CHEMICAL BONDING

ELECTROVALENT OR IONIC BOND

* This type of bond is form between two dissimilar atoms A and B.

* The atom A has one or more electrons more than nearest inert gas configuration and has low ionisation potential.

* The atom B has one or more electrons less than nearest inert gas configuration and has high electron affinity.

* The atom A transfers one or more electrons to atom B. such that both the atoms A and B get inert gas configuration. The atoms A and B change into A^{+n} and B^{-n} respectively. The atom A that loss n electrons is said to be oxidise to A^{+n}. Atom B that gain n electron is said to be reduce to B^{-n}.

* The ion A^{+n} and B^{-n} are held together by electrostatic force of attraction as a result ionic or electrovalent bond is formed. Thus the formation of ionic bond from elements involves an oxidation-reduction (Redox reaction).

        such compound which are form by the transferance of one or more electrons from one atom to the other are called electrovalent or ionic compound and the type on linkage is called electrovalent linkage.

e.g.: NaCl.

$$\underset{2.8.1}{Na\overset{x}{\cdot}} \xrightarrow[\text{electron(x)}]{\text{transference of}} \cdot \overset{\cdot\cdot}{\underset{\cdot\cdot}{Cl}} : \longrightarrow \underset{\substack{2.8 \\ \text{inert gas Neon} \\ \text{configuration}}}{Na^+} + \underset{\substack{2.8.8 \\ \text{inert gas argon} \\ \text{configuration}}}{\overset{\cdot\cdot}{\underset{\cdot\cdot}{\overset{x}{Cl}}} {}^-}$$

CONDITION NECESSARY FOR THE FORMATION OF IONIC BOND

* **Low ionisation energy**
one atom should have low ionisation energy and form a cation by the loss of one or more electrons. The cation becomes stable by attaining inert gas configuration.
$$Na + 118.5 \text{ KJ/mole} \longrightarrow Na^+(g) + e^{\ominus}$$
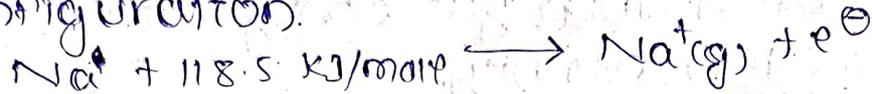
* **Electron affinity**
one atom (usually non metallic) should have high electron affinity and form anion by the gain of one or more electron. The anion becomes stable by attaining inert gas configuration.
$$Cl(g) + e^- \longrightarrow Cl^-(g) + 83.5 \text{ kcal/mole}$$
(Iron gas configuration)
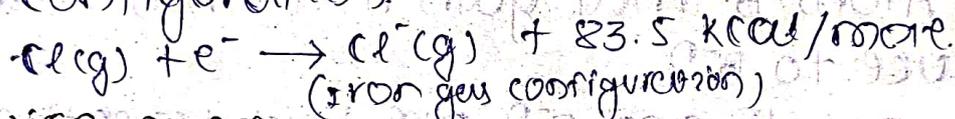
* **Lattice energy**
It is the amount of energy released when oppositely charged ions get attracted by strong electrostatic force of attraction to form a one mole of no substance.

It is also the amount of energy required to separate the ion from one mole of the ionic solid.

$$NaCl + \text{lattice energy} \longrightarrow Na^+ + Cl^-$$
$$(182.5 \text{ kcal/mole})$$
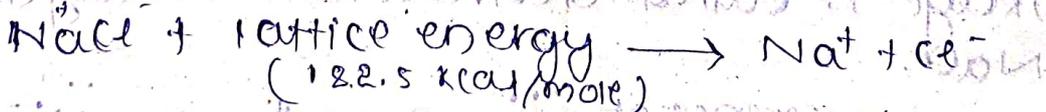
GENERAL CHARACTERISTICS OF IONIC COMPOUND

* **Hard and rigid**

Ionic compounds are hard and rigid. Reason:- The cations and anions are held togeather by strong electrostatic force of attraction in ionic compounds. Thus these are hard and rigid.

* **High density**

$$d = m/v$$

Reason:- The cations and anions are held togeather by strong electrostatic force of attraction in an ionic compound. The volume of the system thus decreases and density increases.

* **High melting and boiling point**

Reason:- The cations and anions are held togeather by strong electrostatic force of attraction in an ionic compound. A large amount of energy is needed to overcome these force to cause breaking down of crystal lattice i.e. fusion (melting point) or vaporisation of ionic compound.

* **Good electrical conductivity**

Reason:- When an ionic compound is fused or dissolves in water it splicts of into cations and anions. When electric current is passed through such solution the ions moves to oppositely charged electrodes. Thus these compound are good conducter of electricity.

* **Non- directional nature**

Ionic bond is non-directional in nature. Reason:- A cation and anion are consider as charged sphere. These ions have a uniform field of force around them. These ions, thus attract each other. This electrical charge is responsible for their mutual force of attraction and repulsion. Since

these ions are uniform field of force
around them. These ions will thus
attract oppositely charged ions from all
direction hence ionic bond is non-directional.
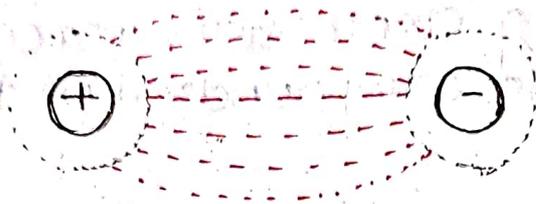
* **High solubility in water**
  Reason:- Due to high dielectric constant of
  water (K=180). The force of attraction
  between the cations and anions decreases.
  Thus the ions separate and ionic compound
  dissolve in water.

* **Tendancy to have fast reaction**
  Reason:- When an ionic compounds dissolve
  in water its split into charged particle
  called ions.
      When aqueous solution of two
  ionic compound are mixed together the
  oppositely charged ions combine at once
  to give the product. It is because no
  force is required to break the bond on
  reacting molecules.

CALCULATION OF LATTICE ENERGY OF IONIC SOLIDS (BORN'S EQUATION)
      The lattice energy of an
  ionic crystal is determine by coulombic
  intraction between all of its ions present
  in the crystal. These intraction are two
  types.
      1- Attractive intraction between ions
         of opposite charge.
      2- Repulsive intraction due to interpenitr-
         ation of similarly charge electron
         charge clouds.

① **Attractive intraction between ions of opposite charge.**

Consider a pair of ions of opposite charges z_1 & z_2. Let e be the electronic charge. If r is the distance between the ions then potential energy of a pair of ions is given by the reaction.

$$P.E_{(attraction)} = \frac{z_1 z_2 (+e)(-e)}{r} = \frac{-z_1 z_2 e^2}{r} \quad ①$$

in case of NaCl, Na⁺ Cl⁻, $z_1 = +1$, $z_2 = -1$

② **Repulsive intraction due to interpenitration of similarly charge electron charge clouds**

When a cation comes very closed to anion interpenitration of similarly charge electron charge clouds take place and repulsion result between them. The potential energy due to this repulsion is inversely proportional to the nth path of the distance between the ions. Thus

$$P.E_{(repulsion)} = \frac{be^2}{r^n} \quad ②$$

where b is the repulsion co-efficient and n is the Born exponent.

The net potential energy for a pair of ions of opposite charge obtained by combining eq ① and ②

$$P.E = \frac{-z_1 z_2 e^2}{r} + \frac{be^2}{r^n} \quad ③$$

This eq ③ is called Born's equation.

This eq ③ gives the energy release when a cation separated from an anion in gaseous state by an infinite distance is brought at a distance r in a crystal.

The equation also indicates that $\frac{be^2}{r^n}$ repulsion term increases more rapidly than first term with decrease in magnitude of r.

APPLICATION OF BORN-EQUATION (BORN-LANDE EQUATION)
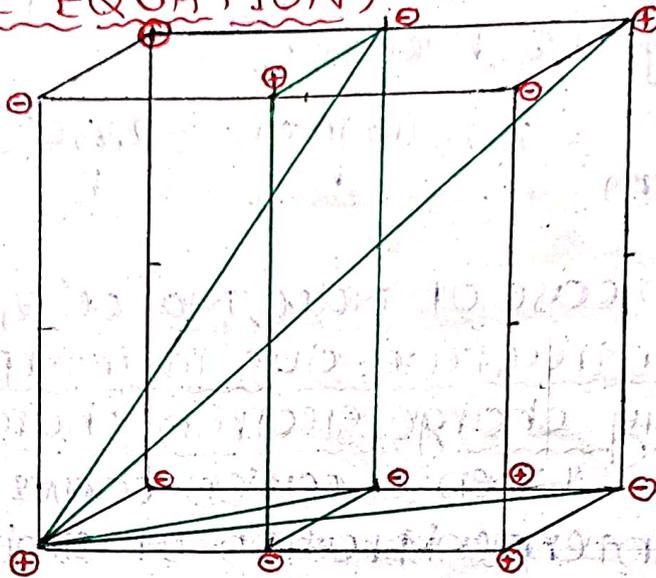
Born-equation is useful to calculate the lattice energy of ionic crystal. For example - Let us consider the force of attraction and repulsion involved in a crystal of NaCl. In a crystal, there are a large number of cations and anions and not one cation and one anion only. These ions are arranged together in a specific geometry. Thus, we are to consider the forces of attraction and repulsion between all the ions. In case of NaCl crystal, each Na⁺ ions is surrounded by

* 6 Cl⁻ ions at a distance r
* 8 more Cl⁻ ions at a distance $\sqrt{3}\,r$
* 24 more Cl⁻ ions at a distance $\sqrt{5}\,r$
* 6 more Na⁺ ions at a distance $2r$
* 12 more Na⁺ ions at a distance $\sqrt{2}\,r$
* 24 more Na⁺ ions at a distance $\sqrt{6}\,r$

Because of above arrangement, there will be forces of attraction between Na^+ and Cl^- ions and forces of repulsion between Na^+ ions and Na^+ ions.

