



VANDER WAAL'S FORCES

- These are the weakest type of inter molecular forces that exist among the chemical species which bring a significant change in physical properties.
- These are non-directional, non-valence cohesive forces. These attractive forces being played between the two molecules, are independent of the presence of other molecules.
- Solid, liquid or gaseous states of many molecules are explained on the basis of inter molecular forces other than covalent, ionic or metallic bonds. Although inert gases do not form any type of bond but may exist in liquid and solid states. This shows that the atoms of inert gases are attracted by each other through some type of intermolecular forces. These intermolecular forces are called Vander Waals forces.

➤ **Types of Vander Waal's Forces**

(1) Dipole-dipole interaction :

The force of attraction between the oppositely charged poles of two polar molecules (for example : H₂S, HCl, PH₃ etc.) is called dipole-dipole attraction.

- Two type of arrangements:
 - (a) Head to Tail (in gas): H – Cl^{-δ} H^{+δ} – Cl ($E \propto 1/r^6$)
 - (b) Anti parallel (in solid and liquid): H^{+δ} – Cl^{-δ} ($E \propto 1/r^3$)



- (1)** Anti parallel arrangement is better arrangement than Head to Tail arrangement, when

(a) Thermal agitation is not too high **(b)** Molecule is not too fatty.

- (2)** Dipole-induced dipole interaction : This type of cohesive forces occurs in a mixture of polar and non polar molecules. For example force of attraction between Cl₂ and H₂O.

- Size of non polar molecules increases then interaction between molecules increases.

- (3)** Instantaneous dipole-Induced dipole interaction : The weak intermolecular forces operating in similar non polar gaseous molecules are called London forces. These forces are very weak in nature and exists only at low temperature. For example weak intermolecular forces in F₂, Cl₂, N₂, molecules and in nobel gases.

[Notation: upward arrow (↑) represent increasing value, down ward arrow (↓) represent decreasing value]

- London forces present in both polar and non-polar species but dominate in non-polar molecule.
- [Size ↑, LDF ↑, attraction ↑]
- LDF depends upon-

**(a) size****(b) molecular mass****(c) polarizable electron**

- **Other type of interaction :**

(1) Ion-dipole interaction :

Polar molecules are attracted by ions. The negative pole is attracted by cation and positive pole attracted by the anion.



(2) Ion-induced dipole interaction :

When non polar molecules come in contact with ions, its electron cloud gets polarized and the oppositely charged end of it is attracted by the ion. For example attraction between Na^+ and Cl_2 molecule.

- Size of non-polar molecule increases, attraction force increases.



- Boiling point depends on molecular mass and interaction force between molecules.

$$\left[\begin{array}{l} \text{Boiling point} \propto \text{molecular mass} \\ \propto \text{Interaction between molecules} \end{array} \right]$$

- Order of boiling point

(1) $\text{BF}_3 < \text{B}(\text{Me})_3$	(2) $\text{NF}_3 < \text{N}(\text{Me})_3$
(3) $\text{CO} > \text{N}_2$	(4) $\text{ICl} > \text{Br}_2$
(5) $\text{CCl}_4 > \text{SiCl}_4$	(6) $\text{CH}_4 < \text{SiH}_4 < \text{GeH}_4 < \text{SnH}_4 < \text{PbH}_4$
(7) $\text{HF} > \text{HI} > \text{HBr} > \text{HCl}$	(8) $\text{H}_2\text{O} > \text{H}_2\text{Te} > \text{H}_2\text{Se} > \text{H}_2\text{S}$
(9) $\text{H}_2\text{O} > \text{HF} > \text{NH}_3$	(10) $\text{H}_2\text{SO}_4 > \text{Me}_2\text{SO}_4$
(11) $\text{H}_3\text{PO}_4 > \text{Me}_2\text{PO}_4$	(12) $\text{H}_3\text{BO}_3 > \text{Me}_3\text{BO}_3$
(13) $\text{CH}_4 < \text{CF}_4$	(14) $\text{C}_2\text{H}_6 < \text{C}_2\text{F}_6$
(15) $\text{C}_3\text{H}_8 < \text{C}_3\text{F}_8$	(16) $\text{C}_5\text{H}_{12} > \text{C}_5\text{F}_{12}$
(17) $\text{H}_2 > \text{He}$	

- Interaction energy relation with radius :

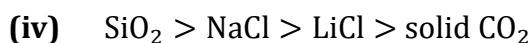
Ion-dipole attraction	$\propto \frac{1}{r^2}$
Dipole- dipole attraction (E_k)	$\propto \frac{1}{r^3}$
Ion-induced dipole attraction	$\propto \frac{1}{r^4}$
Dipole induced dipole attraction (E_d)	$\propto \frac{1}{r^6}$
Instantaneous dipole-induced dipole attraction (E_L)	$\propto \frac{1}{r^6}$

$$E_k > E_d > E_L \text{ (interaction energy)}$$

Note : H-bonding is a special case of Dipole-Dipole attraction

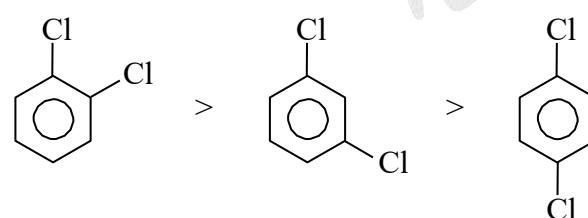
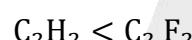
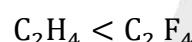
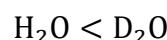
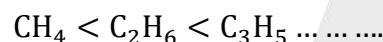
- Generally boiling point of ionic compound is greater than the covalent compound unless covalent compound do not have 3-D network like structure.

- **Order of boiling point**



- When the non-polar gas or molecule is passed into polar solvent, after crystallization the compound obtained is called **clathrates**. (Ex:- $\text{XeF}_6 \cdot 6\text{H}_2\text{O}$)

- **Order of Boiling Point :**



Molecular weight :

84

300

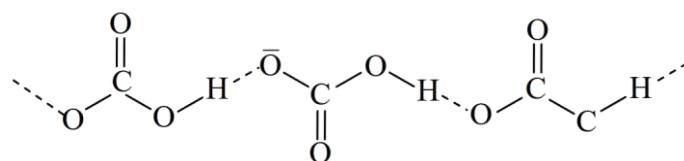
(Approx)

(Inorganic Chemistry)

- Solved Example :

Sodium bicarbonate partially soluble in water while potassium bicarbonate completely soluble in water.

Reason → NaHCO_3 exist in polymer form KHCO_3 exist in dimer form



[Massive hydrogen bonding]



[Compact hydrogen bonding]

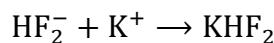
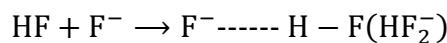
Q. Compound in which ion dipole interaction (H-bond) is present

- | | | | |
|-------|--|---|--|
| (i) | H_2CO_3 | $\rightarrow \text{NaHCO}_3$ ✓ | |
| | | $\rightarrow \text{Na}_2\text{CO}_3$ ✗ | |
| (ii) | H_2SO_5
(caro's acid) | $\rightarrow \text{KHSO}_5$ ✓
Oxone | |
| | | $\rightarrow \text{K}_2\text{SO}_5$ ✗ | |
| (iii) | HNO_3
(Aqua forties) | $\rightarrow \text{NaNO}_3$ ✗
(Chile salt petre) | |
| | | $\rightarrow \text{KNO}_3$ ✗
(Indian salt petre) | |
| (iv) | H_3PO_4 | $\rightarrow \text{H}_2\text{PO}_4^-$ ✓
1° Phosphate | |
| | | $\rightarrow \text{HPO}_4^{2-}$ ✓
2° Phosphate | |
| | | $\rightarrow \text{PO}_4^{3-}$ ✗ | |
| (v) | H_3PO_4
(Phosphoric acid) | $\rightarrow \text{NaH}_2\text{PO}_3$ ✓ | |
| | | $\rightarrow \text{Na}_2\text{H PO}_3$ ✗ | |
| (vi) | H_2SO_4
(oil of vitrole
or
king of chemicals) | $\rightarrow \text{KHSO}_4$ ✓ | |
| | | $\rightarrow \text{K}_2\text{SO}_4$ ✗ | |

(Inorganic Chemistry)

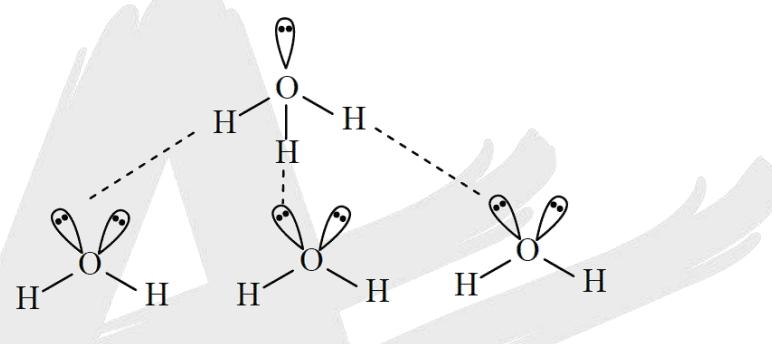
Q. KF & HF are soluble in each other why?

Due to ion dipole attraction

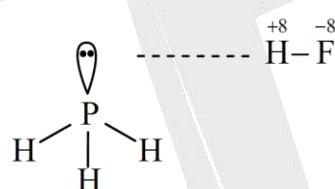


Identify the type of force of attraction :-

- (1) $\text{Na}(\text{H}_2\text{O})_x^-$ -ion dipole attraction
- (2) $\text{I}(\text{H}_2\text{O})_x^-$ -ion dipole attraction
- (3) $[\text{Co}(\text{NO}_2)_6]^{3+}$ -ion dipole attraction
- (4) H_9O_4^+ dipole-dipole, ion-dipole attraction & hydrogen bond



- (5) $\text{H}_3\text{P} \cdots \text{HF}$ dipole-dipole intercation



- (6) $\text{H} - \text{C} \equiv \text{N} \cdots \text{H} - \text{C} \equiv \text{N} = 3.25$ dipole-dipole interaction

- (7) CHCl_3 $\text{O}(\text{CH}_3)_3$ dipole-dipole interaction



- (8) $\text{C}_2\text{H}_5\text{NO}_2 > \text{C}_2\text{H}_6$ dipole-induced interaction

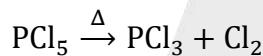
Polar Non polar



DO YOURSELF - 1

1. Dipole-dipole interaction energy between stationary polar molecules (as in solids) is proportional to
 (A) $\frac{1}{r^3}$ (B) $\frac{1}{r^4}$ (C) $\frac{1}{r^6}$ (D) $\frac{1}{r^{12}}$
2. Which of the following possess large dipole moments and has more intermolecular attractive forces?
 (A) $\text{CH}_3 - \text{NO}_2$ (B) $\text{CH}_3 - \text{CH}_3$ (C) $\text{CH}_3 - \text{Cl}$ (D) $\text{CH}_3 - \text{CH}_2 - \text{Cl}$
3. Which of the following order is INCORRECT against the indicated properties
 (A) $\text{CCl}_4 > \text{SiCl}_4$ (boiling point) (B) $\text{C}_5\text{H}_{12} > \text{C}_5\text{F}_{12}$ (boiling point)
 (C) $\text{CF}_4 < \text{CH}_4$ (boiling point) (D) $\text{NaCl} < \text{SiO}_2$ (boiling point)
4. Which of the following statements are INCORRECT?
 (A) BF_3 is more volatile than BI_3
 (B) Xe(g) has lesser interatomic forces than Xe(s)
 (C) The boiling point of H_2 is lesser than He
 (D) OF_2 has higher boiling point than CF_4
5. Which of the following has Vander Waal's interaction with permanent dipole only ?
 (A) Liquid- NH_3 (B) Liquid-He
 (C) $\text{Xe} - \text{H}_2\text{O}$ (D) Both (A) and (C)

BENT'S RULE



If all the bonds are $\text{sp}^3\text{d} - 3\text{p}$ then why are there strength is different?

- **Reason:**

It is due to the difference in % s character of hybrid orbital.

$$\cos \theta = \frac{s}{s-1} \quad \text{or} \quad \frac{p-1}{p} \quad \text{Where } \theta \text{ is Bond Angle}$$

Equatorial

Axial

$$\theta = 120^\circ$$

$$\theta = 90^\circ$$

$$\cos 120^\circ = \frac{s}{s-1}$$

$$\cos 90^\circ = \frac{s}{s-1}$$

$$\% \text{ s} = 33.33\%$$

$$\% \text{ s} = 0$$

- **Key Point:**

Bond Angle \uparrow , % s \uparrow , attraction \uparrow , Bond Length \downarrow , Bond Strength \uparrow

(Bond Length = Hybrid orbital length + size of Surrounding atom/central atom)

(Inorganic Chemistry)

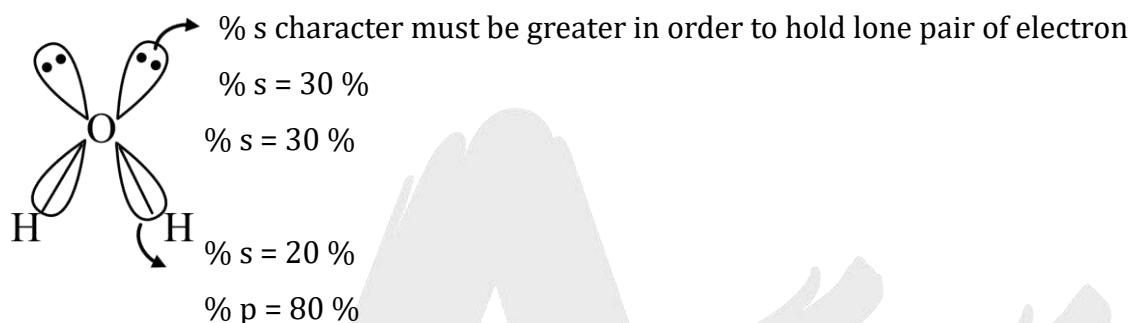
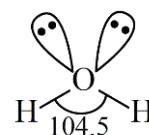
➤ Type of hybridization

Equivalent hybridization = sp, sp^2, sp^3, sp^3d^2 Non-equivalent hybridization = sp^3d, sp^3d^3 Hybridisation in H_2O :-

$$\cos 104.5 = -0.25$$

$$\cos \theta = \frac{s}{s-1}$$

$$s = 20\%$$



Hybridisation of bonded orbital in water = sp^3 (only denotes % s-character, not related with number of orbital)

➤ **NOTE:** In a molecule, % s character of lone pair is always greater than that of bonded orbital.

