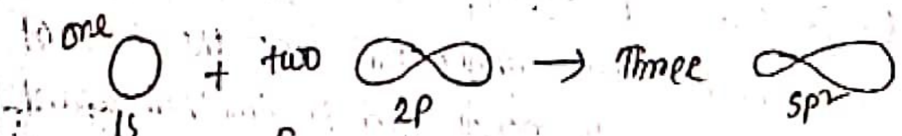


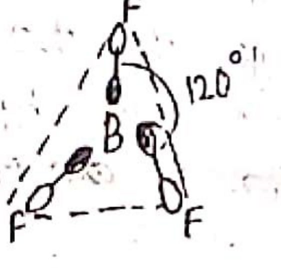
$\boxed{\text{Shape : Linear}}$ $\boxed{C \equiv C}$

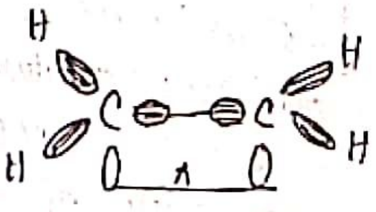
C_2H_2

sp^2 . When an s and two p orbitals mix up to hybridize, there result three new orbitals called sp^2 hybrid orbitals. Each sp^2 hybrid orbitals has 33% s-character and 67% p character. They are directed at an angle of 120° to one another. For this reason, sp^2 hybrid orbitals are also called Trigonal hybrids, and the process is called Trigonal hybridization.

Example: BF_3, NO_3^- etc.





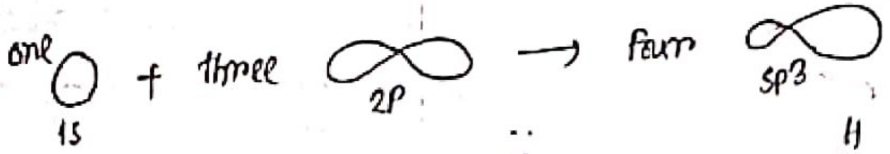


$C = 1s^2 \boxed{2s^1 2p_x^1 2p_y^1} 2p_z^1$

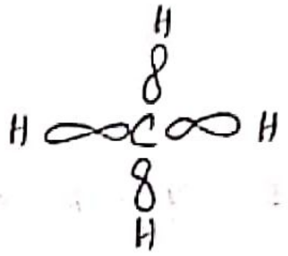
$B = 1s^2 \boxed{2s^1 2p_x^1 2p_y^1} 2p_z$

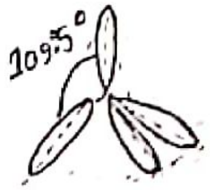
sp3: The four new orbitals formed by mixing an s and three p orbitals of an atom are known as sp3 hybrid orbitals. Each sp3 hybrid orbital has 25% s character and 75% p character. Each of four hybrid orbitals are directed towards the four ~~corners~~ of corners of a regular tetrahedron. For this reason, this is also called "Tetrahedral" hybridization. The angle formed between them is 109.5°.

Example: CH_4, SO_4^{2-}, ClO_4^- etc.



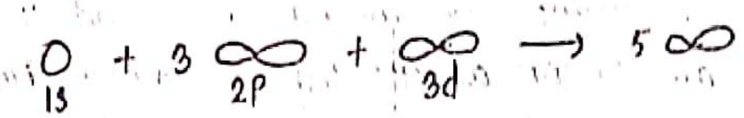
$C(6) = 1s^2 \boxed{2s^1 2p_x^1 2p_y^1 2p_z^1}$



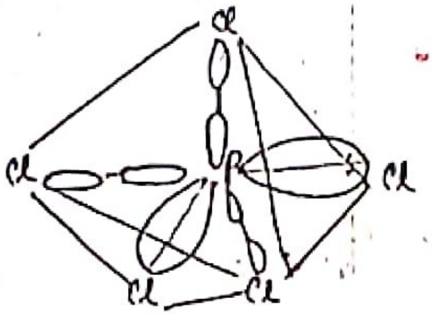


sp³d:

When **one d** type of orbital takes part in hybridization with **one s type** and **three p type** orbitals, **five** hybrid orbitals are created which is called **sp³d**. The five new hybrid orbitals will be furthest apart by arranging **three** of them in a plane at an angle of **120°** to one another and the other **two** in a direction **perpendicular** to the plane. This type of hybridization is called **Trigonal bipyramidal hybridization**.