The force of attraction lead to lowering of energy and hence potential energy is given a negative sign. The force of repulsion lead to raise in potential energy and hence potential energy is given a positive sign.

By adding the effect of all the above attraction and repulsion, intraction.

$$(P.E)_1 = -\frac{6Z_1Z_2e^2}{r} - \frac{8Z_1Z_2e^2}{\sqrt{3}\,r} - \frac{24Z_1Z_2e^2}{\sqrt{5}\,r} + \frac{6Z_1Z_2e^2}{2r} + \frac{12Z_1Z_2e^2}{\sqrt{2}\,r}$$

$$+ \frac{24Z_1Z_2e^2}{\sqrt{6}\,r} + \dots \qquad —④$$

$$= -\frac{Z_1Z_2e^2}{r}\left[6 + \frac{8}{\sqrt{3}} + \frac{24}{\sqrt{5}} - \frac{6}{2} - \frac{12}{\sqrt{2}} - \frac{24}{\sqrt{6}} + \dots\right]$$

NaCl is a uni-univalent ions so for NaCl $Z_1 = 1$, $Z_2 = 1$. The sum total of all the terms in the bracket give raise to a quantity is called madelung constant (A) for NaCl. The value of A for NaCl is 1.747558.

All the salt having geometrical arrangement similar to NaCl will have same value of A.

$$(P.E)_1 = -\frac{AZ_1Z_2e^2}{r}$$

$$(P.E)_1 = -\frac{AZ^2e^2}{r} \qquad —⑤ \quad (\because Z_1 = Z_2 = Z)$$

Let us consider the second term in Born equation. This term arises because as a cation and anion come very close to each other, there is a repulsion between

them because of interpenetration of similarly charge electron cloud.

In NaCl crystal each Na ion is surrounded by 6 Cl^- ions so, repulsion energy term = $\dfrac{6be^2}{r^n}$. The term $6be^2$ is generally replaced by the term B where

$$B = be^2 \times no.\ of\ nearest\ neighbours.$$

second term = B/r^n —— ⑥

$$P.E = -\dfrac{Az^2e^2}{r} + \dfrac{B}{r^n} \quad ——⑦$$

It can be done by realising that an ion will be in stable equilibrium position when attractive and repulsive forces acting on it are equally balanced. In this situation the potential energy of the ion is minimum and $\dfrac{d}{dr}(P.E) = 0$. Also, inter ionic distance r may be taken as r_0.

Thus constant B can be eliminated by differentiating eqⁿ

$$P.E = -\dfrac{Az^2e^2}{r} + \dfrac{B}{r^n} \quad ——⑧$$

$$P.E = -Az^2e^2\ r^{-1} + B\ r^{-n} \qquad \boxed{\dfrac{d}{dx}x^n = n\,x^{n-1}}$$

$$\dfrac{d}{dr}(P.E) = -Az^2e^2(-1)\,r^{-2} + B\,(-n).\,r^{(-n-1)}$$

$$= Az^2e^2\,r^{-2} - n\,B\,r^{(-n-1)}$$

since $\dfrac{d}{dr}(P.E) = 0$ and $r = r_0$

$$\Rightarrow Az^2e^2\,r_0^{-2} - n\,B\,r_0^{(-n-1)} = 0$$

$$\Rightarrow Az^2e^2\,r_0^{-2} = n\,B\,r_0^{(-n-1)}$$

$$\Rightarrow \dfrac{r_0^{-2}}{r_0^{-n-1}} = \dfrac{nB}{Az^2e^2}$$

$$\Rightarrow r_0^{n-1} = \dfrac{nB}{Az^2e^2}$$

$$\Rightarrow r_0 = \left(\dfrac{nB}{Az^2e^2}\right)^{\frac{1}{n-1}}$$

$$\Rightarrow B = \frac{A z^2 e^2}{n} \times r_0^{n-1}$$

substituting the value of B in the eq^n (8)

$$P.E = -\frac{A z^2 e^2}{r_0} + \frac{A z^2 e^2}{n r_0^n} \times r_0^{n-1}$$

$$\therefore - \frac{A z^2 e^2}{r_0} + \frac{A z^2 e^2}{n r_0}$$

$$P.E = \frac{A z^2 e^2}{r_0} \left(\frac{1}{n} - 1\right) \quad \text{——} \quad \text{(9)}$$

since lattice energy U_0 is defined as the amount of energy released when one mole of a crystal is form from the constituent gaseous ions separated at infinite distance from one another. Hence

$$U_0 = N_0 \times P.E \quad \text{——} \quad \text{(10)}$$

where N_0 = Avogadro's number
P.E = potential energy
U_0 = lattice energy

substituting the value of P.E from eq^n (9) in eq^n (10) we get

$$U_0 = N_0 \times \frac{A z^2 e^2}{r_0} \left(\frac{1}{n} - 1\right)$$

$$\Rightarrow \boxed{U_0 = \frac{N_0 A z^2 e^2}{r_0} \left(\frac{1}{n} - 1\right)} \quad \text{——} \quad \text{(11)}$$

This equation is called Born-lande equation.

postulates of this theory

* A covalent bond is form when half filled atomic orbital (containing 1 unpaired electron) of one atom overlap with the half filled overlaps of another atom.

* The combining half filled atomic orbital merge together to form a localised molecular orbital (bond orbital/covalent bond) in which both the electrons occupied their space. Two types of covalent bonds sigma (σ) and pi (π) bonds.

* The two electrons which occupy the same localised molecular orbital must have opposite spin.

* The localised molecular orbital is consider to belongs to the electrons of both the combining atom.

* Maximum electron density lies some where in the overlaps region. The force that binds the covalently bonded atoms due to electrostatic force of attraction between the nuclei and the accumulated electron clouds between them.

$$\psi_a = \psi_A(1)\,\psi_B(2) - \psi_A(2)\,\psi_B(1)$$

$$\psi = \psi_A(1)\,\psi_B(2)$$

$$\psi_s = \psi_A(1)\,\psi_B(2) + \psi_A(2)\,\psi_B(1)$$

separated atoms

BONDING ENERGY
E = 6 KCal/mol

$E_0 = 72$ KCal/mol

EXCHANGE ENERGY.

$r_0 = 0.87 \, A^\circ$

P.E

INTERNUCLEAR DISTANCE
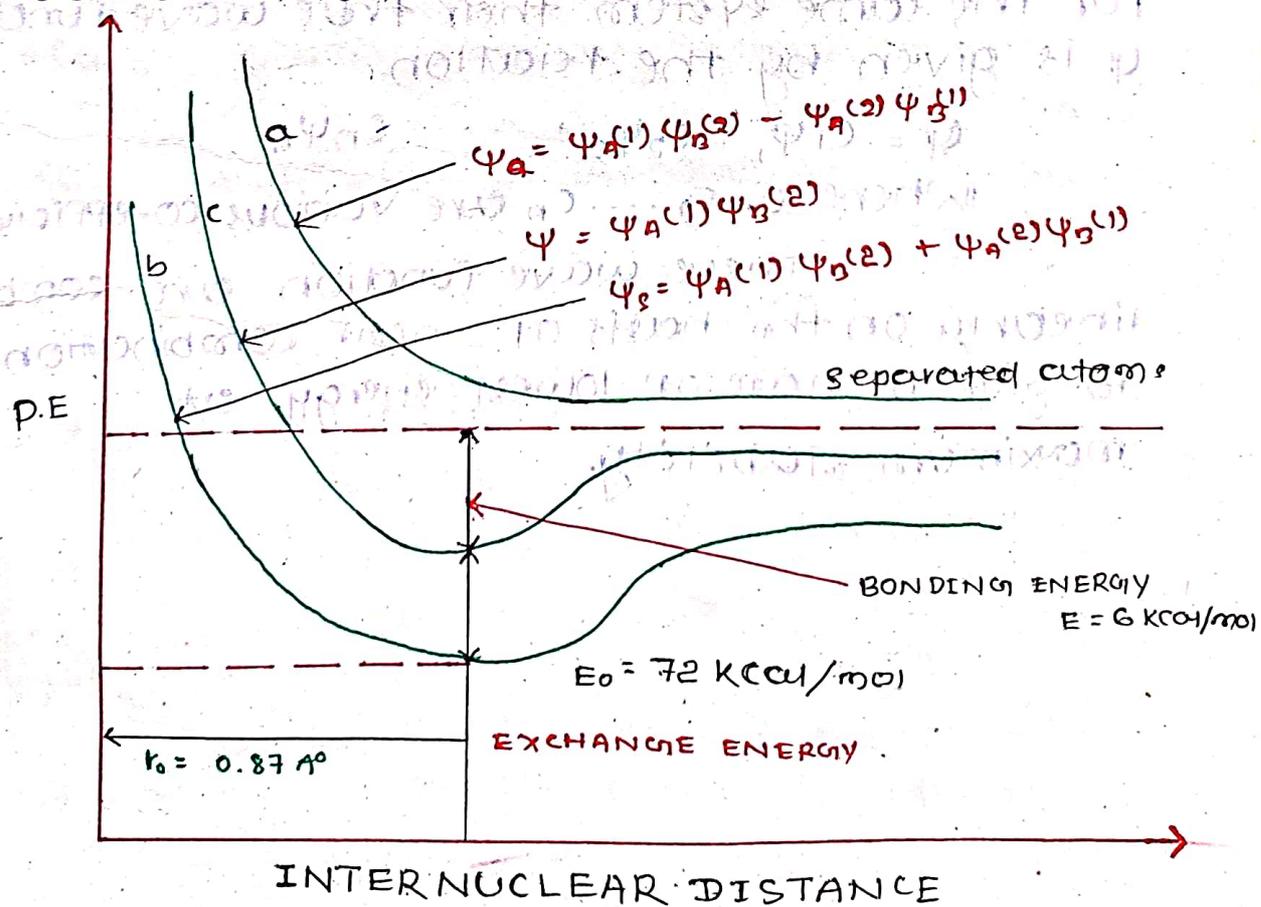
Energy changes during bond formation.
When a bond is formed energy is released.
It can be explain with the help of Heitler
London Theory.