➤ Statement of Bent's Rule:

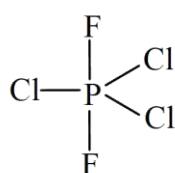
- (a) When all surrounding atom are attached with central atom through single bond, then more electronegative surrounding atom prefer to stay with that hybrid orbital which has less percentage of s-character.
- (b) Multiple bond and lone pair prefer to stay with that hybrid orbital which has more percentage s-character.
- (c) Lone pair has slightly more percentage s character than multiple bond.

➤ Percentage of s-character can be defined by mathematical equation.

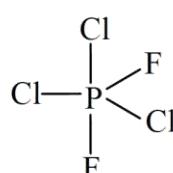
$$\boxed{\cos \theta = \frac{s}{s-1} \text{ or } \frac{p-1}{p}} \quad \text{Where } \theta \text{ is Bond Angle}$$

Ex. Draw the geometry of $PCl_3 F_2$

Sol.



Correct
Structure



Wrong
Structure

(Inorganic Chemistry)

➤ **Reason:**

Because highly electronegative atom occupy axial position (axial position has smaller percentage of s-character)

• **Solved Example:**

1. Compare the C – H Bond Length in F_3CH and Cl_3CH

Ans. $\text{F}_3\text{CH} < \text{Cl}_3\text{CH}$

2. Compare $\text{H} - \hat{\text{C}} - \text{HH} - \hat{\text{C}} - \text{FF} - \hat{\text{C}} - \text{F}$ bond angle in CH_2F_2

Ans. $\text{H} - \hat{\text{C}} - \text{H} > \text{H} - \hat{\text{C}} - \text{F} > \text{F} - \hat{\text{C}} - \text{F}$

3. Compare the dipole moment (μ) for the given compound:

Ans. $\text{P}(\text{CH}_3)_2(\text{CF}_3)_3 > \text{P}(\text{CH}_2)_3(\text{CF}_3)_2$

4. Compare P – F Bond Length in

Ans. $\text{PF}_2(\text{CH}_3)_3 > \text{PF}_2(\text{CF}_3)_3$

5. Compare O – O Bond Length in H_2O_2 and O_2F_2

Ans. $\text{H}_2\text{O}_2 > \text{O}_2\text{F}_2$.

6. Compare N – N Bond Length in

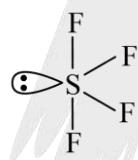
Ans. (a) $\text{N}_2\text{H}_4 > \text{N}_2\text{F}_4$ (b) $\text{N}_2\text{H}_2 > \text{N}_2\text{F}_4$

7. Compare $F_{\text{eq}} - \hat{S} - F_{\text{eq}}$ in SF_4 and SOF_4

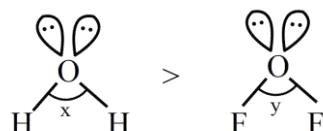
Ans. $\text{SF}_4 > \text{SOF}_4$

• **Shape of SF_4 molecule**

- | | | |
|-----------------------|-----------------|------------------|
| 1. See saw | 2. Sawhorse | 3. Teeter totter |
| 4. Squash tetrahedral | 5. Disphenoidal | |



8. Compare x and y



Exception of bent's Rule:

Order of Bond Angle: $\text{H}_2\text{O} < \text{OCl}_2$ (110.8°)

$\text{H}_2\text{O} < \text{OBr}_2$ (111°)

$\text{H}_2\text{O} < \text{OI}_2$ (112°)

(Inorganic Chemistry)

9. Compare C-F bond length in

Ans. $\text{CH}_4 < \text{CHF}_3 < \text{CH}_2\text{F}_2 < \text{CH}_3\text{F}$

10. Compare O-F bond length in

Ans. $\text{O}_2\text{F}_2 > \text{OF}_2$

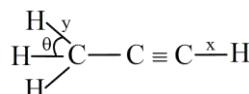
11. Which of the following is correct regarding H_2CSF_4 ?

(A) $\text{H} - \hat{\text{C}} - \text{H} < \text{F}_{\text{eq}} - \hat{\text{S}} - \text{F}_{\text{eq}}$ (B) $\text{H} - \hat{\text{C}} - \text{H} > \text{F}_{\text{eq}} - \hat{\text{S}} - \text{F}_{\text{eq}}$

(C) Nodal plane of π -bond present in axial plane (D) Maximum 6 atoms in one plane.

Ans. (B, C, D)

12. Select the correct statement for given compound :



(A) $\theta > 109$

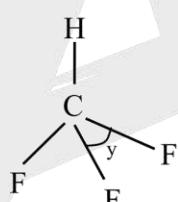
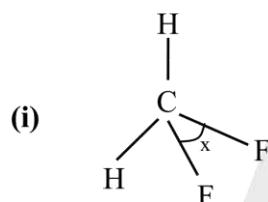
(B) $\theta < 109$

(C) $\theta = 109$

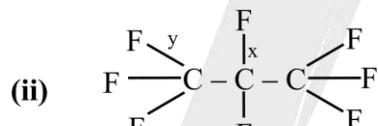
(D) Data is insufficient

Ans. (B)

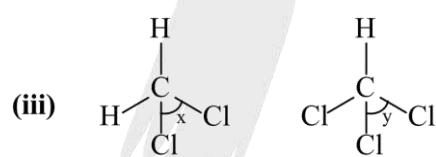
13. Compare x and y.



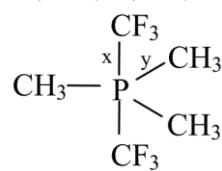
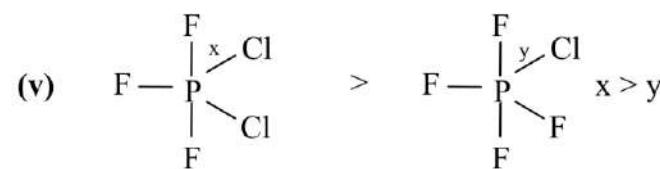
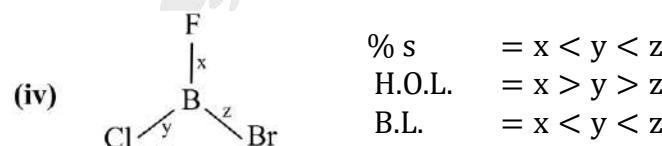
Ans. $x < y$

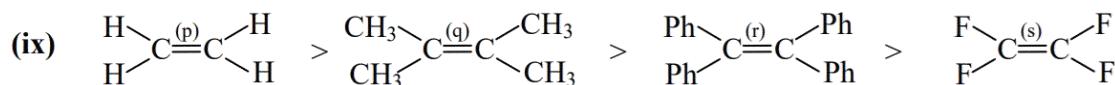
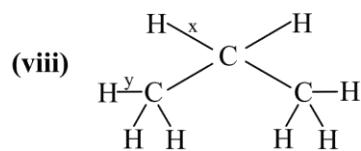
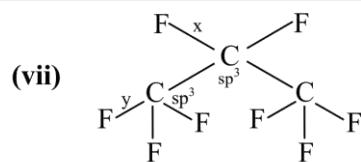


Ans. $x > y$

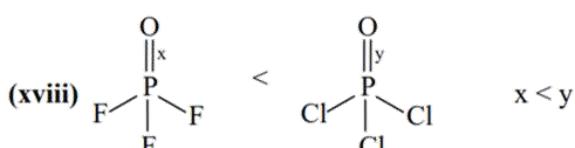
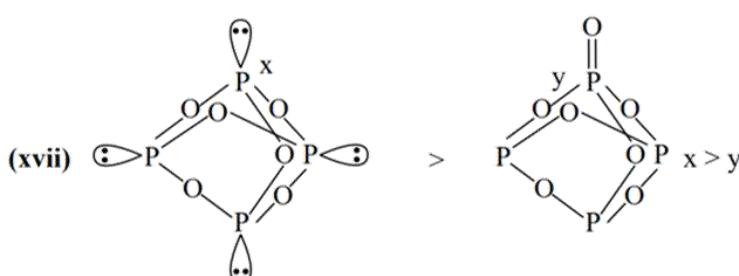
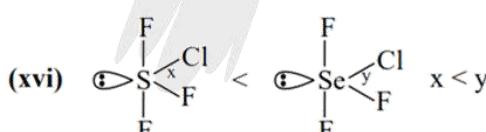
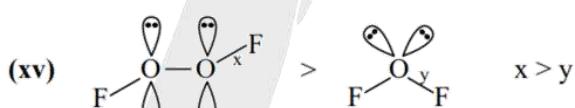
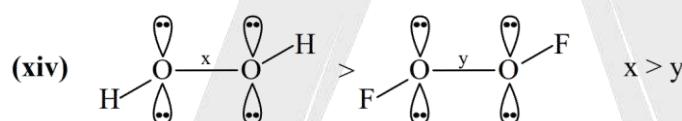
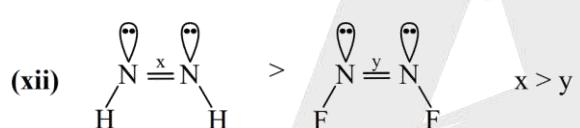
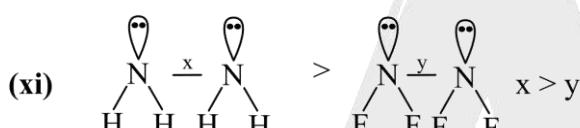


Ans. $x > y$ (Steric Repulsion)

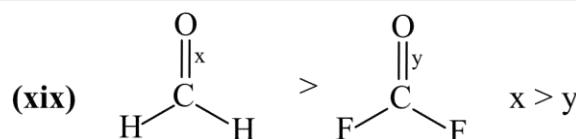




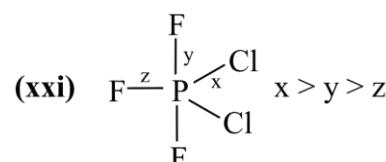
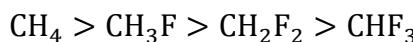
$p > q > r > s$



(Inorganic Chemistry)



(xx) Compar CH bond length in CH_4 , CH_3F , CH_2F_2 , CHF_3



DRAGO'S RULE

- On the basis of experimental bond angles of certain molecules fulfilling the following three conditions,
- (i) Central atom belongs to third or lower period in periodic table
- (ii) Central atom must contain atleast one lone pair of electron
- (iii) Electronegativity of surrounding atom is < 2.5
- Drago generalised that in such molecules justification of experimental bond angle can be made satisfactory if one considers no hybridisation, i.e., overlapping of almost pure atomic orbitals from central atom.
- In such molecules bond angle is approximately 90° .

Group 15	Bond angle	Group 16	Bond angle
NH_3	$107^\circ 48'$	H_2O	$104^\circ 28'$
PH_3	$93^\circ 36'$	H_2S	92°
AsH_3	$91^\circ 48'$	H_2Se	91°
SbH_3	$91^\circ 18'$	H_2Te	90.5°

- Right order of bond angle.

- (a) $\text{H}_2\text{O} > \text{H}_2\text{S} > \text{H}_2\text{Se} > \text{H}_2\text{Te}$
 (b) $\text{NH}_3 > \text{PH}_3 > \text{AsH}_3 > \text{SbH}_3$

Ex: PH_3

Explanation :

$\because 600 \text{ kJ/mole}$ (energy required for hybridization) $> 3 \text{ P-H bond energy}$

Hence, hybridisation does not occur in PH_3 .

Ex: PH_4^+

Explanation:

sp^3 hybridisation.

Hybridisation occurs because 600 kJ/mole (energy required for hybridization) $< 4 \text{ P-H bond energy}$.

Other example is SiH_4

Ex: P₄

Explanation:

No hybridisation because central atom belongs to third period and Electronegativity of surrounding atom less than 2.5 .

Que. What is the % of p character in P_4 ?

Ans. (B)

Ex: $\text{P}(\text{SiH}_3)_3$ (Tri silyl phosphine)

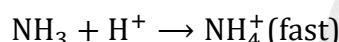
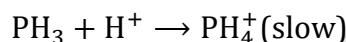
Explanation:

No hybridisation

Geometry : Pyramidal

- **Effect on properties:**

- (a) Formation of NH_4^+ or PH_4^+



- (b) Solubility in water : $\text{NH}_3 > \text{PH}_3$



Que. Compare bond angle

- (A) $\text{PF}_3 < \text{PCl}_3$ (B) $\text{PF}_3 > \text{PH}_3$ (C) $\text{BF}_3 < \text{BCl}_3$ (D) All of these

Ans. (A, B)

Some important order :

- | | | | | | | | |
|--|-----------------|---|-----------------|---|------------------|---|-------------------------------------|
| • % of s character in orbital of lone pair | NH ₃ | < | PH ₃ | < | AsH ₃ | < | SbH ₃ |
| • % of p character in NH bond | NH ₃ | < | PH ₃ | < | AsH ₃ | < | SbH ₃ |
| • M – H bond length
(M = N, P, As, Sb) | NH ₃ | < | PH ₃ | < | AsH ₃ | < | SbH ₃ |
| • Bond angle | NH ₃ | > | PH ₃ | > | AsH ₃ | > | AsH ₃ > SbH ₃ |
| • Bond energy | NH ₃ | > | PH ₃ | > | AsH ₃ | > | AsH ₃ > SbH ₃ |
| • Thermal stability | NH ₃ | > | PH ₃ | > | SbH ₃ | | |
| • Acidic strength | NH ₃ | < | PH ₃ | < | AsH ₃ | | |
| • Lewis basic strength | NH ₃ | > | PH ₃ | > | AsH ₃ | > | SbH ₃ |
| • Reducing nature | NH ₃ | < | PH ₃ | < | AsH ₃ | < | SbH ₃ |
| • Order of solubility in water : | NH ₃ | > | PH ₃ | | | | |

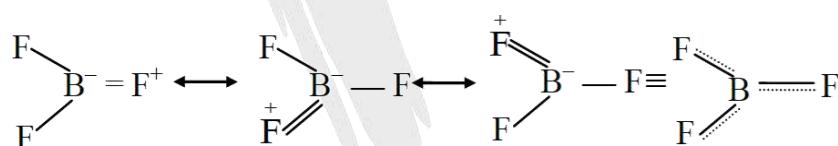
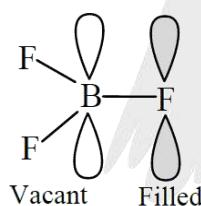
DO YOURSELF - 2

- Q.1** Which of the following has greater bond length?
 (A) P – O (B) S – O (C) Cl – O (D) O = O
- Q.2** The percentage of p-character in the orbital forming P-P bonds in P_4 is -
 (A) 25 (B) 33 (C) 50 (D) 75
- Q.3** Which one of the following has the highest bond angle -
 (A) H_2O (B) H_2S (C) NH_3 (D) PH_3
- Q.4** 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_3
- Q.5** What can not be explained by VBT -
 (A) Overlapping (B) Bond formation
 (C) Paramagnetic nature of oxygen (D) Shapes of molecules.