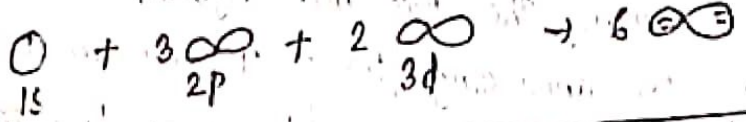
P(15) → $\boxed{1s^2 2s^2 2p^6 3s^1 3p_x^1 3p_y^1 3p_z^1 3d_{xy}^1}$ $3d_{yz}$ $3d_{zx}$ $3d_{x^2-y^2}$ $3d_{z^2}$



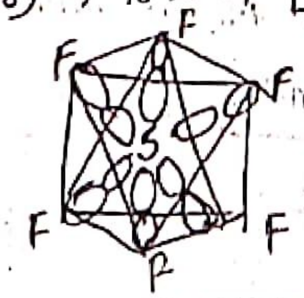
$\boxed{PCl_5}$

☐ $\boxed{sp^3d^2}$

When two d type ~~of~~ orbitals take part in hybridization with one s and three p type orbitals, six hybrid orbitals is called sp^3d^2. Four of them are dispersed in a plane at an angle of 90° each and the other two are directed up and below of this plane. This type of hybridization is called octahedral hybridization.



S (16) → $1s^2 2s^2 2p^6$ $\boxed{3s^1 3p_x^1 3p_y^1 3p_z^1 3d_{xy}^1 3d_{yz}^1}$ $3d_{zx}$ $3d_{x^2-y^2}$ $3d_{z^2}$



octahedral

☐ Valence Bond Theory

(I) The orbitals entering into combination must have only one electron.

(II) The atom with valence or bonding orbitals (half filled) should approach sufficiently close to one another with the axis of their orbitals in proper alignment.

☐ Limitation of Valence Bond Theory:

(I) The presence of other nuclei should affect the electronic arrangement of all the atoms in the molecules.

(II) Sometimes a single electronic structure does not explain all know properties of that molecule or ion and we have the many electroni structure called resonating structure.

(III) Valence Bond Theory fails to explain the Bonding in electron deficient compounds.

(IV) It fails to explain the paramagnetic character of oxygen molecule.

Molecular Orbital Theory:

The main features of molecular orbital theory are –

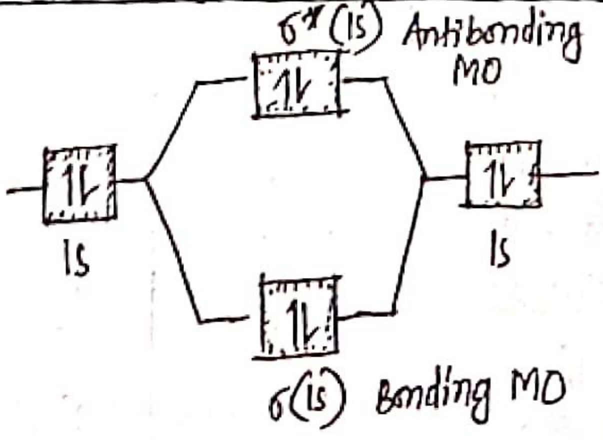
(i) A molecule is quite different from its constituent atoms. All the electrons belong to the constituent atom and are considered to be moving under the influence of all nuclei.

(ii) Atomic orbitals of individual atoms combine to form molecular orbitals and these MOs are filled up in the same way as atomic orbitals are formed. In other words, Pauli's exclusion principle, Aufbau principle and Hund's rule of maximum multiplicity are followed.

(iii) The molecular orbitals have definite energy levels.

(iv) The shapes of MOs formed depend upon the shape of combining atomic orbitals.

Bonding and antibonding molecular orbital.



Bond Order = (No of bonding electron orbital − No. of antibonding orbital) / 2

$$\boxed{BO = \frac{N_b - N_a}{2}}$$

Fig: Energy level diagram for bonding and antibonding MO

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Magnetic properties

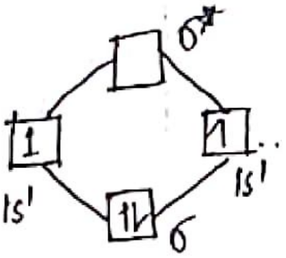
Presence of unpaired electron – Paramagnetic in nature

Absence of unpaired electron – Diamagnetic in nature.