HEITLER LONDON THEORY

This theory explain the energy
changes taking place during the formation
of H_2 Molecules.

principle of the theory

Following are the two principle
of this theory for any two independent
system A and B.

* If ψ_A and ψ_B are the wave function for
any two isolated independent atoms A & B.
then total wave function ψ.

$$\psi = \psi_{(A)} \times \psi_{(B)}$$

While energy 'E' of the system
is given by the reiation

$$E = E_A + E_B$$

* If $\psi_1, \psi_2 \ldots \psi_n$ are various wave function
for the same system. their true wave function
ψ is given by the reiation

$$\psi = C_1 \psi_1 + C_2 \psi_2 + \cdots \cdots C_n \psi_n$$

where $C_1, C_2 \ldots C_n$ are various co-efficient.
These wave function are combined
linearly on the basis of linear combination
to give a state of lowest energy at
maximum stability.

APPLICATION OF PRINCIPLES TO EXPLAIN THE FORMATION OF H_2 MOLECULE

Consider two H atom, $H_A(1)$ and $H_B(2)$
Here A and B represent the nuclei while 1 & 2 represent electrons associated with H_A & H_B atoms respectively.

Let $\psi_A(1)$ be the wave function for the H_A atom and $\psi_B(2)$ be the wave function for the H_B atom.

(a) When H_A and H_B are at infinite distance.
* The total wave function ψ for separate atoms is given by the relation.

$$\psi = \psi_A(1)\, \psi_B(2)$$

* The total energy of the system is assume to be zero.

(b) When H_A and H_B atom are brought closer.
When H_A and H_B atom are brought closer, the energy of the system decreases and reaches a certain minimum as a result hydrogen molecule is formed. The internuclear distance at this stage $r_0 = 0.87 A°$ but actually $r_0 = 0.74 A°$

(c) Fall in potential energy called bonding energy = 6 kcal/mol. But actual bond energy in the formation of H_2 molecule = 103.2 kcal/mol

$$H_A(1)\, H_B(2) \qquad\qquad H_A(2)\, H_B(1)$$
$$(I) \qquad\qquad\qquad\qquad (II)$$
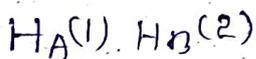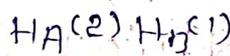
If ψ_1 and ψ_2 are the wave function associated with structure (I) & (II) respectively. Then

$$\psi_1 = \psi_A(1)\cdot \psi_B(2) \quad\text{———} (2)$$

$$\psi_{II} = \psi_A(2)\cdot \psi_B(1) \quad\text{———} (3)$$

The true wave function ψ, for the hydrogen molecule is given by the relation.

$$\psi = c_1 \psi_1 + c_1 \psi_{II} \quad\text{———} (4)$$

substituting the value of ψ_1 & ψ_{11}

$$\psi = C_1 \psi_A(1) \psi_B(2) + C_{11} \psi_A(2) \psi_B(1)$$

where C_1 and C_{11} are mixing co-effi cient for H_2 molecule, when $C_1 = 1$ and $C_{11} = \pm 1$, so there will be two possible value, such as

$$\psi_s = \psi_A(1) \cdot \psi_B(2) + \psi_A(2) \cdot \psi_B(1)$$

When $C_1 = 1$ and $C_{11} = +1$

$$\psi_a = \psi_A(1) \cdot \psi_B(2) - \psi_A(2) \cdot \psi_B(1)$$

When $C_1 = 1$ and $C_{11} = -1$

Curve-a

curve-a represent ψ_a state. in this state the two electron in H_A and H_B atoms are at parallel spin and energy increases as the two atom come closer. As a result no bond is formed. Thus ψ_a represent repulsive state or the non-bonding state.

Curve-b

The curve b represent ψ_s state. in this state the two electrons in H_A & H_B atom are at opposite spin and energy decreases and the two atom come closer. As a result bond is formed. Thus ψ_s represent attractive state or bonding state.

SIGMA BOND (σ)

The axial or haedern overlapping of the half filled atomic orbital is called sigma bond.

✳ s-s overlapping

When a partially filled s-orbital of one atom overlaps with partially filled s-orbital of another atom. then the overlapping and the bond formed is called s-s bond

eg:- H_2 Molecule

H - 1s'

1s atomic   1s atomic
orbital   orbital.

→ overlapping
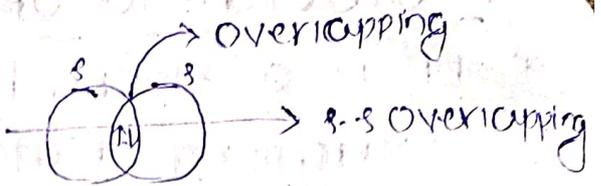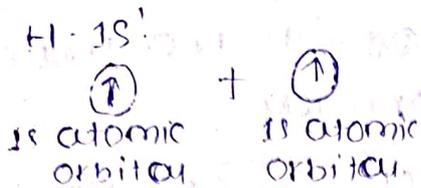
→ s-s overlapping

* s-p overlapping

The bond formed by the overlap of partially filled s-orbital of one atom and p-orbital of another atom is again a sigma bond, It is known as s-p bond and this type of overlapping is known as s-p overlapping.

e.g:- HCl

H - 1s'

Cl - $1s^2 \, 2s^2 \, 2p^6 \, 3s^2 \, 3p^5$

3Pₓ	3Py	3Pz
↑↓	↑↓	↑
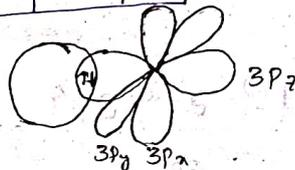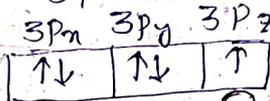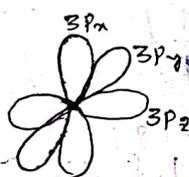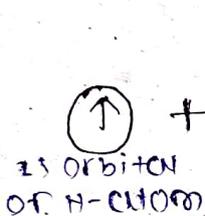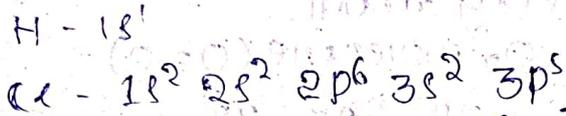
1s orbital
of H-atom

* p-p overlapping

When the two partially filled p-orbitals overlape, the overlapping is known as p-p overlapping. The bond formed by overlapping of two partially filled p-orbital is p-p sigma bond.

e.g:- F_2 F = $1s^2 \, 2s^2 \, 2p_x \, 2p_y \, 2p_z$

F = $1s^2 \, 2s^2 \, 2p_x \, 2p_y \, 2p_z$
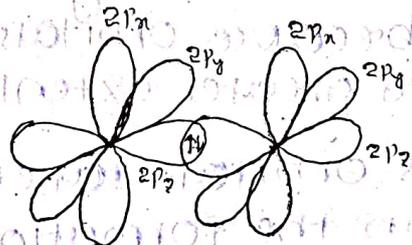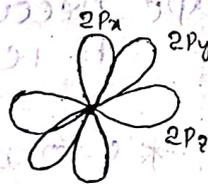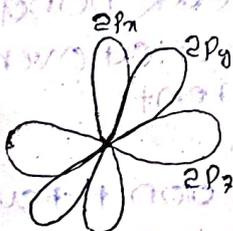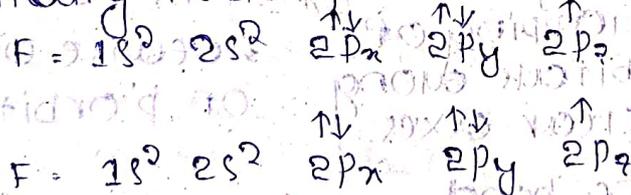
Characteristics of sigma bond

* It is a strong bond due to maximum overlapping of atomic orbital.