ELECTRON DEFICIENT BONDING**(1) BACK BONDING**

Back bonding generally takes place when out of two bonded atoms one of the atom has vacant orbitals (generally this atom is from second or third period) and the other bonded atom is having some non-bonded electron pair (generally this atom is from the second period). Back bonding increases the bond strength and decreases the bond length.

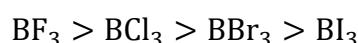
For example, in BF_3 the boron atom completes its octet by accepting 2p-electrons of fluorine into 2p empty orbital.



2p-orbital 2p-orbital

Decrease in $B - F$ bond length is due to delocalised $p\pi - p\pi$ back bonding between filled p-orbital of F atom and vacant p-orbital of B atom.

The extent of back bonding is much larger if the orbitals involved in the back bonding are of same size, for example the extent of back bonding in boron trihalides is as follows :

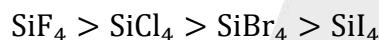
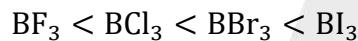


There is $p\pi - p\pi$ back bonding in boron trihalide. The extent of back bonding decreases from BF_3 to BI_3 because of increasing size of p-orbitals participating in back bonding that is from 2p (in F) to 5p (in I).

Molecules	Type of back bonding	Shape
BF_3	$2\text{p}_\pi - 2\text{p}_\pi$	planar
$\text{N}(\text{CH}_3)_3$	no back bonding	pyramidal
$\text{N}(\text{SiH}_3)_3$	$2\text{p}_\pi - 3\text{d}_\pi$	planar
$\text{P}(\text{SiH}_3)_3$	No back bonding	pyramidal
CH_3NCS	No back bonding	bent
SiH_3NCS	$2\text{p}_\pi - 3\text{d}_\pi$	linear
$\text{N}(\text{GiH}_3)_3$	$2\text{p}_\pi - 4\text{d}_\pi$	planar
GiH_3NCS	No back bonding	bent

- **Lewis Basic Order:** $\text{N}(\text{CH}_3)_3 > \text{P}(\text{SiH}_3)_3 > \text{N}(\text{SiH}_3)_3$

- **Lewis Acid Order:**



- **Carbene:**

Triplet Carbene-: CH_2 (Multiplicity = 3)

Singlet Carbene-: CH_2 (Multiplicity = 1)

Triplet carbene is more stable than singlet carbene.

- **Dichlorocarbene- : CCl_2^-**

Singlet dichlorocarbene is more stable than triplet dichlorocarbene.

Que. Which is better proton donor acid- Between $(\text{CH}_3)_3 - \text{C} - \text{OH}$ & $(\text{CH}_3)_3 - \text{Si} - \text{OH}$?

Ans. $(\text{CH}_3)_3 - \text{Si} - \text{OH}$, because $(\text{CH}_3)_3 - \text{Si} - \text{O}^-$ is stabilized by $2\text{p}_\pi - 3\text{d}_\pi$ back bonding.

Que. Which is better proton donor acid between CHF_3 and CHCl_3 ?

Ans. CHCl_3 , because CCl_3^- is stabilized by $2\text{p}_\pi - 3\text{d}_\pi$ back bonding.

- **Effect of Back Bonding:**

a. Bond Length must be decrease.

b. Bond angle may be change

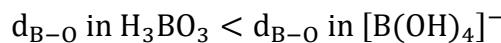
c. Hybridization may be change

- When lone pair of central atom involved in back bonding, bond angle increases.

- When lone pair of surrounding atom involved in back bonding, bond angle increases due to bond pair- bond pair repulsion.

(Inorganic Chemistry)

- Comparison of Bond Length:**



Hint:- No back bonding involved in $[B(OH)_4]^-$ and BF_4^-

➤ **Some Important Order:**

- Extent of Back Bonding:** $OCl_2 < O(SiH_3)_2$

- Lewis Basic Nature:** $NCl_3 > NF_3$

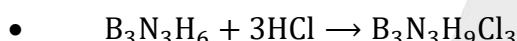
No back bonding in NCl_3 due to its explosive nature.

- Order of Bond Angle:** $x < y < z$

where $x = \angle BOH$ in $B(OH)_3$, $y = \angle BOC$ in $B(OCH_3)_3$ and $z = \angle BOS$ in $B(OSiH_3)_3$

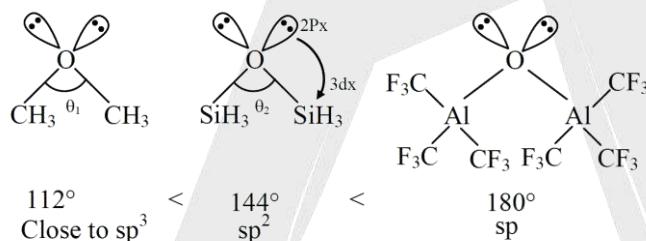
- Metaboric Acid (HBO_2):** $HBO_2 \rightarrow (BO_2^-)_n$

$B_3O_6^-$ is aromatic, planer, O and B are sp^2 Hybridized

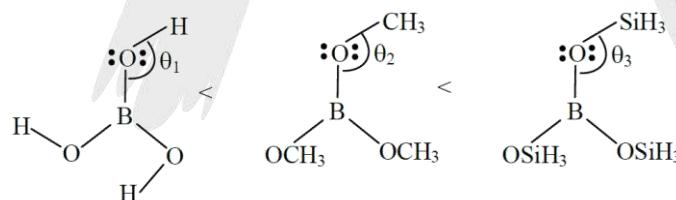


$2p_\pi - 2p_\pi$ back bonding involved in $(BN)_x$

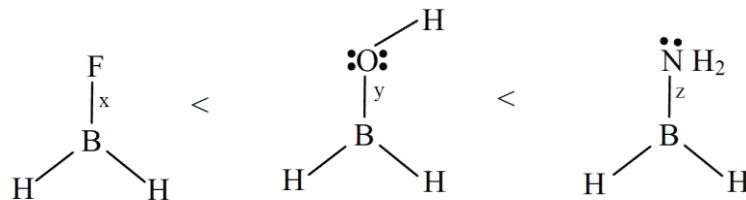
Q. Order of bond angle



Q. Order of bond angle :-

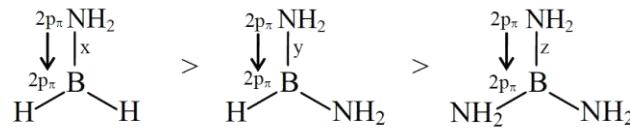


Q. Order of Strength Back Bonding :



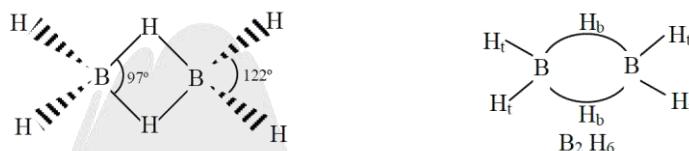
Q. Order of Strength Back Bonding :

➤ Number of donor atom \downarrow strength back bonding \uparrow



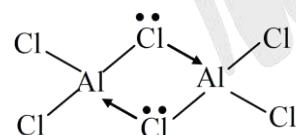
(2) BRIDGE BONDING

There are many compounds in which some electron deficient bonds are present apart from normal covalent bonds or coordinate bonds which are $2c - 2e^-$ bonds (two centre two electron bonds). These electron deficient bonds have less number of electrons than the expected such as three centre-two electron bonds ($3c - 2e$) which are present in diborane B_2H_6 , $Al_2(CH_3)_6$, $BeH_2(s)$ etc.



The structure of diborane containing four terminal (t) and two bridging(b) hydrogen atoms. The model determined by molecular orbital theory indicates that the bonds between boron and the terminal hydrogen atoms are conventional $2c - 2e^-$ covalent bonds. The bonding between the boron atoms and the bridging hydrogen atoms is, however different from that in molecules such as hydrocarbons. Having used two electrons in bonding to the terminal hydrogen atoms, each boron has one valence electron remaining for additional bonding. The bridging hydrogen atoms provide one electron each. Thus the B_2H_2 ring is held together by four electrons, an example of $3c - 2e^-$ bonding. This type of bond is sometimes called as '**banana bond**'. Group 13, gallium is known to form a similar compound, digallane, Ga_2H_6 .

But Al_2Cl_6 have covalent bond only and there is no electron deficient bonding as depicted in the given structure.



(Bridging $Al - Cl - Al$ is $3c - 4e$ bond)

➤ Keypoints:

- **Two Types:** (i) $3c - 4e$ bond (surrounding atom has lone pair)
(ii) $3c - 2e^-$ bond (surrounding atom has no lone pair)
- $3c - 4e^-$ bond remove more deficiency as compared to $3c - 2e^-$.
- Vacant orbital takes part in hybridisation.

(Inorganic Chemistry)

(A) Al_2Cl_6 :**Information:-**

- Number of $3c - 2e^-$ bond = 2,
- Number of $2c - 2e^-$ bond = 4
- Hybridisation of central atom = sp^3
- Octet complete

(B) I_2Cl_6 :**Information:-**

- Planarity:- planar
- Hybridisation of central atom = $\text{sp}^3 \text{d}^2$
- Maximum number of atom in a plane = 8
- Number of $3c - 2e^-$ bond = 2,
- Number of $2c - 2e^-$ bond = 4
- Octet complete

(C) B_2H_6 :**Information:-**

- Planarity:- Non- planar
- Maximum number of atom in a plane = 6
- Octet: incomplete, Lewis Acid
- $3c - 2e^-$ bond = 2
- $2c - 2e^-$ bond = 4
- Bridge bonds are stronger and longer than the terminal bonds.
- 2 bridging ' H ' are perpendicular to the plane.

(D) $\text{Al}_2(\text{CH}_3)_6$:**Information:-**

- Hybridisation of central atom = sp^3
- Planarity:- non- planar
- Number of $3c - 2e^-$ bond = 2
- Number of $2c - 2e^-$ bond = 22
- Maximum number of atoms in one plane = 10

(E) Be_2Cl_4 **Information:-**

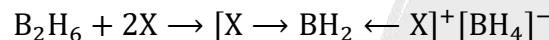
- Hybridisation of central atom = sp^2

(Inorganic Chemistry)

- Planarity:-Planar (all atoms are in one plane)
- e⁻ Deficient
- Number of 3c – 4e⁻bond = 2
- Number of 2c – 2e⁻bond = 2

(F) Be₂H₄:**Information:-**

- Hybridisation of central atom = sp³
- Planarity:-Non- Planar

Borane:**(a) NidoBorane:** B_nH_{n+4} **Ex:** B₂H₆ (di borane), B₃H₇ (tri borane)**(b) ArachnoBorane:** B_nH_{n+6} **Ex:** B₂H₈ (di borane - 8), B₃H₉ (tri borane - 9)**DO YOURSELF - 3****Q.1** N(SiH₃)₃ has -

- (A) sp³ hybridisation, pyramidal shape
 (B) sp² hybridisation, planar shape
 (C) sp³ hybridisation, tetrahedral shape
 (D) dsp² hybridisation, square planar shape

Q.2 Correct statement regarding this reaction

- (A) Hybridisation of N is changed
 (B) Hybridisation of B is changed
 (C) NH₃ act as a lewis base
 (D) (B) & (C) both

Q.3 Shape of N(CH₃)₃ is

- (A) pyramidal (B) Linear (C) Tetrahedral (D) None of these

Q.4 Which of the following molecule is stable by back bonding

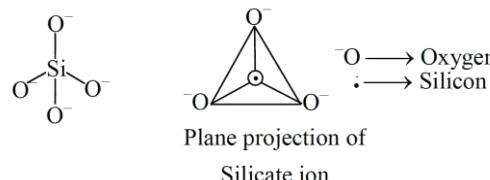
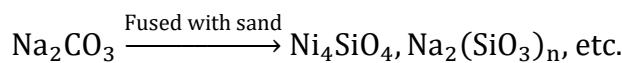
- (A) AlCl₃ (B) AlH₃ (C) BCl₃ (D) ICl₃

Q.5 Which of the following represents (3C – 4e⁻)Bridge bonding

- (A) Al₂Cl₆ (B) BH₃ (C) B₂H₆ (D) none of these

SILICATES

- Silicates are metal derivatives of silicic acid, H_4SiO_4 or $Si(OH)_4$. Silicates are formed by heating metal oxide or metal carbonates with sand, e.g.



- Silicates have basic unit of SiO_4^{4-} , each silicon atom is bonded with four oxide ions tetrahedrally.
- There are following types of silicates

Silicates	Sharing of O – atom / Basic Tetrahedral unit	Contribution of O – atom/Basic Tetrahedral unit	General formula
Ortho (neso)	0	4	SiO_4^{4-}
Pyro (closo)	1	3.5	$Si_2O_7^{6-}$
Cyclic (cyclo)	2	3	$(SiO_3)_n^{2n-} (n = \text{finite})$
Simple chain (pyroxene)	2	3	$(SiO_3)_n^{2n-} (n = \text{infinite})$
Double chain (amphibole)	(3,2) avg. = 2.5	$\frac{11}{4} = \left(\frac{5.5}{2}\right)$	$(Si_4O_{11})_n^{6n-}$
2D or (sheet or phyllo)	3	2.5	$(Si_2O_5)_n^{2n-}$
3D (tecto)	4	2	$(SiO_2)_n$

ODD ELECTRON MOLECULES

- If number of electron present in molecule are in odd number.
- **Example:-** Odd electron molecule NO_2 ClO_3 OF O_2^- ClO_2
Number of electron 23 41 17 17 33
- **Information:**
 - (i) All odd electron molecules are paramagnetic in nature.
 - (ii) Odd Electron bond formation tendency increases then dimerization tendency decreases.