H_2

** H_2

$H \rightarrow 1s^1$

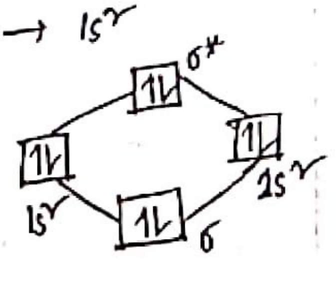


$$BO = \frac{N_b - N_a}{2} = \frac{2-0}{2} = 1, \quad \boxed{\text{Diamagnetic}}$$

He_2

** He_2

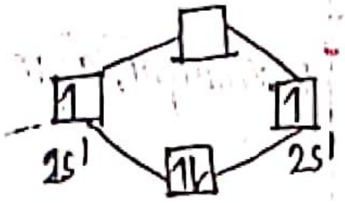
$He \rightarrow 1s^2$

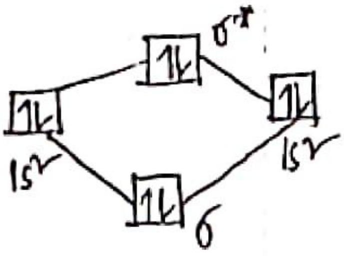


$$BO = \frac{N_b - N_a}{2} = \frac{2-2}{2} = 0, \quad \boxed{\text{does not exist}}$$