* Free rotation of molecule about sigma bond is possible.

PI BOND (π)

This type of bond is formed by the sidewise overlapping on half filled atomic orbital in a direction perpendicular to the inter nuclear axes. It is a weak bond as the extent of overlapping of atomic orbital is very small.

e.g:- formation of O_2 molecule $(O = O)$.

$$O_8 = 1s^2 \ 2s^2 \ 2p^4$$

$2P_x$	$2P_y$	$2P_z$
↑↓	↑	↑

$$O_8 = 1s^2 \ 2s^2 \ 2p^4$$

$2P_x$	$2P_y$	$2P_z$
↑↓	↑	↑
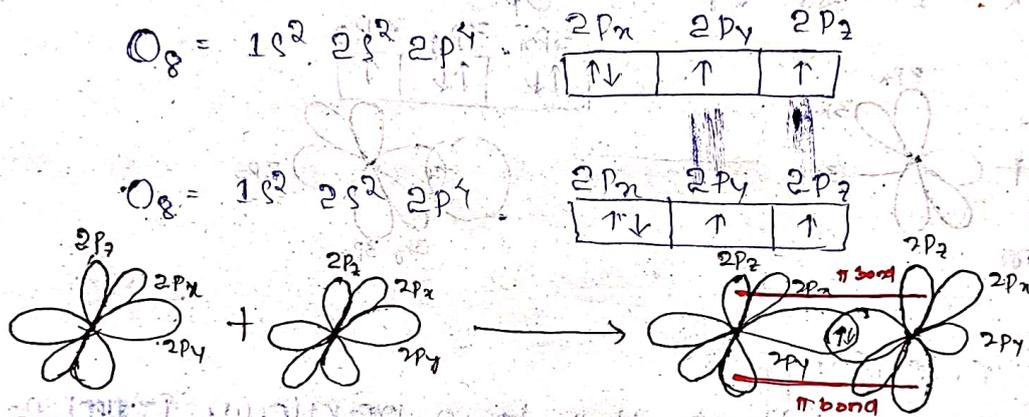
DIFFERENCE BETWEEN SIGMA & PI BOND

| sigma bond	pi bond
* It is formed by the hadern overlapping on s-s, s-p, p-p orbitals along the internuclear axes.	* It is formed by the sidewise overlapping of p orbital.
* It is a strong bond because orbitals overlape to greater extent.	* It is a weak bond because orbital overlaps to less extent.
* s-orbitals take part in the formation of σ bond.	* s-orbitals don't take part in the formation of π-bond.
* There is a free rotation of atom about the σ bond.	* There no free rotation of atom about the π bond.

HYBRIDIZATION

Hybridization is the concept or intermixing of the orbitals of an atom having nearly the same energy to give exactly equivalent with same energy, identical shape and symmetrical orientation in space.

EX:- Since in the formation of bivalent compounds of berilium one s and one p orbital is involve in hybridization, It is called s-p hybridization and the two identical orbitals which result this process are known as s-p hybrid orbital.

Hybridization


```
S-P _____A_____ (Hybrid)

Exited _____ (1s², 2s¹, 2p¹)

Ground _____ (1s², 2s²)
State (B.E)ₐ

              C
            _____ (B.E),
```