(Inorganic Chemistry)

- (iii) Bond Order of odd electron molecule is 0.5.
- (iv) Bond Order of simple covalent bond is 1.
- (v) All odd electron molecules are free radicals
- (vi) Odd Electron Bond act as a σ as well as π bond
- Examples: NO , O_2^- , ClO_2 (Odd electron act as π bond)
 N_2^+ , Li_2^+ , Na_2^+ , (Odd electron acts as σ bond)

• **Hybridisation of odd electron molecule:**

According to fact orbital having odd electron present at high energy level so it doesn't involve in hybridisation but if surrounding atom is more electronegative than central atom, then it develops partial positive charge on central atom so orbital contracts towards central atom and involve in hybridisation.

Odd Electron Molecule	Hybridisation of central atom	odd electron present in	formation of dimer
NO_2	sp^2	sp^2 hybrid orbital	Yes
ClO_3	sp^3	sp^3 hybrid orbital	Yes
CH_3	sp^2	p- orbital	Yes
CF_3	sp^3	sp^3 hybrid orbital	Yes
ClO_2	sp^2	3 d- orbital	No

- Bond order of Cl – O bond in ClO_2 is 1.75.

➤ **Structure of odd e⁻ molecules**

- (1) NO_2 Structure:-
- (2) ClO_2 Structure:-
- (3) ClO_3 Structure:-
- (4) CH_3 Structure:-
- (5) CF_3 Structure:-

Q. Which of the following statements is correct for ClO_2

$$\text{Hybridisation} = \text{sp}^2$$

Orbital of odd e⁻ = d

Resonance present

Number of R.S. = 2

D orbital is involved in resonance bond order = 1.75

(Inorganic Chemistry)

$$1 + \frac{\pi}{6} = 1.5 + 0.25$$

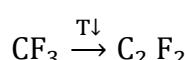
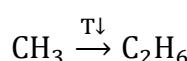
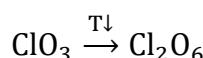
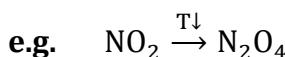
Explosive in nature

Cl_2O_4 is not a dimer of ClO_2 actually it is a combination of $\text{Cl}_2\text{O}_4 \rightarrow \text{Cl}^+ + \text{ClO}_4^-$

Key point :-

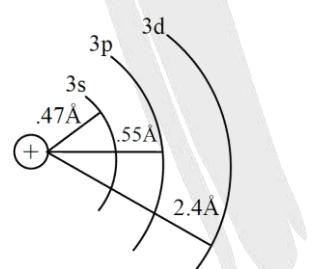
Species	Type of orbital (odd e')
NO_2	sp^2
CF_3	sp^3
ClO_3	sp^3
CH_3	Pure 'P'
ClO_2	d-orbital

→ Species in which odd e^- bond is absent forms strong dimer



MOLECULES DO NOT EXIST

1. Due to d-orbital contraction:



High energy difference

Ex. $\text{PH}_5, \text{SH}_4, \text{SH}_6, \text{XeH}_2, \text{XeH}_4, \text{ClI}_3, (\text{SiH}_6)^{-2}$

Do not exist

- PH_5
- SH_6
- SH_4
- XeH_2
- XeH_4
- XeO_2H_4
- XeO_2H_2
- XeH_6
- XeH_5^+
- XeH_5^-

Exist

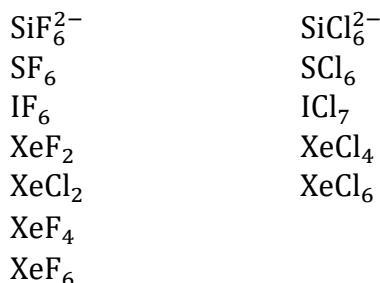
- PF_5
- SF_6
- SF_4
- XeF_2
- XeF_4
- XeO_2F_4
- XeO_2F_2
- XeF_6
- XeF_5^+
- XeF_5^-



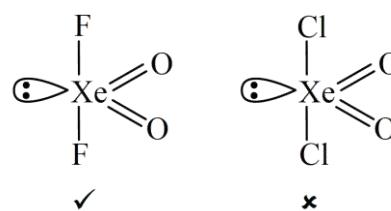
2. Due to steric repulsion:

Ex. BCl_4^- , B_2Cl_6 , B_2Br_6 , B_2I_6 , B_2F_6 , SCl_6 , SBr_6 , SI_6 , ICl_7 , ClI_7 , $[\text{SiCl}_6]^{-2}$

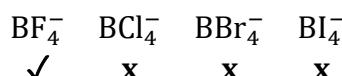
Do not exist



Exist

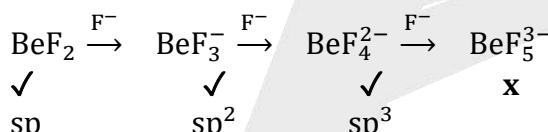


PCl_6^- is possible but PBr_6^- does not exist PBr_2 (cembinate of $\text{PBr}_4^- + \text{PBr}_3^-$) possible but PI_2 does not exit

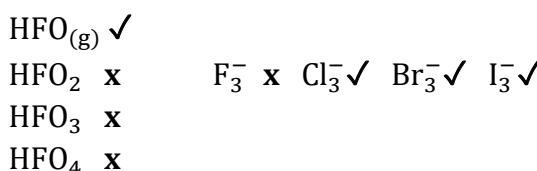
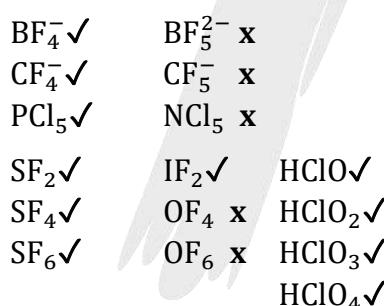


3. Due to absence of vacant orbital

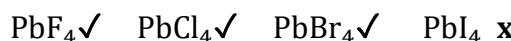
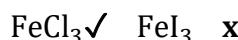
BeF_2 , BeF_3^- , BeF_4^{2-} are possible while BeF_5^{3-} due to absence of vacant orbital.



Other example :



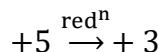
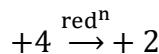
4. Due to reducing nature



Reason :- down the group size of halide increases, reducing nature increases.

(Inorganic Chemistry)

- I⁻ strong reducing nature as compared to F⁻, Cl⁻ and Br⁻ Order of stability



BeF₅ is possible

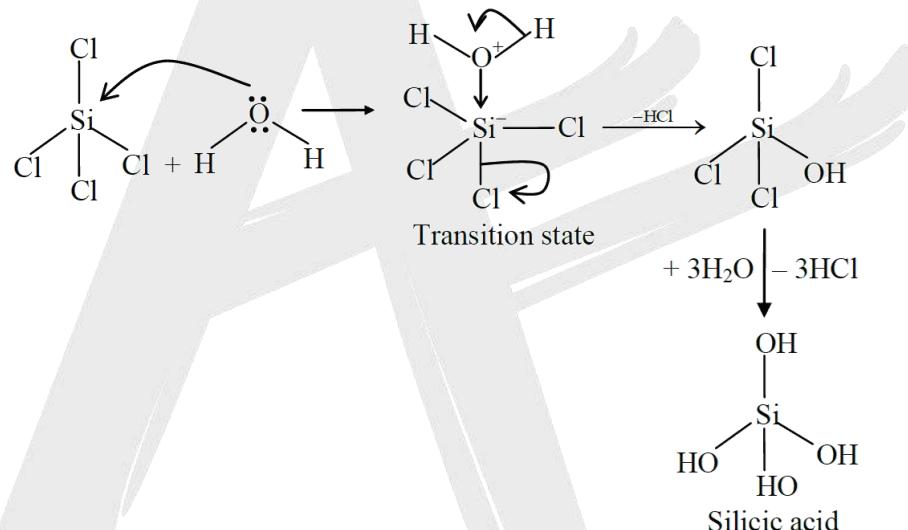
but BiCl₅, BiBr₅, BiI₅ does not exist

Because BiF₅ is strong O.A. as compared to other.

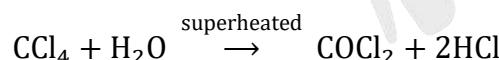
HYDROLYSIS

In hydrolysis of covalent molecules the nucleophilic centre of molecule is replaced by OH⁻ group of water generally through nucleophilic substitution reaction.

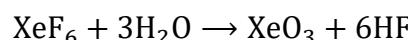
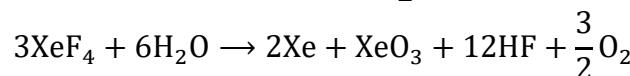
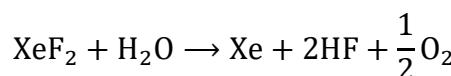
Ex. Hydrolysis of SiCl₄



Note: CCl₄, NF₃, is inert towards hydrolysis due to the absence of d orbital, but under drastic condition these molecules undergo hydrolysis.



Note: Hydrolysis of XeF₂ & XeF₄ takes place through redox reaction.



- Condition for SN²:

- One bonded atom is positively charged (for interaction with water)
- The same atom must have vacant orbital for taking lone pair of water.
- There should not be any steric hindrance. (SF₆ don't hydrolyse due to this reason)

(Inorganic Chemistry)

Ex: $\text{CCl}_4 + \text{H}_2\text{O} \rightarrow$ No hydrolysis due to absence of vacant d-orbital (possible through SN^1 mechanism)

Ex: $\text{SiCl}_4 + 4\text{H}_2\text{O} \rightarrow \text{Si(OH)}_4 + 4\text{HCl}$

- **Explanation:**

(i) Product is oxyacid as well as hydracids.

(ii) Hybridisation of reactant is sp^3 but that of transition state is sp^3 d.

(iii) Generally the oxyacid form of central atom and same oxidation state.

(iv) Generally the hydracid form by surrounding atom.

- **Solved Example:**

Ex: $\text{NCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{NH}_3 + 3\text{HOCl}$

- **Explanation:**

(i) Product is base and oxyacid.

(ii) Hybridisation of central atom doesn't change in transition state.

(iii) Electronegativity of nitrogen and chlorine is almost equal.

Ex: $\text{PCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_3 + 3\text{HCl}$

Note: Basicity of $\text{H}_3\text{PO}_3 = 2$

- **Explanation:** Condition for proton transfer

(i) Central atom should have lone pair.

(ii) Should have acidic hydrogen ($\text{O} - \text{H}$)

(iii) $\text{P} = \text{O} \gg \text{P} - \text{O}$ (π -bond should be

(a) $2\text{p}_\pi - 2\text{p}_\pi$,

(b) $2\text{p}_\pi - 3\text{p}_\pi$

(c) $2\text{p}_\pi - 3\text{d}_\pi$)

Ex: $\text{AsCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{As(OH)}_3 + 3\text{HCl}$

Note: Basicity of $\text{H}_3\text{AsO}_3 = 3$

Q.1. Compare rate of hydrolysis?

- (i) (A) MgCl_2 (B) AlCl_3 (C) CCl_4 (D) SiCl_4 (E) PCl_5

Ans. Correct order $\text{CCl}_4 < \text{MgCl}_2 < \text{AlCl}_3 < \text{SiCl}_4 < \text{PCl}_5$

- (ii) (A) SnCl_2 (B) SnCl_4

Ans. $\text{SnCl}_2 < \text{SnCl}_4$

- (iii) (A) SnCl_4 (B) SnMe_4

Ans. $\text{SnCl}_4 > \text{SnMe}_4$

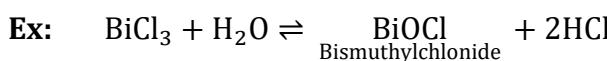
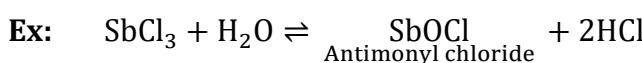
Rate of hydrolysis order

$\text{PCl}_3 > \text{AsCl}_3 > \text{SbCl}_3 > \text{BiCl}_3$
--

(Inorganic Chemistry)

- **Note:**

- (i)** BeX₂ – Predominantly covalent (X = F, Cl, Br, I)
 - (ii)** MgX₂ - Predominantly covalent (X = Cl, Br, I)
 - (iii)** AlX₃ – Predominantly covalent (X = Cl, Br, I)
 - (iv)** LiF/MgF₂/AlF₃ – Predominantly ionic



NOTE: On adding acid, equation shifts backward and turbidity disappears

To distinguish between SbO^+ and BiO^+ , we add tartaric acid. Turbidity of SbO^+ disappears but not of BiO^+ this is used to distinguish between the two.

Que. Which of the following ions are present in BiOCl ?

- (A) Bi^+ (B) BiO^+ (C) OCl^- (D) Cl^-

Ans. (B, D)

- **Remember:**

Parent Oxyacid of following atoms:

- (a)** P → (i) H_3PO_3 (ii) H_3PO_4

(b) S → (i) H_2SO_3 (ii) H_2SO_4

(c) N → (i) HNO_2 (ii) HNO_3

(d) Cl → (i) HClO (ii) HClO_2 (iii) HClO_3 (iv) HClO_4

(e) Se → H_2SeO_4 , Te → H_6TeO_6 , B → H_3BO_3 , Si → H_4SiO_4

Que. Identify the product obtained on hydrolysis?