$\boxed{Li_2}$

$\boxed{Li} \rightarrow 1s^2 2s^1$





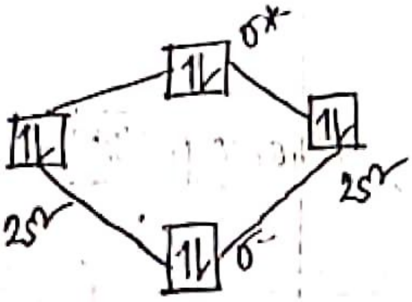
$$BO = \frac{N_b - N_a}{2}$$

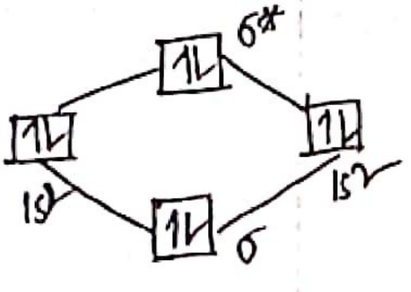
$$= \frac{2-0}{2} = 1$$

$\boxed{\text{Diamagnetic}}$

$\boxed{Be_2}$

$\boxed{Be} \rightarrow 1s^2 2s^2$





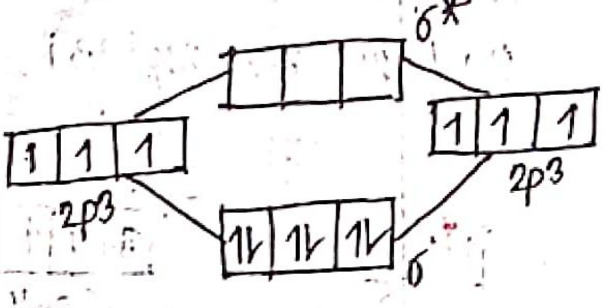
$$BO = \frac{N_b - N_a}{2}$$

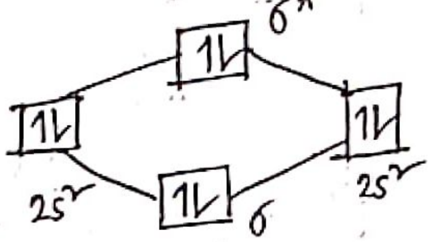
$$= \frac{2-2}{2}$$

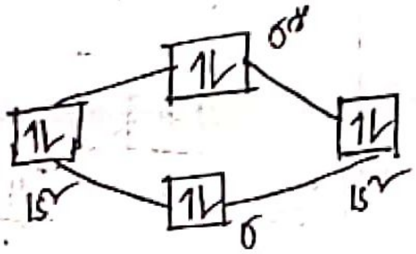
$$= 0$$

$\boxed{\text{does not exist}}$

*- $\boxed{N_2}$ → $1s^2 2s^2 2p_x^1 2p_y^1 2p_z^1$







$$BO = \frac{N_b - N_a}{2}$$

$$= \frac{8-2}{2}$$

$$= 3$$

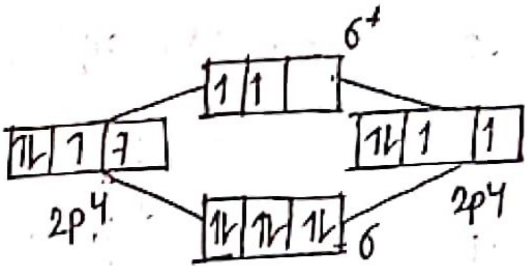
Diamagnetic

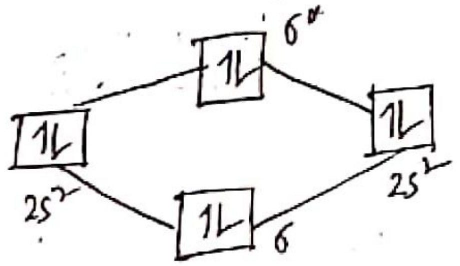
- consider $\boxed{2s^2 2p^3}$ for $\boxed{BO}$