VBT


```
Exited _____E_____ 1s²2s¹2p¹

Ground _____ 1s²2s²
(B.E)

            _____ (B.E)₂
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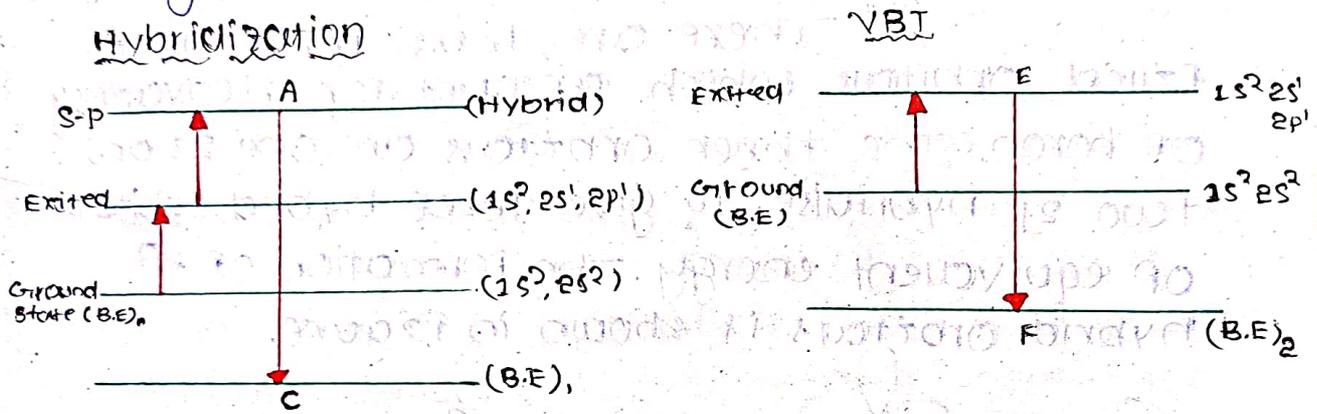
The amount of energy release (B.E), due to the formation of sigma bond between Berilium and x-atoms involving hybrid orbitals is greater than the energy release $(B.E)_2$ in case of the sigma bond hard involve the pure s & p orbitals. It is evident from the figure that the some additional energy is released due to the involvement of the s-p hybrid orbital in the bond formation. Because of this additional decrease of energy. The sigma bonds form by hybrid orbital of Berillium atom are stronger the bonds forms by pure 's' and p' orbitals.


S-orbital

Pz Orbital

large lobe

small lobe
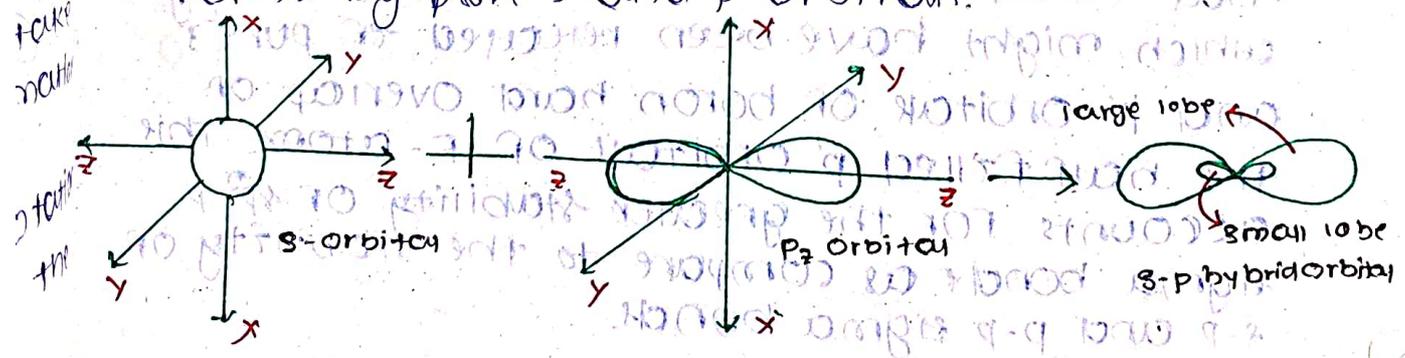
S-P hybrid orbital

A pure s and a pure p orbital orientation in the z direction. Each sp hybrid orbital consist of one large lobe and one small lobe. It may be noted p is more spread as compare to s.

SP² HYBRIDISATION OF ORBITALS OF BORON ATOM

The outer electronic configuration of boron atom in its ground state is $1s^2 2s^2 2p^1$. Promotion of one of the 2s electrons into one of the vacant 2p orbital gives rise to an excited state configuration i.e. $1s^2 2s^1 2p_x^1 2p_y^1$.

There are, thus three half filled orbitals which account for tricovalency of boron. The three orbitals are one 2s and two 2p hybridise to give three hybrid orbitals of equivalent energy. The formation of sp^2 hybrid orbitals is shown in figure.

s-orbital   p-orbital sp^2-hybridised orbitey

Hybrid State ———————— Sp² hybridisation
Excited ———————— $1s^2 2s^1 2p^2$
ground ———————— $1s^2 2s^2 2p^1$

Excited ———————— $1s^2 2s^1 2p^2$
Ground ———————— $1s^2 2s^2 2p^1$

Hybr st
Exc
Gr
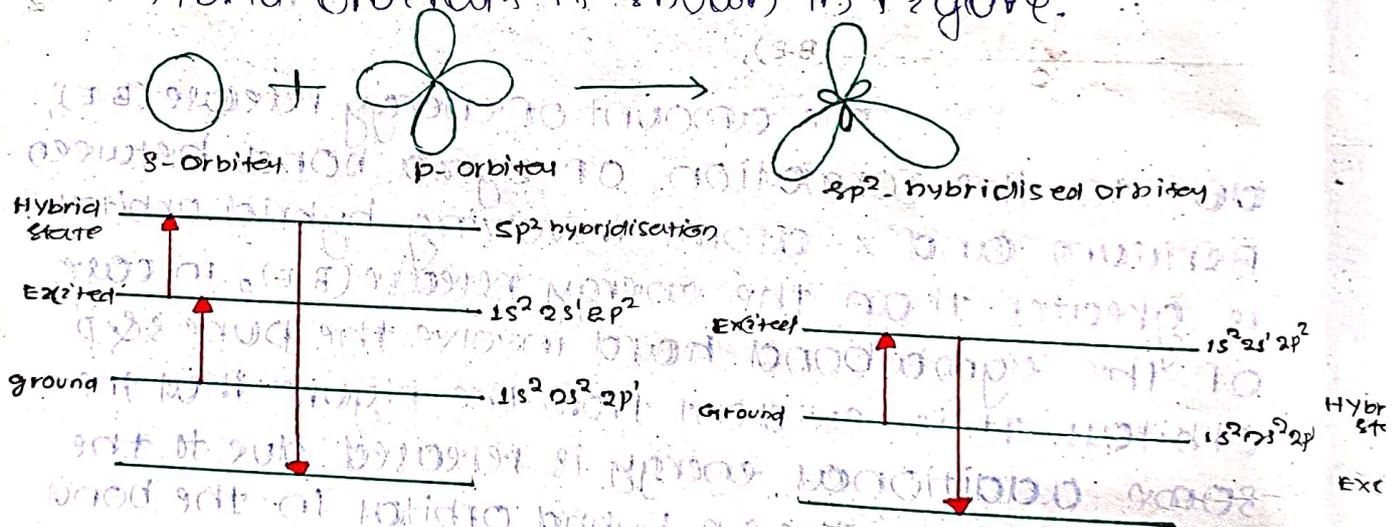
A large amount of energy is release during to the formation of sp^2-p sigma bonds in BF_3 molecule. The amount of energy thus release is much more then the energy which might have been release in pure s and p orbitals of boron hard overlap of the half filled p orbital of F-atoms. This accounts for the greater stability of sp^2-p sigma bonds as compare to the stability of s-p and p-p sigma bonds.

SP³ HYBRIDISATION OF ORBITALS OF CARBON ATOM

The outer electronic configuration of carbon atom in ground state is $1s^2 2s^2 2p^2$. Promotion of one of the $2s$ electrons into one of the vacant $2p$ orbitals due to the energy released in the formation of CH_4 molecule gives rise to excited state configuration is $1s^2 2s^1 2p_x^1 2p_y^1 2p_z^1$.

There are now four half-filled orbitals which account for tetra-covalency of carbon. The four orbitals are one s and three p hybridise to give four sp^3 hybrid orbitals of equivalent energy. The formation of sp^3 hybrid orbitals is shown in figure.

s-orbital   p-orbital sp^3-hybridised orbital
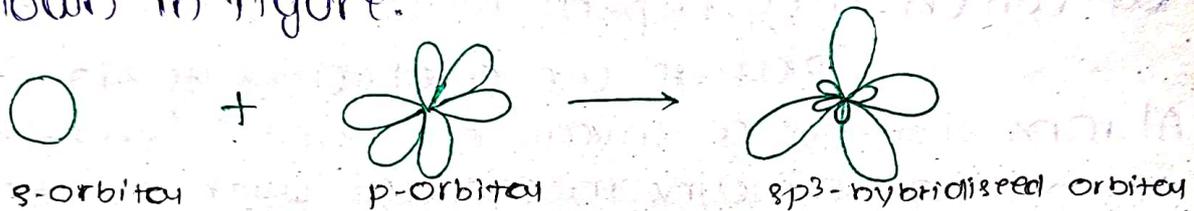
In the formation of methane molecule, the half-filled $1s$ orbital of each hydrogen atom overlaps with each of the four half-filled sp^3 hybrid orbitals of carbon atom, as shown in fig.

Hybrid state — sp^3 hybridisation

Excited — $1s^2 2s^1 2p^3$

Ground — $1s^2 2s^2 2p^2$

A

B

Excited — $1s^2 2s^1 2p^3$

Ground — $1s^2 2s^2 2p^2$

C

D
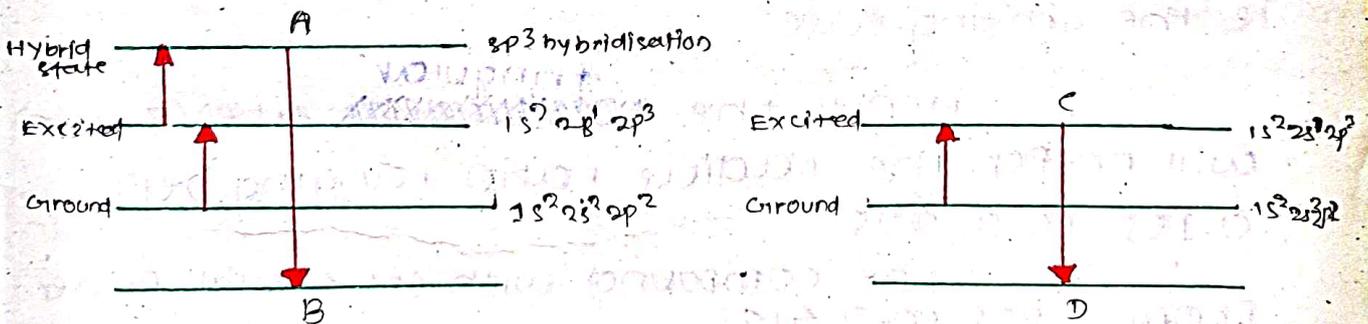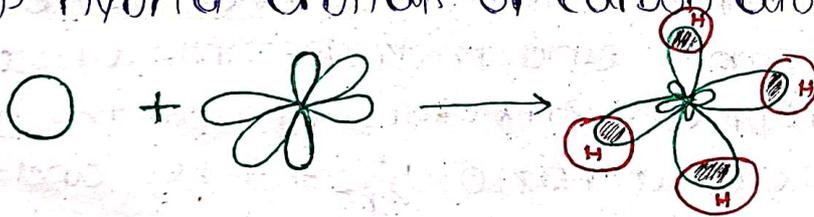
A large amount of energy is released during the formation of sp^3-p sigma bonds in CH_4 molecule.

OBJECTIVE PROBLEMS

1. Polar covalent compounds are soluble in :
   (a) Polar solvents
   (b) Non-polar solvents
   (c) Concentrated acids
   (d) All solvents

2. The unequal sharing of bonded pair of electrons between two atoms in a molecule gives rise to :
   (a) Ionic bond
   (b) Polar covalent bond
   (c) Non-polar covalent bond
   (d) None of these

3. A triple bond is made of :
   (a) One σ- and two π-bond
   (b) Two σ- and one π-bond
   (c) Three σ- and three π-bond
   (d) One σ- and four π-bond

4. The bonds present in N_2O_5 are :
   (a) Ionic
   (b) Covalent and co-ordinate
   (c) Covalent
   (d) Ionic and covalent

5. A sp^3-hybrid orbital contains :
   (a) 1/4 s-character
   (b) 1/2 s-character
   (c) 2/3 s-character
   (d) 3/4 s-character

6. Most covalent halide of aluminium is :
   (a) $AlCl_3$
   (b) AlI_3
   (c) $AlBr_3$
   (d) AlF_3

7. Most predominantly ionic compounds are obtained by the combination of the groups :
   (a) 1 and 7
   (b) 2 and 6
   (c) 4 and 8
   (d) 3 and 5

8. Octet rule is not valid for the molecule :
   (a) CO_2
   (b) H_2O
   (c) O_2
   (d) CO

9. Formation of π-bond :
   (a) Increases bond length
   (b) Decreases bond length
   (c) Distorts the geometry of molecule
   (d) Makes homoatomic molecule more reactive

10. The maximum number of hydrogen bonds in which water molecule can participate is:
    (a) 1
    (b) 2
    (c) 3
    (d) 4

11. In water molecule, oxygen is :
    (a) sp-hybridized
    (b) sp^3-hybridized
    (c) sp^2-hybridized
    (d) None of these

12. Among the following which one is planar:
    (a) BCl_3
    (b) $SOCl_2$
    (c) NH_3
    (d) NF_3

13. Dative bond is present in :
    (a) SO_3
    (b) NH_3
    (c) $BaCl_2$
    (d) BF_3

14. Strongest bond is formed by the head on overlapping of:
    (a) 2s- and 2p-orbitals
    (b) 2p- and 2p-orbitals
    (c) 2s- and 2s-orbitals
    (d) All of these

15. Which ion has a higher polarising power:
    (a) Mg^{2+}
    (b) Al^{3+}
    (c) Ca^{2+}
    (d) Na^+

16. Elements whose electronegativities are 1.2 and 3.0, combine together to form:
    (a) Ionic bond
    (b) Covalent bond
    (c) Co-ordinate bond
    (d) Metallic bond

17. Decreasing order of size of various hybrid orbitals is:
    (a) $sp > sp^2 > sp^3$
    (b) $sp^3 > sp^2 > sp$
    (c) $sp^2 > sp > sp^3$
    (d) $sp > sp^3 > sp^2$

18. In the series ethane, ethylene and acetylene, the C—H bond energy is:
    (a) The same in all the three compounds
    (b) Greatest in ethane
    (c) Greatest in ethylene
    (d) Greatest in acetylene

19. Among the following bonds which has the most polar character :
    (a) C—O
    (b) C—Br
    (c) C—F
    (d) C—S

20. Which does not show inert pair effect:
    (a) Al
    (b) Sn
    (c) Pb
    (d) Thallium

21. The pair having similar geometry is:
    (a) BF_3, NF_3
    (b) BF_3, AlF_3
    (c) BeF_2, H_2O
    (d) BCl_3, PCl_3

22. How many bonded electron pairs are present in IF_7 molecule:
    (a) 6
    (b) 7
    (c) 5
    (d) 8

23. The pairs of bases in DNA are held together by:
    (a) Hydrogen bonds
    (b) Ionic bonds
    (c) Phosphate groups
    (d) Deoxyribose groups