Sol. (i) $\text{Cl}_2\text{O} + \text{H}_2\text{O} \rightarrow \text{HClO}$

(ii) $\text{SF}_4 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3 + \text{HF}$

(iii) $\text{SO}_2\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 + \text{HCl}$

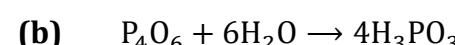
(iv) $\text{N}_2\text{O}_3 + \text{H}_2\text{O} \rightarrow \text{HNO}_2$

(v) $\text{N}_2\text{O}_5 + \text{H}_2\text{O} \rightarrow \text{HNO}_3$

(vi) $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3$

(vii) $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$

- Addition and addition elimination reaction;

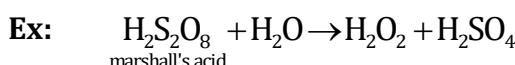




(Inorganic Chemistry)

Que. Identify the product obtained on hydrolysis?

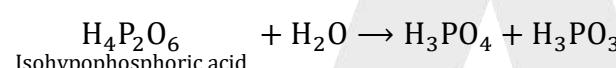
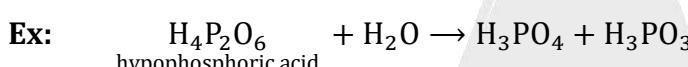
- Sol.**
- (i) $\text{P}_4\text{O}_{10} + \text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4$
 - (ii) $\text{P}_4\text{O}_9 + \text{H}_2\text{O} \rightarrow 3\text{H}_3\text{PO}_4 + \text{H}_3\text{PO}_3$
 - (iii) $\text{P}_4\text{O}_8 + \text{H}_2\text{O} \rightarrow 2\text{H}_3\text{PO}_4 + 2\text{H}_3\text{PO}_3$
 - (iv) $\text{P}_4\text{O}_7 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4 + 3\text{H}_3\text{PO}_3$
 - (v) $\text{P}_4\text{O}_6 + \text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_3$



(i) Partial hydrolysis of $\text{H}_2\text{S}_2\text{O}_8$



(ii) Complete hydrolysis of $\text{H}_2\text{S}_2\text{O}_8$



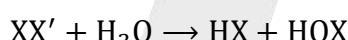
Note: Product obtained after hydrolysis of both given compound is same.

- **Important**

Hydrolysis of Interhalogen compound

- (i) $\text{ICl} + \text{H}_2\text{O} \rightarrow \text{HOI} + \text{HCl}$
- (ii) $\text{IF}_3 + \text{H}_2\text{O} \rightarrow \text{HIO}_2 + 3\text{HF}$
- (iii) $\text{BrF}_5 + \text{H}_2\text{O} \rightarrow \text{HBrO}_3 + 5\text{HF}$
- (iv) $\text{IF}_7 + \text{H}_2\text{O} \rightarrow \text{HIO}_4 + 7\text{HF}$

Que. Which of the following statement is correct about X and X'?



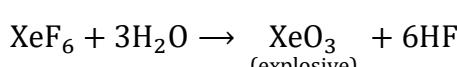
- (A) X is more electronegative than X' (B) X' has larger size than X
 (C) Both (A) and (B) (D) None of these

Ans. (C)

- **Important**

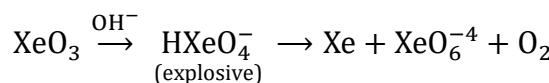
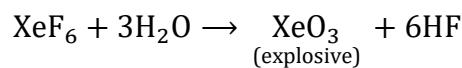
Hydrolysis of noble gases compound

- (i) $\text{XeF}_2 + \text{H}_2\text{O} \rightarrow \text{Xe} + \text{O}_2 + \text{HF}$
- (ii) $6\text{XeF}_4 + 12\text{H}_2\text{O} \rightarrow 4\text{Xe} + 2\text{XeO}_3 + 24\text{HF} + 3\text{O}_2$
- (iii) Hydrolysis of XeF_6



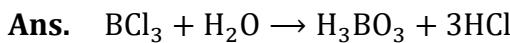
- (iv) Alkaline hydrolysis of XeF_6

(Inorganic Chemistry)

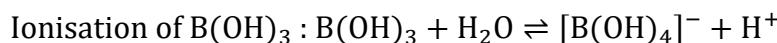


Two gaseous product Xe and O₂ are obtained during alkaline hydrolysis.

Que. Hydrolysis of BCl₃



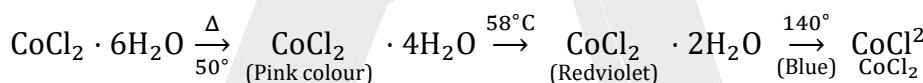
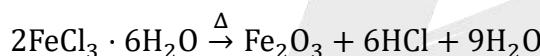
Product of hydrolysis of BCl₃ is H₃BO₃ and HCl.



- **Hydrolysis of Carbide:**

- (i) Be₂C + H₂O → Be(OH)₂ + CH₄
- (ii) Al₄C₃ + H₂O → Al(OH)₃ + CH₄
- (iii) CaC₂ + H₂O → Ca(OH)₂ + C₂H₂
- (iv) BaC₂ + H₂O → Ba(OH)₂ + C₂H₂
- (v) Mg₂C₃ + H₂O → Mg(OH)₂ + C₃H₄

- **Other example of hydrolysis on heating:**



- **Sulphide:**

- (i) MgS + H₂O → hydrolysed BaS = Soluble
- (ii) M₂S + H₂O → x
(where M = Alkali metal)

Note: Sulphide does not hydrolysed, they are soluble in water.

- (iii) Exception:

- (a) Al⁺³ + S⁻² $\xrightarrow{\text{H}_2\text{O}}$ Al₂S₃ → Al(OH)₃ + H₂S (white ppt)
- (b) Cr⁺³ + S⁻² $\xrightarrow{\text{H}_2\text{O}}$ Cr₂S₃ → Cr(OH)₃ + H₂S (green ppt)
- (c) Mg⁺² + S⁻² $\xrightarrow{\text{H}_2\text{O}}$ MgS → Mg(OH)₂ + H₂S (white ppt)

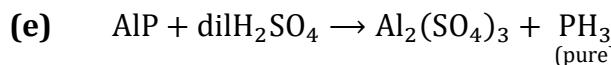
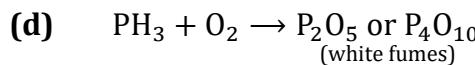
➤ **Phosphides:**

- (a) M₃P + H₂O → MOH + PH₃ (M = alkali metals)
- (b) M₃P₂ + H₂O → M(OH)₂ + PH₃ (M = alkaline earth metals)
- (c) Ca₃P₂ + H₂O → Ca(OH)₂ + PH₃

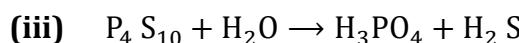
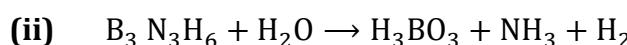
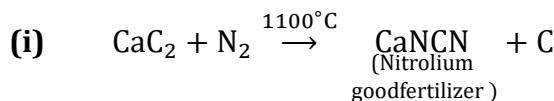
(Inorganic Chemistry)

Note: Ca_3P_2 and CaC_2 mixture used as Holme's signal.

Impure PH_3 is inflammable due to impurities.

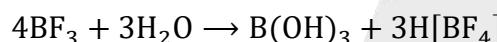


- **Important**



Note: P_4O_{10} and P_4S_{10} are isostructural

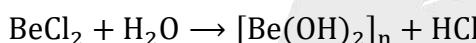
(vi) BF_3 undergoes partial hydrolysis



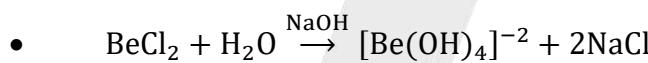
(v) SiF_4 undergoes partial hydrolysis.



(vi) Hydrolysis of BeCl_2



- **Alkaline hydrolysis of BeCl_2**

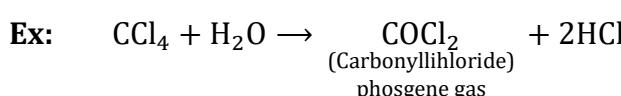
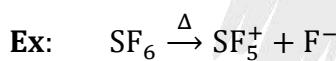


(vii) Rate of hydrolysis

Order : $\text{SF}_6 < \text{SeF}_6 < \text{TeF}_6$

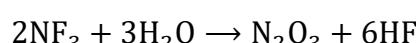
Conclusion : Size \uparrow , steric crowding \downarrow , rate of hydrolysis \uparrow

- SN^1 / Drastic condition



Note: CCl_4 is a fire extinguisher but it is not used as fire extinguisher at high temperature because it forms COCl_2

Ex: Hydrolysis of NF_3 by SN^1 mechanism:

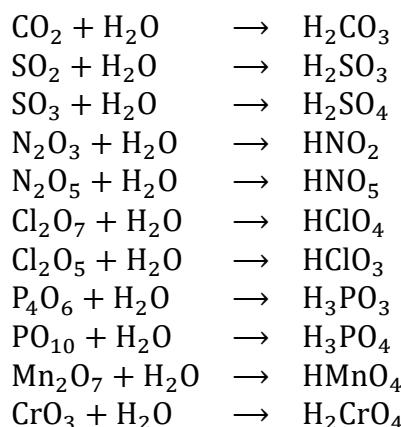


Note: Via SN^1 , hydrolysis of SF_6 , CCl_4 , NF_3 Can be done.

(Inorganic Chemistry)

- Other example

Hydrolysis of oxide



An example of disproportionation reaction requires bond combination of group number & oxidation state must be in odd & even.

(1) AX type

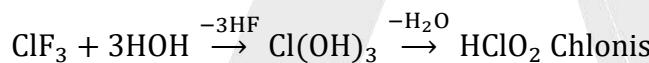


Halous HXO_2

Halic HXO_3

Per halic HXO_4

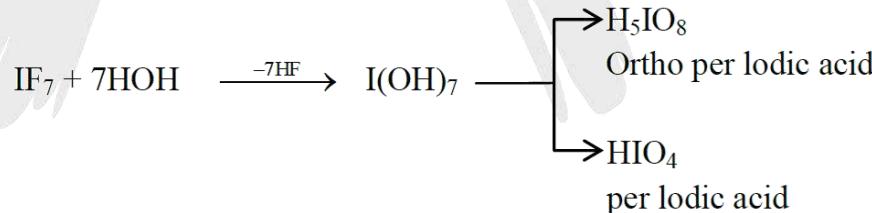
(2) AX_3 type



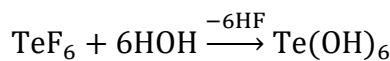
(3) AX_5 type



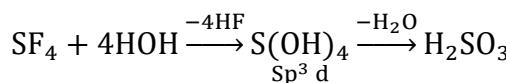
(4) AX_7 type



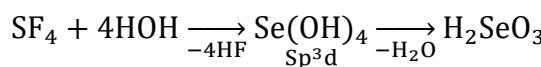
➤ **Hydrolysis of TeF_6**



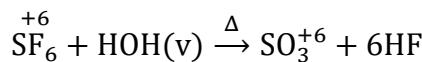
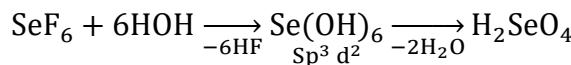
➤ **Hydrolysis of SF_4**



➤ **Hydrolysis of SeF_4**



(Inorganic Chemistry)

➤ **Hydrolysis of SF₆**➤ **Hydrolysis of SeF₆**• **Some common name :**

KHSO ₅	Na ₂ O ₂	(H ₂ SO ₄)
Oxone	solozone	oil of vitrol

Or

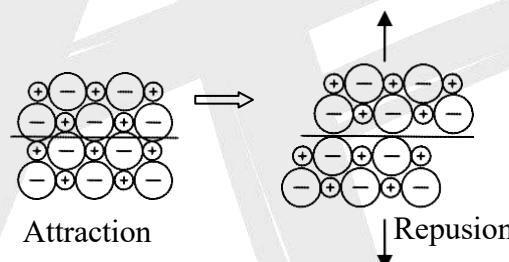
Flocool

IONIC COMPOUNDS

➤ **Properties of ionic compound****(a) Physical state:**

Ionic compounds are hard, crystalline and brittle due to strong electrostatic force of attraction.

Brittleness → {Same charged ions comes nearer. So they repel each other}

**(b) Isomorphism:**

The phenomenon of different ionic compounds, having same crystal arrangement of ions is termed as isomorphism

• **Condition of Isomorphism:**

- (i) Same charge on cation & anion between isomorphs
- (ii) Same radius ratio range of cation & anion between isomorphs
- (iii) Same number of water of crystallization between isomorphs

Ex. (i) ZnSO₄ · 7H₂O, FeSO₄ · 7H₂O are isomorphous

(ii) All alums are isomorphous

(c) Boiling point and melting point:

Ionic compounds have high boiling point and melting point due to strong electrostatic force of attraction among oppositely charged ions.

(d) Conductivity: It depends on ionic mobility.

(Inorganic Chemistry)

- (i) In solid state - No free ions - Bad conductor of electricity.
- (ii) In fused state or aqueous solution Due to free ions - Good conductor of electricity.
- Conductivity order: Solid state < fused state < Aqueous solution

(e) Solubility:

Ionic compounds are more soluble in polar solvents and less soluble in non polar solvents.

Solubility of ionic compounds in water mainly depends upon hydration energy & lattice energy.

Que. Why does the solubility of alkaline earth metal hydroxides in water increase down the group?

Ans. Among alkaline earth metal hydroxides, the anion being common, the cationic radius will influence the lattice enthalpy. Since lattice enthalpy decreases much more than the hydration enthalpy with increasing ionic size, the solubility increases as we go down the group.

Que. Why does the solubility of alkaline earth metal carbonates and sulphates in water decrease down the group?

Ans. The size of anions being much larger compared to cations, the lattice enthalpy will remain almost constant within a particular group. Since the hydration enthalpies decrease down the group, solubility will decrease as found for alkaline earth metal carbonates and sulphates.