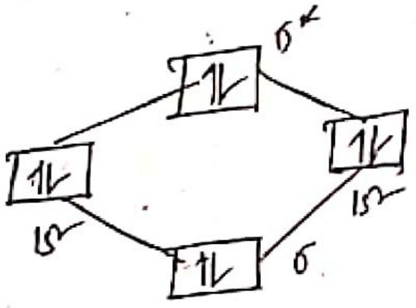
Always last shell
<u>consider</u>

*- $\boxed{O_2}$

$1s^2 2s^2 2p_x^2 2p_y^1 2p_z^1$







$$BO = \frac{N_b - N_a}{2}$$

$$= \frac{8-4}{2}$$

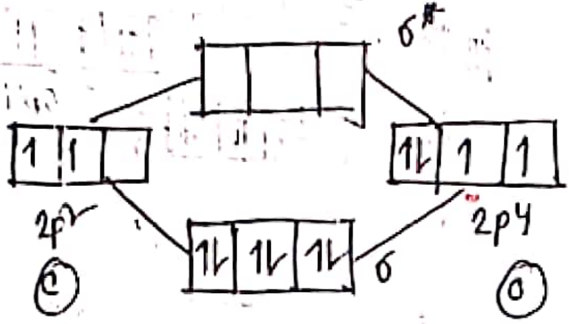
$$= 2$$

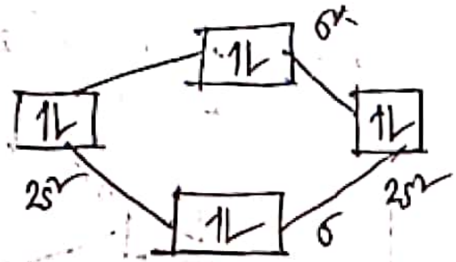
Paramagnetic

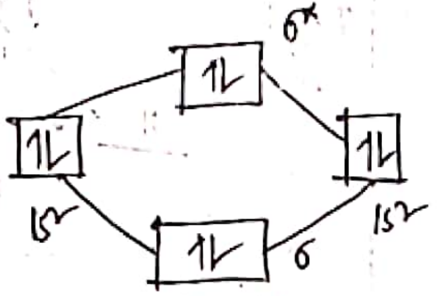
CO

C → $1s^2 2s^2 2p_x^1 2p_y^1 2p_z^0$

O = $1s^2 2s^2 2p_x^2 2p_y^1 2p_z^1$







$$BO = \frac{N_b - N_a}{2}$$

$$= \frac{8-2}{2}$$

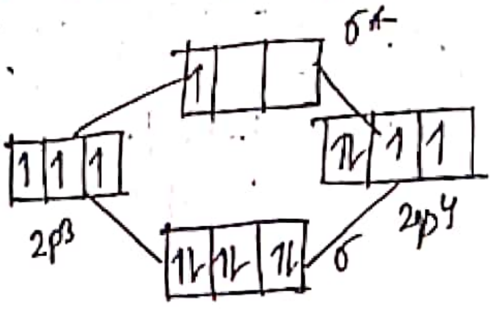
$$= 3$$

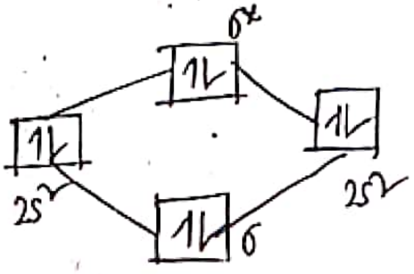
Diamagnetic

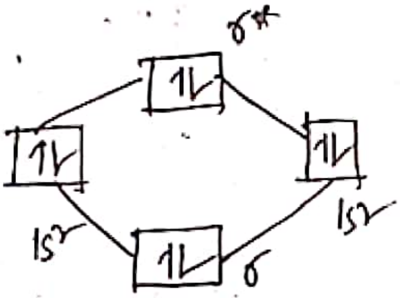
4 NO

N → $1s^2 2s^2 2p_x^1 2p_y^1 2p_z^1$

O → $1s^2 2s^2 2p_x^2 2p_y^1 2p_z^1$







$$BO = \frac{N_b - N_a}{2}$$

$$= \frac{8-3}{2}$$

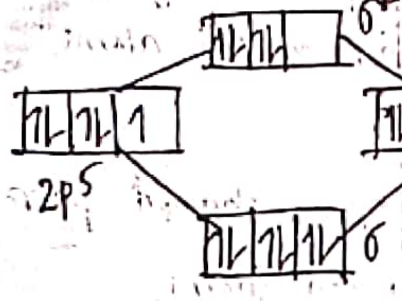
$$= \frac{5}{2}$$

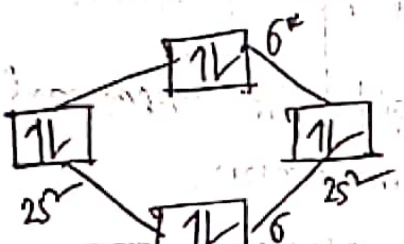
$$= 2.5$$

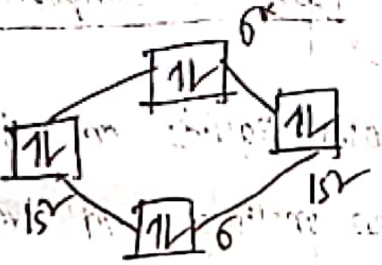
Paramagnetic

$\boxed{F_2}$

$1s^2 2s^2 2p_x^2 2p_y^2 2p_z^1$







$$BO = \frac{N_b - N_a}{2} = \frac{8-6}{2} = \frac{2}{2} = 1$$

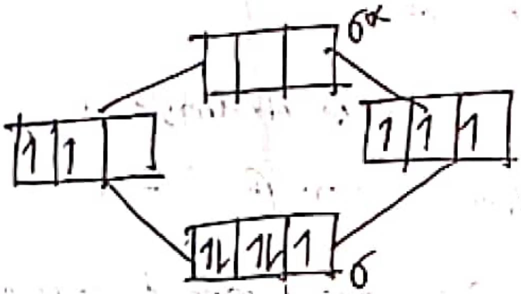
Diamagnetic

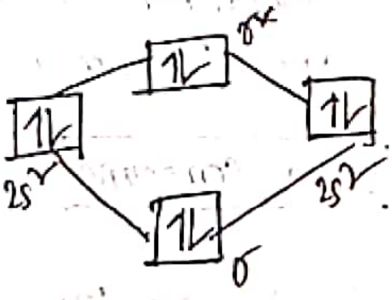
BO = 0 হলে molecule Does not exist.

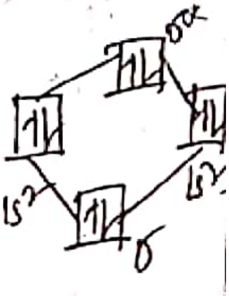
$\boxed{CN}$

$C - 1s^2 2s^2 2p_x^1 2p_y^1 2p_z^0$

$N - 1s^2 2s^2 2p_x^1 2p_y^1 2p_z^1$





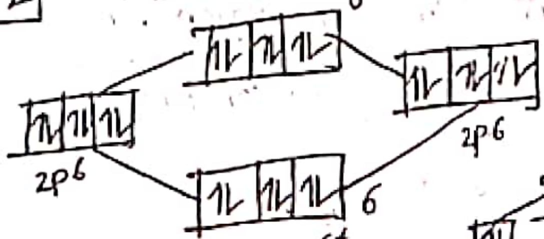


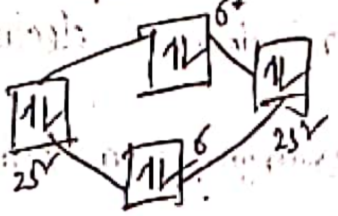
$$BO = \frac{N_b - N_a}{2} = \frac{7-2}{2} = 2.5$$

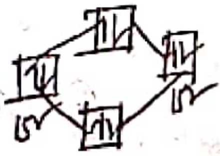
Paramagnetic

$\boxed{Ne_2}$

$\rightarrow 1s^2 2s^2 2p^6$







$$BO = \frac{N_b - N_a}{2} = \frac{8-8}{2} = 0$$

Does not exist.