24. Intramolecular hydrogen bonding is found in:
    (a) Salicyldehyde
    (b) Water
    (c) Acetaldehyde
    (d) Phenol

25. How many unpaired electrons are present in N_2^+ :
    (a) 1
    (b) 2
    (c) 3
    (d) 4

26. The pair of elements which on conbination are most likely to form an ionic compound is :
    (a) Na and Ca
    (b) K and O_2
    (c) O_2 and Cl_2
    (d) Al and I_2

27. Which have zero dipole moment:
    (a) 1, 1-Dichloroethene
    (b) Cis-1, 2-dichloroethene
    (c) Trans-1, 2-dichloroethene
    (d) None of these

28. The orbitals of same energy level providing the most efficient overlapping are :
    (a) sp^3-sp^3
    (b) sp-sp
    (c) sp^2-sp^2
    (d) All of these

29. Proton plays an important role in ..... bonding:
(a) Electrovalent
(b) Hydrogen
(c) Covalent
(d) Co-ordinate

30. Which p-orbitals overlapping would give the strongest bond:

(a)

(b)

(c)

(d)
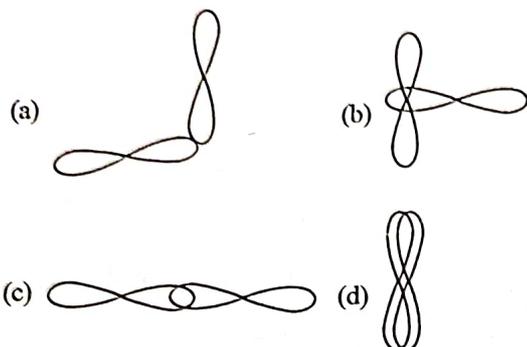
31. The hydration of ionic compounds involves:
(a) Evolution of heat
(b) Weakening of attractive forces
(c) Dissociation into ions
(d) All of these

32. The ratio of σ and π-bonds in benzene is:
(a) 2
(b) 6
(c) 4
(d) 8

33. In the following molecule, the two carbon atoms marked by asterisk (*) possess the following type of hybridised orbitals:

$$H_3C\overset{*}{-}C\equiv\overset{*}{C}-CH_3$$
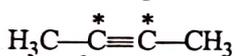
(a) sp^3-orbital
(b) sp^2-orbital
(c) sp-orbital
(d) s-orbital

34. Which has trigonal planar geometry :
(a) IF_3
(b) PCl_3
(c) NH_3
(d) BF_3

35. The internuclear distance in H_2 and Cl_2 molecules are 74 and 198 pm respectively. The bond length of HCl may be:
(a) 272 pm
(b) 70 pm
(c) 136 pm
(d) 248 pm

36. Intramolecular hydrogen bonding is found in :
(a) Salicyldehyde
(b) Water
(c) Acetaldehyde
(d) Phenol

37. Example of super octet molecule is:
(a) F_3Cl
(b) PCl_5
(c) IF_7
(d) All of these

38. The shape of covalent molecule MX_3 is:
(a) Triangular
(b) T-shape
(c) Pyramidal
(d) Either of these depending on number of lone pairs of electron on M

39. Which of the following is not isoelectronic:
(a) NO^-
(b) CN^-
(c) N_2
(d) O_2^{2+}

40. Number of non-bonding electron in N_2 is:
(a) 4
(b) 10
(c) 12
(d) 14

41. Bond-length of HCl is; 1.275 Å ($e = 4.8 \times 10^{-10}$ esu). If $\mu = 1.02$ D then HCl is:
(a) 100% ionic
(b) 83% covalent
(c) 50% covalent
(d) 40% ionic

42. Among the following compounds the one that is polar and has the central atom with sp^3-hybridisation is:
(a) H_2CO_3
(b) SiF_4
(c) BF_3
(d) $HClO_2$

43. Which of the following molecule consists of multicentre π-bonding:
(a) Ethene
(b) Butane
(c) Benzene
(d) None of these

44. The hybrid state of positively charged carbon in vinyl ($CH_2=CH^+$) cation is:
(a) sp^2
(b) sp
(c) sp^3
(d) Unpredictable

45. In which of the following species the hybrid state of the central atom is same:
(a) SO_2, SO_3
(b) SO_3, SO_4^{2-}
(c) SO_2, SO_3^{2-}
(d) $CH_4, HCOOH$

46. A σ- bonded moleculer MX_3 is T-shaped. The number of lone pairs of electrons around M is:
(a) Zero
(b) 2
(c) 1
(d) Unpredictable

47. Two ice cubes are pressed over each other and unite to form one cube. Which force is responsible for holding them together:
(a) van der Waals' forces
(b) Covalent attraction
(c) Hydrogen bond formation
(d) Dipole-dipole attraction

48. Which of the following has fractional bond order:
(a) O_2^{2+}
(b) O_2^{2-}
(c) F_2^{2-}
(d) H_2^-

49. Which has a giant covalent structure?
(a) PbO_2
(b) SiO_2
(c) $NaCl$
(d) $AlCl_3$

50. Which contains both covalent and ionic bonds?
(a) CCl_4
(b) KCN
(c) $CaCl_2$
(d) H_2O

51. The bond angle in PH_3 is:
(a) Much lesser than in NH_3
(b) Equal to than in NH_3
(c) Much greater than in NH_3
(d) Slightly more than in NH

52. The species which does not show paramagnetism is:
(a) O_2
(b) O_2^+
(c) O_2^{2-}
(d) H_2^+

53. The bond length in O_2^+, O_2, O_2^- and O_2^{2-} follows the order
(a) $O_2^{2-} > O_2^- > O_2 > O_2^+$
(b) $O_2^+ > O_2 > O_2^- > O_2^{2-}$
(c) $O_2 > O_2^- > O_2^{2-} > O_2^+$
(d) $O_2^- > O_2^{2-} > O_2^+ > O_2$

54. H—B—H bond angle in BH_4^- is:
(a) 180°
(b) 120°
(c) 109°
(d) 90°

55. The bond angle and hybridisation in ether (CH_3OCH_3) is:
    (a) $106°\,51',\,sp^3$
    (b) $104°\,31',\,sp^3$
    (c) $110°,\,sp^3$
    (d) None of these

56. The shape of a molecule which has 3 bond pairs and one lone pair is:
    (a) Octahedral
    (b) Pyramidal
    (c) Triangular planar
    (d) Tetrahedral

57. The number of ions formed when a molecule of $K_4Fe(CN)_6$ dissociates is :
    (a) 4
    (b) 5
    (c) 6
    (d) 2

58. The covalency of nitrogen in HNO_3 is :
    (a) 0
    (b) 3
    (c) 4
    (d) 5

59. Which of the following pairs of elements form oxides of polyanions and polycations respectively:
    (a) Si and Al
    (b) Cu and Si
    (c) Al and B
    (d) Ti and As

60. Which of the following halides is not oxidised by MnO_2:
    (a) F^-
    (b) Cl^-
    (c) Br^-
    (d) I^-

61. Which statement is correct about HCHO:
    (a) It has sp^2-hybridised carbon
    (b) The bond angles $\angle HCH$ and $\angle HCO$ are 116° and 122° respectively
    (c) It involves multiple bond pair — Bond pair repulsion
    (d) All of these

62. In the cyanide ion the formal negative charge is on:
    (a) C
    (b) N
    (c) Both C and N
    (d) Resonate between C and N

63. Bond angle between two hybrid orbitals is 105°. Hybrid character in orbital is:
    (a) Between 20 – 21%
    (b) Between 19 – 20%
    (c) Between 21 – 22%
    (d) Between 22 – 23%

64. N—O—N bond angle is maximum in :
    (a) NO_2^+
    (b) NO_2
    (c) NO_3
    (d) N_2O_3

65. Which of the following would have permanent dipole moment:
    (a) SF_4
    (b) XeF_4
    (c) SiF_4
    (d) BF_3

66. Which bond angle, θ would result in the maximum dipole moment for the triatomic molecule XY_2 shown below:

    (a) θ = 90°
    (b) θ = 120°
    (c) θ = 150°
    (d) θ = 180°

67. The correct order of increasing covalent character is :
    (a) $NaCl < LiCl < BeCl_2$
    (b) $BeCl_2 < NaCl < LiCl$
    (c) $BeCl_2 < LiCl < NaCl$
    (d) $LiCl < NaCl < BeCl_2$

68. The correct hybridisation state of sulphur atom in SF_2, SF_4 and SF_6 molecules is respectively:
    (a) $sp^3d,\ sp^3,\ sp^3d^2$
    (b) $sp^3,\ sp^3d,\ sp^3d^2$
    (c) $sp^3d^2,\ sp^3,\ sp^3d$
    (d) $sp^3d^2,\ sp^3d,\ sp^3$

69. Which molecule is T-shaped:
    (a) BeF_2
    (b) BCl_3
    (c) NH_3
    (d) ClF_3

70. In dry ice there are:
    (a) Ionic bond
    (b) Covalent bond
    (c) Hydrogen bond
    (d) None of these

71. PCl_5 exists but NCl_5 does not because:
    (a) Nitrogen has no vacant $2d$-orbitals