FAJAN'S RULE

- Just as all the covalent bonds have some partial ionic character, the ionic bonds also have partial covalent character. The partial covalent character of ionic bonds was discussed by Fajans in terms of the following rules :
- The smaller the size of the cation and the larger the size of the anion, the greater the covalent character of an ionic bond.
- The greater the charge on the cation, the greater the covalent character of the ionic bond.
- For cations of the same size and charge, the one, with electronic configuration $(n-1)d^xns^0$, typical of transition metals, is more polarising than the one with a noble gas configuration, ns^2np^6 , typical of alkali and alkaline earth metal cations.
- The cation polarises the anion, pulling the electronic charge toward itself and thereby increasing the electronic charge between the two. This is precisely what happens in a covalent bond, i.e., buildup of electron charge density between the nuclei. The polarising power of the cation, the polarisability of the anion and the extent of distortion (polarisation) of anion are the factors, which determine the per cent covalent character of the ionic bond.
- ⇒ Polarisation power of a cation is usually called ionic potential or charge density.

$$\text{Ionic potential } \phi(\text{phi}) = \frac{\text{Charge on cation}}{\text{Size of cation}}$$



(Inorganic Chemistry)

➤ APPLICATION OF THE CONCEPT OF POLARISATION:

- (a) To compare the covalent and ionic character of molecule
- (b) To compare the nature of oxide
- (c) To compare the electrical conductivity of ionic compounds
- (d) Tendency of the formation of complex compounds
- (e) To compare the thermal stability of metal salts
- (f) To compare the intensity of colour of compounds
- (g) To compare the solubility of heavier metal halide in water.

➤ Factors Affecting polarization :

(1) Charge on cation :

charge ↑, ϕ ↑, polarisation ↑, covalent character ↑, ionic character ↓

Order of covalent character : $\text{NaCl} < \text{MgCl}_2 < \text{AlCl}_3 < \text{SiCl}_4$

(2) Size of cation :

size ↓, ϕ ↑, polarization ↑, covalent character ↑, ionic character ↓

Order of covalent character: $\text{LiCl} > \text{NaCl} > \text{KCl} > \text{RbCl} > \text{CsCl}$

(3) Size of anion :

size ↑, polarization ↑, covalent character ↑, ionic character ↓

Order of covalent character : $\text{NaF} < \text{NaCl} < \text{NaBr} < \text{NaI}$

(4) Charge on anion :

charge ↑, polarization ↑, covalent character ↑, ionic character ↓

Order of covalent character. $\text{LiF} < \text{Li}_2\text{O} < \text{Li}_3\text{N}$

(5) Type of cation :

(i) Inert gas configuration cation : $\text{ns}^2\text{np}^6(8\text{e}^-)$

Ex.: $\text{Na}^+ = 1\text{s}^2 2\text{s}^2 2\text{p}^6$

(ii) Pseudo inert gas configuration cation : $\text{ns}^2\text{np}^6\text{nd}^{10}(18\text{e}^-)$

$\text{Cu}^{\oplus} = 1\text{s}^2 2\text{s}^2 2\text{p}^6 3\text{s}^2 3\text{p}^6 3\text{d}^{10}$

Some other examples are : $\text{Zn}^{+2}, \text{Ga}^{+3}, \text{Ge}^{+4}, \text{Ag}^+, \text{Cd}^{+2}, \text{Au}^+, \text{Hg}^{+2}$

(iii) Non inert gas configuration: $\text{ns}^2\text{np}^6\text{nd}^{10}(n + 1)\text{s}^2(18 + 2\text{e}^-)$

$\text{Tl}^+ = [\text{Xe}]6\text{s}^2 4\text{f}^{14} 5\text{d}^{10}$

Note : order of polarizing power of cation

Non inert gas configuration > Pseudo inert gas configuration > inert gas Configuration

Ex. Order of covalent character :

(a) $\text{NaCl} < \text{CuCl}$

(b) $\text{KCl} < \text{AgCl}$

(Inorganic Chemistry)

- (c) $\text{CaCl}_2 < \text{CdCl}_2$
 (d) $\text{CaCl}_2 < \text{PbCl}_2$
 (e) $\text{CdCl}_2 < \text{PbCl}_2$

INERT PAIR EFFECT

- In p-block elements the stability of the lower oxidation state increases on descending the group. Because increased effective nuclear charge holds ns electrons tightly due to poor shielding effect of inner d & f orbitals and thereby, restrict their (ns electrons) participation in bonding only np electrons take part in bond formation. As a result of this, +1 oxidation state of Tl is more stable than it's +3 oxidation state. Pb shows +2 stable oxidation state and Bi shows +3 stable oxidation state.

➤ **For example:****Group 13**

B(+3)	C(+4)
Al(+3)	Si(+4)
Ga(+3), (+1)	Ge(+4), (+2)
In(+3), (+1)	Sn(+4), (+2)
Tl(+3), (+1)	Pb(+4), (+2)

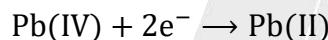
Group 14

Order of stability: $\text{Tl}^{+1} > \text{In}^{+1} > \text{Ga}^{+1}$ (due to inert pair effect)

$\text{Pb}^{+2} > \text{Sn}^{+2} > \text{Ge}^{+2}$ (due to inert pair effect)

Ex. PbCl_4 is stable at room temperature whereas PbI_4 doesn't exist.

Sol. Due to inert pair effect $\text{Pb}(+4)$ is less stable than $\text{Pb}(+2)$. Hence it is very good oxidant.

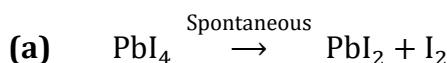


Reducing abilities of halides follows the sequence

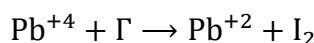
• **Inert pair effect : order of stability****Due to inert pair effect :**

- (a) $\text{Tl}^{+1} > \text{Tl}^{+3}$ (b) $\text{Bi}^{+3} > \text{Bi}^{+5}$ (c) $\text{Pb}^{+2} > \text{Pb}^{+4}$ (d) $\text{Hg} > \text{Hg}^{+2}$
- (a) $\text{Pb}^{+4} + 2\text{e}^\ominus \xrightarrow{\text{(Oxidizing agent)}} \text{Pb}^{+2}$ (b) $\text{T}^{+3} + 2\text{T}^\ominus \xrightarrow{\text{(Oxidizing agent)}}$ (c) $\text{Bi}^{+5} + 2\text{e}^\ominus \xrightarrow{\text{(Oxidizing agent)}}$ $\rightarrow \text{Bi}^{+3}$

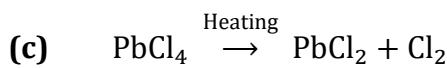
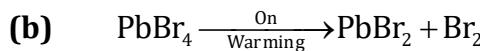
Note: PbO_2 , Pb_2O_3 ($\text{PbO} + \text{PbO}_2$), $\text{Pb}(\text{ClO}_4)$ are oxidizing agents because Pb^{+2} is more stable than Pb^{+4}

• **Reducing power order $\text{I}^- > \text{Br}^- > \text{Cl}^- > \text{F}^-$** 

PbI_4 does not exist because Pb^{+4} act as oxidizing agent and I^- act as reducing agent.



(Inorganic Chemistry)



- $\left. \begin{array}{l} \text{CuI}_2 \\ \text{FeI}_3 \\ \text{BiI}_5 \\ \text{TlI}_3 [\text{with I}^\ominus] \end{array} \right\}$ does not exist

Note : Only pentahalide of Bi is BiF_5 is possible. [F^\ominus is weak reducing agent]

- (a) $\text{Cu}^{+2} + \text{I}^\ominus \xrightarrow[\text{(R.A.)}]{\text{(O.A.)}} \text{Cu}_2\text{I}_2 + \text{I}_2$
- (b) $\text{Fe}^{+3} + \text{I}^\ominus \xrightarrow[\text{(R.A.)}]{\text{(O.A.)}} \text{Fe}^{+2} + \text{I}_2$
- (c) $\text{Bi}^{+5} + \text{I}^\ominus \xrightarrow[\text{(R.A.)}]{\text{(O.A.)}} \text{Bi}^{+3} + \text{I}_2$
- (d) $\text{Tl}^{+3} + 3\text{I}^\ominus \xrightarrow[\text{(R.A.)}]{\text{(O.A.)}} \text{Tl}^+ + \text{I}_2$

But TlI_3 [with I^\ominus] exists, $\text{TlI}_3 \rightarrow \text{Tl}^+ + \text{I}_3^\ominus$

Note : $[\text{CuI}_4]^{2-}$ complex does not exists, $[\text{CuI}_4]^{3-}$ exists.

Stability of higher oxidation state \downarrow down the group

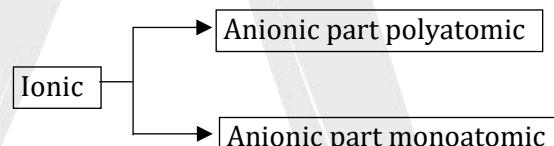
$\text{CX}_4 > \text{SiX}_4 > \text{GeX}_4 > \text{SnX}_4 > \text{PbX}_4$ (Where X is F, Cl, Br, I)

Stability of lower oxidation state \uparrow down the group.

$\text{CX}_2 < \text{SiX}_2 < \text{GeX}_2 < \text{SnX}_2 < \text{PbX}_2$ (Where X is F, Cl, Br, I)

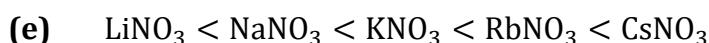
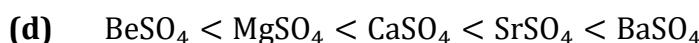
➤ **Application of Fajan's Rule:**

- **Thermal stability:**



- **Thermal stability of Ionic compound having polyatomic anion:**

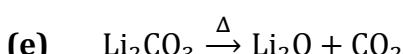
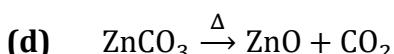
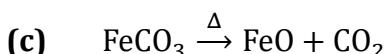
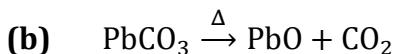
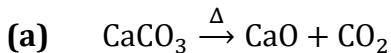
Order of Thermal stability:



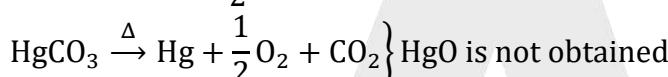
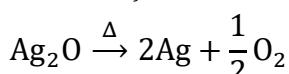
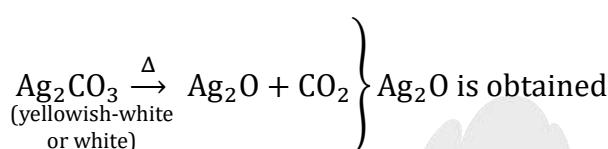
Note: Na, K, Rb, Cs carbonate do not decompose on heating, they melt at high temperature.

(Inorganic Chemistry)

- **Heating effect of carbonate:**



- Oxides of native metal (Ag, Hg, Au, Pt) are less stable and further decompose on heating



Note: CuO Black $\xrightarrow{\text{hightemp.}}$ Cu₂O Red

- Thermal stability of ionic compound having monoatomic anion :



$$L.E = Kq_1q_2/r^2(r_c + r_a)$$

$$\rightarrow \text{L.E.} \propto \text{charge L.E.} \propto \frac{\text{size}}{\text{size}}$$

Charge ↑, L.E. ↑ \Rightarrow size ↑, L.E. ↓

Expt-6) LiCl > NaCl > KCl > RbCl > CsCl (b) LiBr > NaBr > KBr > RbBr > CsBr

(c) Li > Na > K > Rb > Cs > (d) Li > N > K > N > Rb > N

(e) $KF > KCl > KBr > KI$

- Important •

- O_2^{-2} , O_2^{-1} , $-OH$ (They are diatomic anion)
 Peroxide Superoxide

T.S. \longrightarrow acts as polyatomic

Solubility → acts as monoatomic

- (a) $\text{LiOH} < \text{NaOH} < \text{KOH} < \text{RbOH} < \text{CsOH}$

- $$\text{(b)} \quad \text{Na}_2\text{O}_2 < \text{K}_2\text{O}_2 < \text{Rb}_2\text{O}_2 < \text{Cs}_2\text{O}_2$$

- $$(c) \quad K_0 < Rb_0 < Cs_0$$

(Inorganic Chemistry)

- **Colour of Ionic compound :**

Higher the polarization of ionic compound greater will be the colour intensity of ionic compound.

Ex.:	AgF	AgCl	AgBr	AgI
	white	pale yellow	yellow	

Que. Predict the colour of CuCl and CuBr if colour of CuI is white :

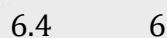
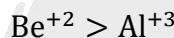
Ans. White

- **Ionic Mobility :**

$\phi \uparrow$, Hydrate size \uparrow , Ionic mobility \downarrow

Exception Case

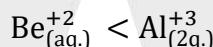
Note : ϕ of :



Hydrate Size



Ionic Mobility



Case-I: Down the group, H.E. \downarrow , L.E. \downarrow , solubility \downarrow

- (a) LiF < NaF < KF < RbF < CsF
- (b) BeO < MgO < CaO < SrO < BaO
- (c) BeS < MgS < CaS < SrS < BaS
- (d) LiOH < NaOH < KOH < RbOH < CsOH

Case-II: Down the group, solubility \downarrow

- (a) $\text{LiClO}_3 > \text{NaClO}_3 > \text{KClO}_3 > \text{RbClO}_3 > \text{CsClO}_3$ (chlorate)
- (b) $\text{LiClO}_4 > \text{NaClO}_4 > \text{KClO}_4 > \text{RbClO}_4 > \text{CsClO}_4$ (perchlorate)
- (c) $\text{BeSO}_3 > \text{MgSO}_3 > \text{CaSO}_3 > \text{SrSO}_3 > \text{BaSO}_3$ (sulphite)
- (d) $\text{BeSO}_4 > \text{MgSO}_4 > \text{CaSO}_4 > \text{SrSO}_4 > \text{BaSO}_4$ (sulphate)
- (e) $\text{BeS}_2\text{O}_3 > \text{MgS}_2\text{O}_3 > \text{CaS}_2\text{O}_3 > \text{SrS}_2\text{O}_3 > \text{BaS}_2\text{O}_3$ (thiosulphate)
- (f) $\text{BeCrO}_4 > \text{MgCrO}_4 > \text{CaCrO}_4 > \text{SrCrO}_4 > \text{BaCrO}_4$ (chromate)
- (g) $\text{BeCO}_3 > \text{MgCO}_3 > \text{CaCO}_3 > \text{SrCO}_3 > \text{BaCO}_3$ (carbonate)

Note : Br^-/I^- : They follow trend of polyatomic

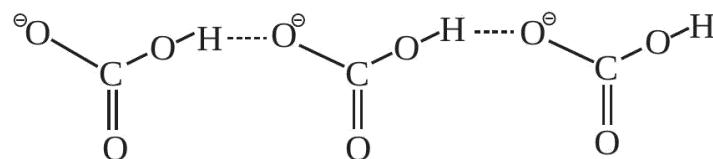
- (a) $\text{LiBr} > \text{NaBr} > \text{KBr} > \text{RbBr} > \text{CsBr}$
- (b) $\underline{\text{NaI}} > \text{LiI} > \text{KI} > \text{RbI} > \text{CsI}$

Case-III: If number of cations $>$ number of anions, then solubility \uparrow down the group.