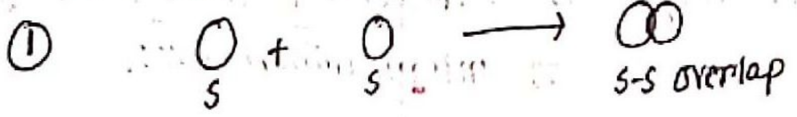
Ionic Bond	Covalent Bond
① formed by transfer of electron from a metal to non metal atom.	① formed by sharing of electrons between non-metal atoms.
② consists of electrostatic force between ⊕ & ⊖ ions	② consists of a shared pair of electrons between atoms.
③ Non rigid, non directional, cannot cause isomerism.	③ Rigid and directional, cause stereoisomerism.

Ionic Compound	Covalent Compound.
① solids at room temperature	(i) Gases, liquids or soft solids.
② High melting and boiling points	② Low melting and boiling points.
③ Hard and brittle	③ soft, much readily broken.
④ soluble in water but insoluble in organic solvents.	④ Insoluble in water but soluble in organic solvents.
⑤ Conductors of electricity	⑤ Non conductors of electricity.
⑥ Undergo ionic reactions which are fast.	⑥ Undergo molecular reactions which are slow.

Sigma bond and Pie Bond

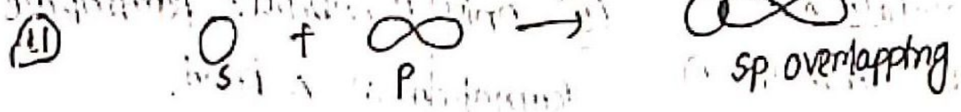
Sigma Bond (σ) : When there is end to end overlapping of atomic orbitals along the internuclear axis, the resulted bond is called sigma bond.

①



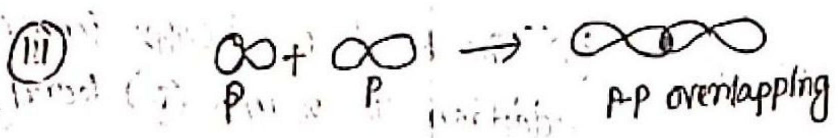
Example H_2

(ii)



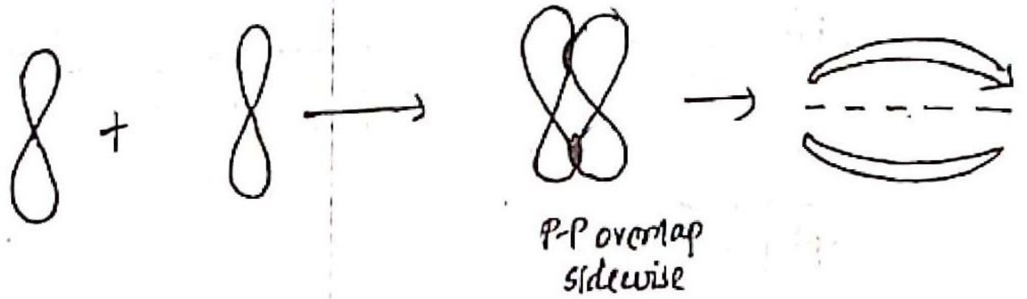
Example HF, HCl

(iii)



Example: F_2, Cl_2

Pie Bond (π): When a covalent bond is formed by the sidewise overlap of the half filled atomic orbitals then it is called Pi (π) bond.



Sigma (σ) Bond	Pi (π) Bond
① It is formed by end to end overlapping of half filled atomic orbitals.	① It is formed by the sidewise overlapping of half filled P orbitals only.
② Overlapping takes place along internuclear axis.	② Overlapping takes place perpendicular to internuclear axis.
③ S and P orbitals can participate in the formation of σ bond.	③ Only P orbitals participate in the formation of π bond.
④ The bond can be present alone.	④ The bond is always formed in addition to sigma (σ) bond.
⑤ sigma bond is stronger than pie bond.	⑤ pie bond is weaker than sigma bond.