    (b) NCl_5 is unstable
    (c) Nitrogen atom is much smaller than P
    (d) Nitrogen is highly inert

72. What is the hybridisation in AsF_4^- ion:
    (a) sp
    (b) sp^2
    (c) sp^3
    (d) sp^3d

73. One among the following is the incorrect order of increasing ionisaton energy:
    (a) $Cl^- < Ar < K^+$
    (b) $K < Ca < Se$
    (c) $Au < Ag < Cu$
    (d) $Cs < Rb < K$

74. $CuSO_4 \cdot 5H_2O$ is represented as:
    (a) $[Cu(H_2O)_5]SO_4$
    (b) $[Cu(H_2O)_3\,SO_4] \cdot 2H_2O$
    (c) $[Cu(H_2O)_4]SO_4 \cdot H_2O$
    (d) $[Cu(H_2O)_5]SO_4$

75. The correct order of increasing electropositive character among Cu, Fe and Mg is:
    (a) $Cu \approx Fe < Mg$
    (b) $Fe < Cu < Mg$
    (c) $Fe < Mg < Cu$
    (d) $Cu < Fe < Mg$

76. Which shows a change in the type of hybridisation when:
    (a) NH_3 combines with H^+
    (b) AlH_3 combines with H^-
    (c) In both cases
    (d) In none cases

77. When temperature is lowered NO_2 dimerises. It is accompanied by:
    (a) An increase in pressure
    (b) Darkening in colour
    (c) Decrease in paramagnetism
    (d) Increase in paramagnetism

78. The dipole moment of NF_3 is very much less compared to that of NH_3 because:
    (a) The size of N atom is much less than that of H atom
    (b) F atom is more electronegative than N atom, whereas H atom is less electronegative than N atom
    (c) Unshared electron pair is not present in NF_3
    (d) No. of lone pairs in NF_3 is much greater than in NH_3

79. In HCHO, there are X non-bonding electron pairs, Y σ-bonds and Z π-bonds, X, Y and Z are:
    (a) 1, 1, 3
    (b) 2, 3, 1
    (c) 1, 2, 3
    (d) None of these

80. For compounds,
    A : Tetracyanoethene
    C : Benzene
    B : Carbon dioxide
    D : 1, 3-Butadiene
    Ratio of σ and π bonds is in order:
    (a) $A = B < C < D$
    (b) $A = B < D < C$
    (c) $A = B = C = D$
    (d) $C < D < A < B$

81. Hypervalent compound is:
    (a) SO_3^{2-}
    (b) NH_3
    (c) BeF_2
    (d) CH_4

82. Which set contains pair of elements that do not belong to same group but show chemical resemblances:
    (a) Hf, Zr
    (b) K, Rb
    (c) Be, Al
    (d) B, Al

83. An element of p-block in which last electron enters into s-orbital of valence shell instead of p-orbital is:
    (a) As
    (b) Ga
    (c) Te
    (d) He

84. Covalent radius of Li is 123 pm. The crystal radius of Li will be:
    (a) > 123 pm
    (b) < 123 pm
    (c) $= 123$ pm
    (d) $= \dfrac{123}{2}$ pm

85. A molecule which can not exist theoretically is:
    (a) SF_4
    (b) OF_2
    (c) OF_4
    (d) O_2F_2

86. Which are true statements among the following:
    (1) PH_5 and $BiCl_5$ do not exist
    (2) $p\pi$-$d\pi$ bonds are present in SO_2
    (3) Electrons travel with speed of light
    (4) SeF_4 and CH_4 have same shape
    (5) I_3^+ has bent geometry
    (a) 1, 3
    (b) 1, 2, 5
    (c) 1, 3, 5
    (d) 1, 2, 4

87. Which pair is isostructural and possesses same number of lone pair of electron on central atom:
    (a) IF_5 and $XeOF_4$
    (b) NH_3 and ClO_3^-
    (c) $SnCl_4$ and ClO_4^-
    (d) $AlCl_3$ and SO_2

88. Which are isostructural species:
    (a) CH_3^- and CH_3^+
    (b) NH_4^+ and NH_3
    (c) SO_4^{2-} and BF_4^-
    (d) NH_2^- and BeF_2

89. The higher values of specific heat of water than other liquids has been accounted in terms of:
    (a) High dielectric constant
    (b) Polarity
    (c) H-bonding
    (d) None of these

90. In which element shielding effect is not possible:
    (a) H
    (b) Be
    (c) B
    (d) N

91. The correct increasing bond angles order is:
    (a) $BF_3 < NF_3 < PF_3 > ClF_3$
    (b) $ClF_3 < PF_3 < NF_3 < BF_3$
    (c) $BF_3 \approx NF_3 < PF_3 < ClF_3$
    (d) $BF_3 < NF_3 < PF_3 < ClF_3$

92. The bond order in O_2^+ is the same as in:
    (a) N_2^+
    (b) CN^-
    (c) CO
    (d) NO^+

93. In the formation of N_2^+, the electron is lost from:
    (a) A σ-orbital
    (b) A π-orbital
    (c) A σ^*-orbital
    (d) A π^*-orbital

94. The most suitable method of separation of a mixture of ortho and para nitrophenol in the ratio 1 : 1 is:
    (a) Distillation
    (b) Crystallisation
    (c) Vaporisation
    (d) Colour spectrum

95. The correct order for triple bond energy in CO, N_2, CN and $C \equiv C$ is :
    (a) $C \equiv O > N \equiv N > C \equiv N > C \equiv C$
    (b) $N \equiv N > C \equiv O > C \equiv C > C \equiv N$
    (c) $C \equiv C > C \equiv O > N \equiv N > C \equiv N$
    (d) $C \equiv N > C \equiv O > N \equiv N > C \equiv C$

96. Which of the following phenomenon will occur when two atoms of an element with same spin of electron approach each other:
    (a) Orbitals overlap will occur
    (b) Orbitals overlap will not occur
    (c) Bonding will occur
    (d) A diatomic molecule will be formed

97. The molecule having three fold axis of symmetry is:
    (a) NH_3
    (b) C_2H_4
    (c) CO_2
    (d) SO_2

98. P in PCl_5 has sp^3d hybridisation which of the following statement is wrong about PCl_5 structure:
    (a) Two P—Cl bonds are stronger and three P—Cl bonds weaker
    (b) Two P—Cl bonds are axial and larger than three P—Cl equatorial bonds
    (c) PCl_5 has trigonal bipyramidal geometry with non-polar nature
    (d) All of these

99. Molecular size of ICl and Br_2 is nearly same but b.pt of ICl is about $40°$ higher than Br_2. This is due to:
    (a) I—Cl bond is stronger than Br—Br bond
    (b) Ionisation energy of I < ionisation energy of Br
    (c) ICl is polar whereas Br_2 is non-polar
    (d) Size of I is larger than Br

100. Which of the following possess lowest bond energy:
    (a) C—C
    (b) N—N
    (c) H—H
    (d) O—O

101. The solubility of KCl is relatively more in:
   (a) $C_6H_6 (D = 0)$
    (b) $(CH_3)_2CO (D = 2)$
    (c) $CH_3OH (D = 32)$
    (d) $CCl_4 (D = 0)$

102. The structure of IF_5 can be best described by:

(c)
$$F - \overset{F}{\underset{F}{\underset{90°}{\mid}}} I \overset{F}{\underset{F}{\big<}} \quad 90°$$
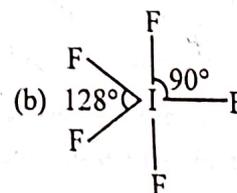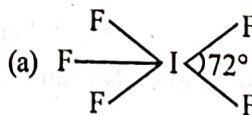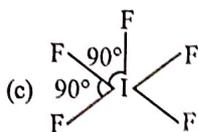
(d) None of these

103. The correct order of increasing bond angles is:
 (a) $PF_3 < PCl_3 < PBr_3 < PI_3$ (b) $PF_3 < PBr_3 < PCl_3 < PI_3$
 (c) $PI_3 < PBr_3 < PCl_3 < PF_3$ (d) $PF_3 > PCl_3 < PBr_3 < PI_3$

104. The hybridisation of P in phosphate ion (PO_4^{3-}) is the same as in:
 (a) I in ICl_4^- (b) S in SO_3
 (c) N in NO_3^- (d) S in SO_3^{2-}

105. The diamagnetic molecules are:
 (a) B_2, C_2, N_2 (b) O_2, N_2, F_2
 (c) C_2, N_2, F_2 (d) B_2, O_2^{2-}, N_2