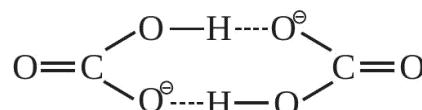
- (a) $\text{Li}_2\text{O} < \text{Na}_2\text{O} < \text{K}_2\text{O} < \text{Rb}_2\text{O} < \text{Cs}_2\text{O}$
- (b) $\text{Li}_2\text{CO}_3 < \text{Na}_2\text{CO}_3 < \text{K}_2\text{CO}_3 < \text{Rb}_2\text{CO}_3 < \text{Cs}_2\text{CO}_3$
- (c) $\text{NaHCO}_3 < \text{KHCO}_3 < \text{RbHCO}_3 < \text{CsHCO}_3$

(Inorganic Chemistry)

- Reason:** Massive H bonding in NaHCO_3 (Sparingly Soluble)



Compact H-bonding in KHCO_3 , RbHCO_3 , CsHCO_3 (Completely Soluble)



Que. Find order of K_{sp} .

Solubility \uparrow , $K_{\text{sp}} \uparrow$

$\text{NaHCO}_3 < \text{KHCO}_3 < \text{RbHCO}_3 < \text{CsHCO}_3$

Case (IV): Number of monoatomic anion $>$ Number of cation, then solubility \uparrow down the group.

$\text{Be}(\text{OH})_2 < \text{Mg}(\text{OH})_2 < \text{Ca}(\text{OH})_2 < \text{Sr}(\text{OH})_2$

But if number of polyatomic anion $>$ number of cation, then solubility \downarrow down the group.

$\text{Be}(\text{NO}_3)_2 > \text{Mg}(\text{NO}_3)_2 > \text{Ca}(\text{NO}_3)_2 > \text{Sr}(\text{NO}_3)_2 > \text{Ba}(\text{NO}_3)_2$

$\text{BeX}_2 > \text{MgX}_2 > \text{CaX}_2 > \text{SrX}_2 > \text{BaX}_2$ ($\text{X} = \text{Cl}, \text{Br}, \text{I}$) – Exception to key point

- Key point : (For Cases I to IV)**

If number of polyatomic anion \geq Number of cation then solubility \downarrow down the group, otherwise solubility increases down the group.

- Alkaline earth metals :**

(a) $\text{BeS}_2\text{O}_3 > \text{MgS}_2\text{O}_3 > \text{CaS}_2\text{O}_3 > \text{SrS}_2\text{O}_3 > \text{BaS}_2\text{O}_3$ (Thiosulphate)

(b) $\text{BeCrO}_4 > \text{MgCrO}_4 > \text{CaCrO}_4 > \text{SrCrO}_4 > \text{BaCrO}_4$ (Chromate)

(c) $\text{BeSO}_3 > \text{MgSO}_3 > \text{CaSO}_3 > \text{SrSO}_3 > \text{BaSO}_3$ (Sulphite)

- Hydroxide :**

(a) $\text{Be}(\text{OH})_2 < \text{Mg}(\text{OH})_2 < \text{Ca}(\text{OH})_2 < \text{Sr}(\text{OH})_2$

(b) $\text{LiOH} < \text{NaOH} < \text{KOH} < \text{RbOH} < \text{CsOH}$

- Carbonate :**

(a) $\text{BeCO}_3 > \text{MgCO}_3 > \text{CaCO}_3 > \text{SrCO}_3 > \text{BaCO}_3$

(b) $\text{Li}_2\text{CO}_3 < \text{Na}_2\text{CO}_3 < \text{K}_2\text{CO}_3 < \text{Rb}_2\text{CO}_3 < \text{Cs}_2\text{CO}_3$

- Nitrate :**

(a) $\text{LiNO}_3 > \text{NaNO}_3 > \text{KNO}_3 > \text{RbNO}_3 > \text{CsNO}_3$

(b) $\text{Be}(\text{NO}_3)_2 > \text{Mg}(\text{NO}_3)_2 > \text{Ca}(\text{NO}_3)_2 > \text{Sr}(\text{NO}_3)_2 > \text{Ba}(\text{NO}_3)_2$

(Inorganic Chemistry)

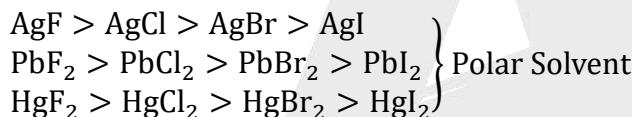
- Other example

- BeS < MgS < CaS < SrS < BaS
- LiF < NaF < KF < RbF < CsF
- BeO < MgO < CaO < SrO < BaO
- $\text{LiClO}_4 > \text{NaClO}_4 > \text{KClO}_4 > \text{RbClO}_4 > \text{CsClO}_4$
- $\text{LiClO}_3 > \text{NaClO}_3 > \text{KClO}_3 > \text{RbClO}_3 > \text{CsClO}_3$
- $\text{BeSO}_4 > \text{MgSO}_4 > \text{CaSO}_4 > \text{SrSO}_4 > \text{BaSO}_4$

- Exception in solubility :

1. $\text{LiCl} > \text{NaCl} > \text{KCl} < \text{RbCl} < \text{CsCl}$
Or
 $\text{LiCl} > \text{CsCl} > \text{RbCl} > \text{NaCl} > \text{KCl}$
2. $\text{MgF}_2 < \text{CaF}_2 < \text{SrF}_2 < \text{BaF}_2 < \text{BeF}_2$
3. Oxalate $\text{MgC}_2\text{O}_4 < \text{CaC}_2\text{O}_4 < \text{SrC}_2\text{O}_4 < \text{BaC}_2\text{O}_4 < \text{BeC}_2\text{O}_4$

- Solubility order of heavier metal halides (in polar solvent):



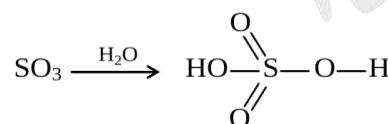
NATURE OF OXIDE

- Order of acidic character:

- | | |
|--|---|
| (a) $\text{Li}_2\text{O} > \text{Na}_2\text{O} > \text{K}_2\text{O} > \text{Rb}_2\text{O} > \text{Cs}_2\text{O}$ | (b) $\text{MgO} > \text{CaO} > \text{SrO} > \text{BaO}$ |
| (c) $\text{ZnO} > \text{MgO} > \text{CaO} > \text{SrO} > \text{BaO}$ | (d) $\text{NiO} > \text{CaO} > \text{SrO} > \text{BaO}$ |
| (e) $\text{PbO} > \text{CaO}$ | (f) $\text{PbO} < \text{PbO}_2$ |
| (g) $\text{SnO} < \text{SnO}_2$ | |

- s block-metal oxide are basic except BeO

- Nature of non-metallic oxides :

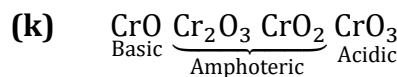
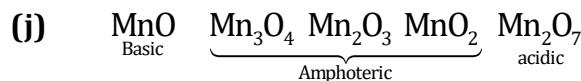
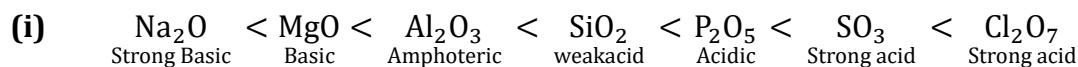
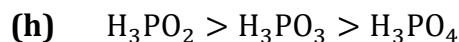


- E.N of non-metal \uparrow , acidic nature \uparrow

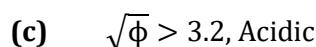
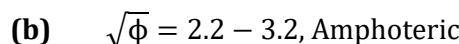
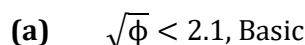
- $\text{CO}_2 > \text{SiO}_2$
- $\text{CO} < \text{CO}_2$ positive charge \uparrow , EN \uparrow , acidic nature \uparrow
- $\text{SO}_2 < \text{SO}_3$
- $\text{N}_2\text{O} < \text{NO} < \text{N}_2\text{O}_3 < \text{N}_2\text{O}_4 < \text{N}_2\text{O}_5$
- $\text{H}_2\text{SO}_3 < \text{H}_2\text{SO}_4$
- $\text{HClO} < \text{HClO}_2 < \text{HClO}_3 < \text{HClO}_4$



(Inorganic Chemistry)



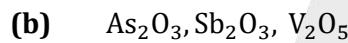
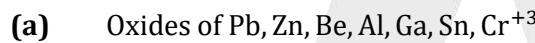
• Rule:



Que. Predict the nature of metal oxide if polarising power of metal cation is 2.2

Ans. $\sqrt{2.2} < 2.1 \Rightarrow$ Basic

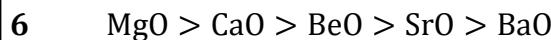
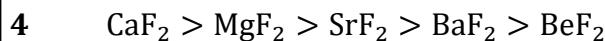
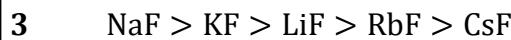
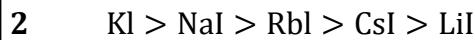
• Amphoteric oxides:



• Melting Point:

Melting point \propto Lattice energyLattice energy $\propto \frac{1}{\text{size}}$, Lattice energy \propto charge

Exception:



DO YOUR SELF - 4

1. In which of the following species the bonds are non-directional ?
 - (A) NCl_3
 - (B) RbCl
 - (C) BeCl_2
 - (D) BCl_3
2. Out of following which one has least value of melting point
 - (A) LiCl
 - (B) BeCl_2
 - (C) MgCl_2
 - (D) CaCl_2
3. Out of following which one has maximum ionic character -
 - (A) NaCl
 - (B) KCl
 - (C) CaCl_2
 - (D) MgCl_2
4. Which of the following has highest melting point -
 - (A) NaCl
 - (B) NaI
 - (C) NaBr
 - (D) NaF
5. Among LiCl , BeCl_2 , BCl_3 and CCl_4 , the covalent bond character follows the order -
 - (A) $\text{LiCl} < \text{BeCl}_2 > \text{BCl}_3 > \text{CCl}_4$
 - (B) $\text{LiCl} > \text{BeCl}_2 < \text{BCl}_3 < \text{CCl}_4$
 - (C) $\text{LiCl} < \text{BeCl}_2 < \text{BCl}_3 < \text{CCl}_4$
 - (D) $\text{LiCl} > \text{BeCl}_2 > \text{BCl}_3 > \text{CCl}_4$

MOLECULAR ORBITAL THEORY (MOT)

➤ Given by Hunds & Mulliken

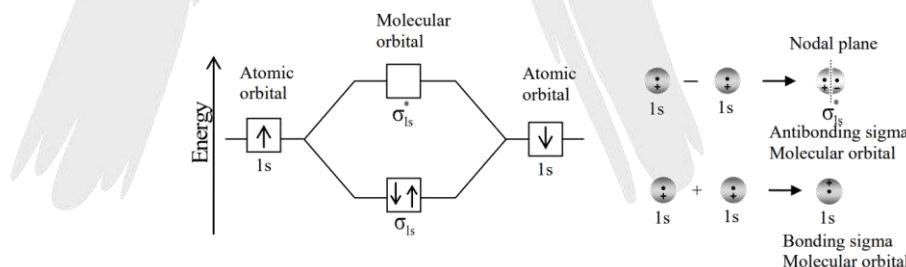
- (1) Two atomic orbital come nearer & then overlap each other to form two molecular orbitals
 (2) Combination of atomic orbital (AO) forms molecular orbital (MO)

Types of molecular orbitals

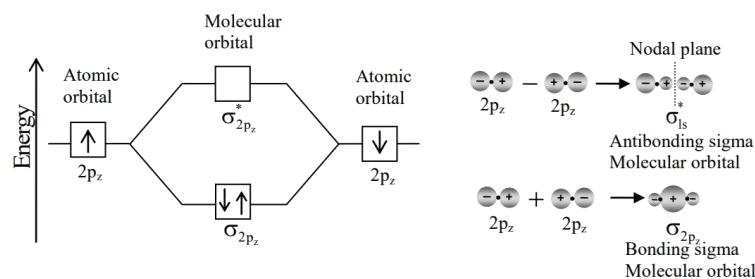
Molecular orbitals of diatomic molecules are designated as σ (sigma), π (pie), δ (delta) etc.

In this nomenclature, the sigma (σ) molecular orbitals are symmetrical around the intermolecular axis (assumed to be z-axis) while pi (π) molecular orbitals are not symmetrical.

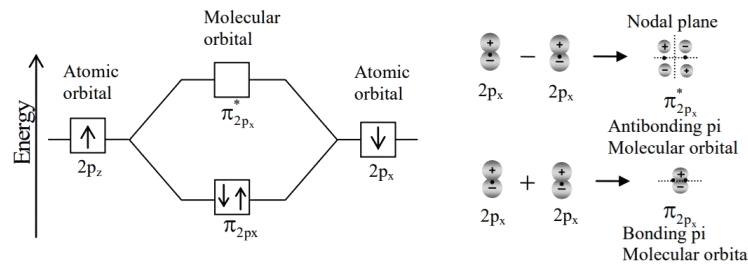
(a) s-s combination of orbitals



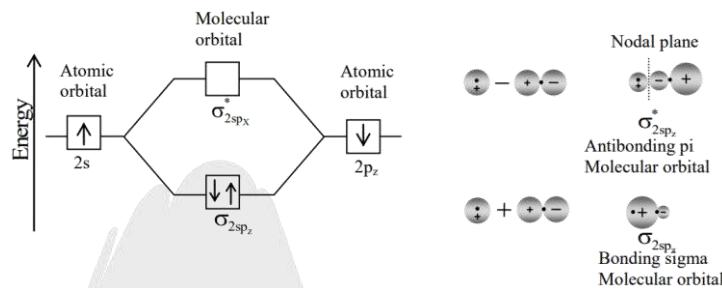
(b) p-p combination of orbital(end to end overlap)



(c) p-p combination of orbitals (side by side overlap)



(d) s-p combination of orbitals



- (3) Energy of BMO < Energy of ABMO.
- (4) Molecular orbitals can be filled by electrons according to Aufbau, Hund's, Pauli's principle.
- (5) Energy order of the molecular orbitals of homonuclear di-atomic molecules.