106. The correct order in which the O—O bond length increases in the following:
 (a) $H_2O_2 < O_2 < O_3$ (b) $O_3 < H_2O_2 < O_2$
 (c) $O_2 < H_2O_2 < O_3$ (d) $O_2 < O_3 < H_2O_2$

107. Heterolytic bond fission in C_2H_6 gives carbonium and carbanion ions. The hybridisation of carbon atoms in these ions is:
 (a) sp^3 (b) sp^2
 (c) sp (d) sp^3, sp^2

108. Maleic acid is stronger than fumaric acid because :
 (a) Fumaric acid shows intermolecular H-bonding
 (b) Fumaric acid shows intramolecular H-bonding
 (c) Maleic acid is dibasic acid
 (d) Maleic acid shows chelation

109. The correct order for bond angles is :
 (a) $NO_2^+ > NO_2 > NO_2^-$ (b) $NO_2^+ > NO_2^- > NO_2$
 (c) $NO_2 > NO_2^- > NO_2^+$ (d) $NO_2^- > NO_2 > NO_2^+$

110. The correct order for bond angles is :
 (a) $NH_4^+ > NH_3 > NH_2^-$ (b) $NH_3 > NH_4^+ > NH_2^-$
 (c) $NH_4^+ > NH_2^- > NH_3$ (d) $NH_3 > NH_2^- > NH_4^+$

111. Which statement is incorrect for OSF_4 :
 (a) S atom has sp^3d hybridisation
 (b) OSF_4 have disterted trigonal pyramidal geometry
 (c) O atom at one of the two axial positions having S=O bond
 (d) O atom at one of the equatorial position having S=O bond

112. The O—O bond length in $O_2, O_2[AsF_4]$ and $K[O_2]$ is :
 (a) $O_2[AsF_4] < O_2 < K[O_2]$ (b) $O_2[AsF_4] < K[O_2] < O_2$
 (c) $O_2 < O_2[AsF_4] < K[O_2]$ (d) $K[O_2] < O_2 < O_2[AsF_4]$

113. N_2 and O_2 are converted to mono cations N_2^+ and O_2^+ respectively which statement is wrong :

(a) In N_2^+, the N—N bond weakens
(b) In O_2^+, the O—O bond order increases
(c) In O_2^+, the paramagnetism decreases
(d) N_2^+ become diamagnetic

114. The correct stability order for N_2 and its given ions is :
 (a) $N_2 > N_2^+ > N_2^- > N_2^{2-}$ (b) $N_2^- > N_2^+ > N_2 > N_2^{2-}$
 (c) $N_2^+ > N_2^- > N_2 > N_2^{2-}$ (d) $N_2 > N_2^+ = N_2^- > N_2^{2-}$

115. The correct bond order for CO and CO^+ are respectively :
 (a) $3, 5/2$ (b) $3, 2$
 (c) $3, 7/2$ (d) $5/2, 3$

116. The pair with more ionic nature and less m.pt. respectively in lithium halides :
 (a) LiF, LiI (b) $LiCl, LiF$
 (c) $LiBr, LiI$ (d) $LiF, LiCl$

117. The shapes of PCl_4^+, PCl_4^- and $AsCl_5$ are respectively :
 (a) Square planar, tetrahedral, see-saw
 (b) Tetrahedral, see-saw, trigonal bipyramidal
 (c) Tetrahedral, square planar and pentagonal bipyramidal
 (d) Trigonal bipyramidal, tetrahedral and square pyramidal

118. During the formation of a molecular orbital from atomic orbital, the electron density is :
 (a) Minimum in nodal plane
 (b) Maximum in nodal plane
 (c) Zero in nodal plane
 (d) Zero on the surface of lobe

119. Which among the following is true :
 (a) Bond order $\propto \dfrac{1}{\text{Bond length}} \propto$ bond energy
 (b) Bond order $\propto$ bond length $\propto \dfrac{1}{\text{Bond energy}}$
 (c) Bond order $\propto \dfrac{1}{\text{Bond length}} \propto \dfrac{1}{\text{Bond energy}}$
 (d) Bond order $\propto$ bond length $\propto$ bond energy

120. For which crystalline substance does the solubility in water increases upto 32°C and then decreases readily :
 (a) $CaCl_2 \cdot 2H_2O$ (b) $Na_2SO_4 \cdot 10H_2O$
 (c) $FeSO_4 \cdot 7H_2O$ (d) Alums

121. Among the following which has resonating structure :
 (a) BF_3 (b) PCl_5
 (c) SF_6 (d) IF_7

122. The correct order of increasing C—O bond lengths in CO, CO_3^{2-} and CO_2 is :
 (a) $CO_3^{2-} < CO_2 < CO$ (b) $CO_2 < CO_3^{2-} < CO$
 (c) $CO < CO_3^{2-} < CO_2$ (d) $CO < CO_2 < CO_3^{2-}$

123. Which statement is wrong about H_2O :
    (a) It has high specific heat relative to other liquids or solids due to strong inter-molecular H-bonding
    (b) H_2O molecule has capacity to form 4 H-bonds
    (c) H_2O has open cage like structure due to intermolecular H-bonding which give rise to low density to ice than liquid H_2O
    (d) H_2O has maximum density at 4°C since upto 4°C, the intermolecular H-bonding persists more and thereby decreasing volume and increasing density

124. In NO_3^- ion, the number of bond pair and lone pair of electrons on N-atom are :
    (a) 2, 2   (b) 3, 1
    (c) 1, 3   (d) 4, 0

125. List I contains some chemical species and List II, the type of hybrid orbitals used in the formation of such species. Match the items of List I with those of List II and select the correct answer using the codes given below the lists:

List I	List II
A. CrO_4^{2-}	1. sp^3d^2
B. BF_4^-	2. sp^3
C. ICl_4^-	3. d^3s
D. $PtCl_4^{2-}$	4. dsp^2

Code:	A	B	C	D
(a)	1	2	3	4
(b)	3	4	2	1
(c)	1	4	3	2
(d)	3	2	1	4

126. Which of the following pairs are correctly matched? Select the correct answer using the codes given below :

Species	Hybridisation
I. $[NO_3]^-$	sp^2
II. $[ClO_3]^-$	sp^3
III. $[Fe(CN)_6]^{3-}$	d^2sp^3
IV. $[ICl_2]^-$	sp^2

    (a) I, II, III and IV   (b) I and III
    (c) II and IV   (d) I, II and III

127. Match list I (Molecules/ions) with list II (Shapes) and select the correct answer using the codes given below the lists:

List I	List II
I. ClF_3	A. Square planar
II. $[PCl_4]^+$	B. T-shaped
III. XeF_4	C. Tetrahedral
IV. XeO_3	D. Pyramidal

    (a) I-B, II-C, III-D, IV-A   (b) I-C, II-B, III-D, IV-A
    (c) I-B, II-C, III-A, IV-D   (d) I-C, II-B, III-A, IV-D

128. Match List I (Species) with List II (Hybridization) and select the correct answer using the codes given below the lists :

List I	List II
A. BCl_3	1. sp^3
B. NH_3	2. sp^3d^2
C. $[Cu(NH_3)_4]^{2+}$	3. sp^2
D. $[Fe(H_2O)_6]^{2+}$	4. dsp^2

Code:	A	B	C	D
(a)	3	1	4	2
(b)	1	3	4	2
(c)	1	3	2	4
(d)	3	1	2	4

129. Match List I with List II and select the correct answer using the codes given below the lists:

List I	List II
A. ClF_3	1. Planar
B. NF_3	2. Pyramidal
C. BF_3	3. T-shaped
D. CrF_3	4. V-shaped

Code:	A	B	C	D
(a)	3	2	1	–
(b)	2	3	1	–
(c)	–	3	2	1
(d)	3	1	2	4

130. Which of the following species have undistorted octahedral structures ?
    1. SF_6 2. PF_6^- 3. SiF_6^{2-} 4. XeF_6
    Select the correct answer using the codes given below :
    (a) 2, 3 and 4   (b) 1, 3 and 4
    (c) 2 and 3   (d) 1, 2 and 3

131. Match List I (Hybridization) with List II (Shapes) and select the correct answer using the codes given below the lists :

List I	List II
A. dsp^2	1. Square planar
B. dsp^3	2. Trigonal bipyramid
C. d^2sp^3	3. Octahedral
D. sp^3d	4. Trigonal bipyramidal

Code:	A	B	C	D
(a)	1	2	3	4
(b)	4	2	3	1
(c)	1	3	2	4
(d)	4	3	2	1

132. Match List I (Molecule) with List II (Shape) and select the correct answer using the codes given below the lists :

List I	List II
A. $(CH_3)_3 B$	1. Square planar
B. NH_4Cl	2. Trigonalbipyramid
C. $[ICl_4]^-$	3. Tetrahedral
D. PCl_5	4. Trigonal planar

Code:	A	B	C	D
(a)	1	3	4	2
(b)	4	3	1	2
(c)	4	2	1	3
(d)	1	2	4	3