Note: Molecular orbital energy order for up to N₂ (molecule having ≤ 14 electrons)

$$\sigma_{1s} < \sigma_{1s}^* < \sigma_{2s} < \sigma_{2s}^* < \pi_{2p_x} = \pi_{2p_y} < \sigma_{2p_z} < \pi_{2p_x}^* = \pi_{2p_y}^* < \sigma_{2p_z}^*$$

Note: Molecular orbital energy order for O₂ and F₂ (molecule having > 14 electrons)

$$\sigma_{1s} < \sigma_{1s}^* < \sigma_{2s} < \sigma_{2s}^* < \sigma_{2p_z} < \pi_{2p_x} = \pi_{2p_y} < \pi_{2p_x}^* = \pi_{2p_y}^* < \sigma_{2p_z}^*$$

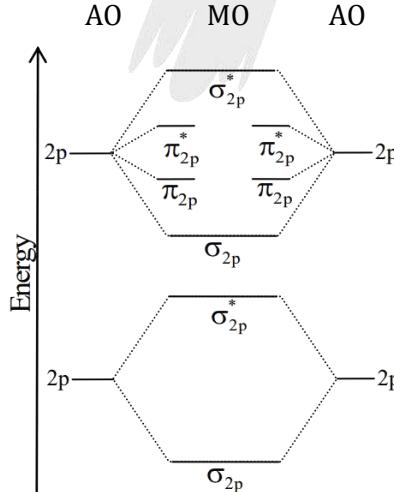
σ^*, π^* = antibonding molecular orbital

σ, π = bonding molecular orbital

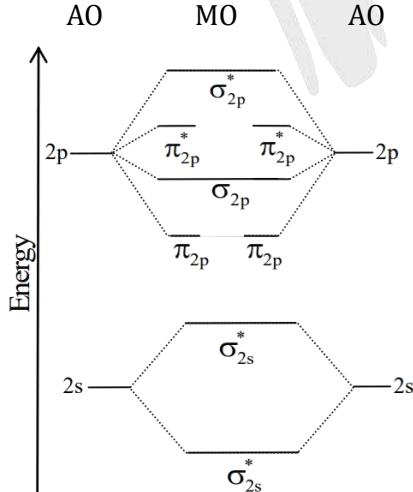
Ex. Why molecular orbitals have different order of energy in N₂ & O₂?

Sol. s-p mixing

Hint:



The correct MO energy-level diagram When s-p mixing is not allowed.



The correct MO energy-level diagram When s-p mixing is allowed, the energies of the σ_{sp} and π_{2p} orbitals are reversed.

(Inorganic Chemistry)➤ **Bond Order**

Bond order can be defined as:

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

N_b = No. of electron in bonding MO's

N_a = No. of electron in antibonding MO's

- If bond order = 0, it means species does not exist.
- Bond order of 1,2 & 3 corresponds to a single bond, double & triple bond respectively.
- Bond order ↑ stability of molecule ↑ bond length ↓

10. Magnetic behaviour

- If the molecule has one or more unpaired electron, it will be paramagnetic,
- If all the electrons are paired it will be diamagnetic.
- Magnetic strength can be calculated by using spin only formula of magnetic moment (μ).
- $\mu = \sqrt{n(n+2)}$ B.M. (where n = number of unpaired electron)

Ex. H_2 = Configuration: $\sigma_{(1s)}^2, \sigma_{(1s)}^{*0}$

$$\text{Bond order} = \frac{N_b - N_a}{2} = \frac{2-0}{2} = 1,$$

Hence H – H (diamagnetic) Order of Ionisation Energy:

- | | | | |
|------------------------|-----------------------|-----------------------|----------------------|
| (a) $N_2 > O_2$ | (b) $N_2 > N$ | (c) $O_2 < O$ | (d) $N_2 > O$ |
| (e) $O_2 < N_2$ | (f) $CO < N_2$ | (g) $O_2 > NO$ | (h) $F_2 > F$ |

- **For Axial:** After two rotation from 180° , If sign is changed then orbital is ungerade, if not then gerade.

Gerade molecular orbital have even no. of nodal plane and ungerade molecular orbital have odd no. of nodal plane.

- **Key Points:** for axial-

$B \rightarrow G \rightarrow 0, A \rightarrow U \rightarrow 1$

For side ways-

$A \rightarrow G \rightarrow 2, B \rightarrow U \rightarrow 1$

Q. Halogen are diamagnetic but colourful. explain:

Colours : F_2 : Pale yellow

Cl_2 : Greenish yellow

Br_2 : Reddish-Brown

I_2 : Violet

Ans. Halogen are colourful due to HOMO-LUMO transition.

HOMO: Highest occupied molecular orbital

LUMO: Lowest unoccupied molecular orbital

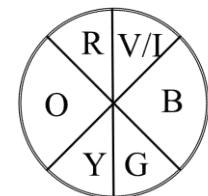
(Inorganic Chemistry)

In F_2 molecule HOMO is ABMO

In O_2 molecule HOMO is ABMO

In N_2 molecule HOMO is BMO

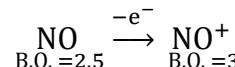
In CO molecule HOMO is NBMO



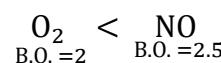
VIBGYOR

- Note :**

- If bond order is fractional, then it wants to make it integer greater than previous



- If bond order is greater, then molecule is more stable.



- CO



Bond order:

$$3 > 3$$

Bond length:

$$1.128 \text{ \AA} \quad 1.115 \text{ \AA}$$

Electron is removed from NBMO having slight anti-bonding character, so bond order slightly increase.

DO YOURSELF - 5

- Q.1** In the conversion of N_2 into N_2^+ the electron will be lost from which of the following molecular orbitals?

(A) $\sigma_{2p_z}^*$ (B) σ_{2p_z} (C) π_{2p_x} (D) $\pi_{2p_x}^*$

- Q.2** The bond orders in BN, BO and CO respectively are -

(A) 2,3,5/2 (B) 2,5/2,2 (C) 2,5/2,3 (D) 5/2,2,3

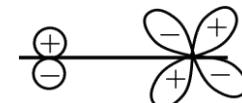
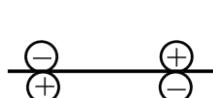
- Q.3** Which of the following leads to bonding?

(A) s-orbital p-orbital (B) s-orbital p-orbital



(C) p-orbital p-orbital

(D) p-orbital d-orbital



- Q.4** In an antibonding molecular orbital, electron density is minimum -

(A) Around one atom of the molecule
 (B) Between the two nuclei of the molecule
 (C) At the region away from the nuclei of the molecule
 (D) at no place

- Q.5** Which have odd bond order -

(A) O_2^+ (B) O_2^- (C) NO (D) All



ANSWER KEY

Do your self - 1

1. C 2. A 3. C 4. D 5. B

Do your self - 2

1. A 2. D 3. C 4. A 5. C

Do your self - 3

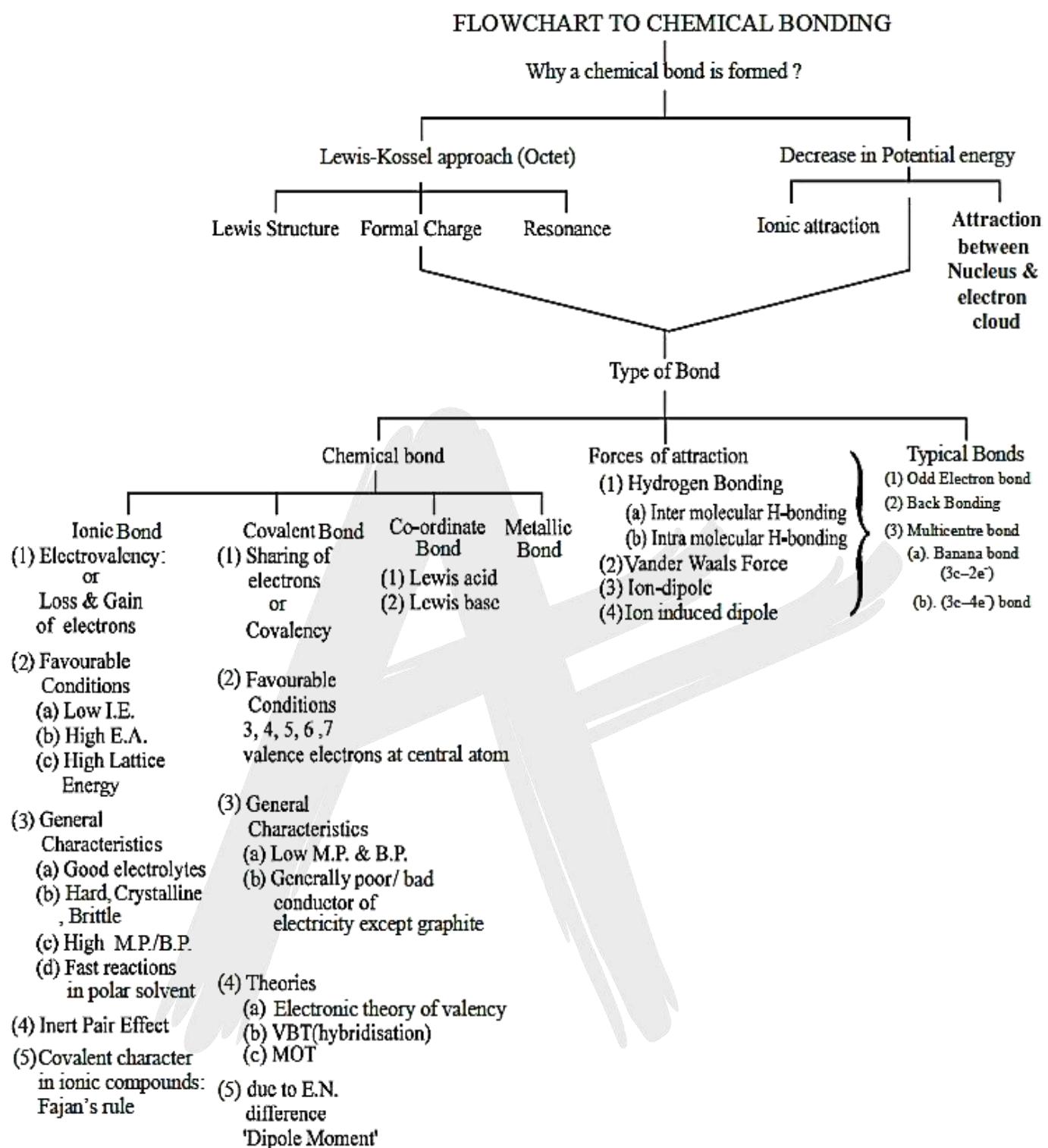
1. B 2. D 3. A 4. C 5. A

Do your self - 4

1. B 2. B 3. B 4. D 5. C

Do your self - 5

1. B 2. C 3. B 4. B 5. D



**EXERCISE - I****WEAK FORCES**

1. The correct order of boiling point of NCl_3 , NClF_2 , NF_3 is :
(A) $\text{NCl}_3 > \text{NClF}_2 > \text{NF}_3$ (B) $\text{NCl}_3 < \text{NClF}_2 < \text{NF}_3$
(C) $\text{NClF}_2 < \text{NCl}_3 < \text{NF}_3$ (D) $\text{NCl}_3 < \text{NF}_3 < \text{NClF}_2$
2. Which of the following option is correct about Boiling point ?
(A) $\text{C}_3\text{F}_8 < \text{C}_3\text{H}_8$ (B) $\text{CH}_4 < \text{CF}_4$
(C) $\text{C}_2\text{H}_6 > \text{C}_2\text{F}_6$ (D) $\text{CF}_4 < \text{CH}_4$
3. At room temperature, iodine is solid, Bromine is liquid and chlorine exist in gaseous phase due to following factor:
(A) Surface area (B) Molecular volume
(C) Ease of polarization (D) All of these
4. Graphite is used as lubricant in high temperature machinery because:
(A) Hexagonal layers slide over each other.
(B) In between two layer Vandar Waal Force is present.
(C) Both A & B
(D) None
5. Dipole-induced dipole interaction depends upon
(A) size of polarisable particle
(B) dipole moment of permanent dipole
(C) Both (A) and (B)
(D) None of these
6. Which of the following interaction is responsible for the formation of clathrates compounds:
(A) Instantaneous dipole-induced dipole interaction
(B) Ion-dipole interaction
(C) Dipole-dipole interaction
(D) Dipole-induced dipole interaction
7. Which of the following statement is correct?
(A) Noble gases are insoluble in water.
(B) The solubility of noble gases in water is fairly high due to London dispersion force.
(C) The solubility of noble gases increases with the decrease in size of the noble gas atom.
(D) The solubility of noble gases in water is fairly high due to dipole- induced dipole interaction.

BENT'S RULE AND DRAGO'S



(Inorganic Chemistry)

16. The correct sequence for polarity of the following molecule

1. Benzene 2. Inorganic Benzene 3. PCl_3F_2 4. PCl_2F_3

(P stands for polar and NP stands for non-polar)

- | | | | |
|--------|----|----|---|
| 1 | 2 | 3 | 4 |
| (A) P | NP | NP | P |
| (C) NP | P | NP | P |

- | | | | |
|--------|----|----|----|
| 1 | 2 | 3 | 4 |
| (B) NP | NP | NP | P |
| (D) NP | P | P | NP |

17. N_2H_4 reacts with conc. H_2SO_4 to produce a salt $[\text{NH}_3 - \text{NH}_3]^{+2}\text{SO}_4^{-2}$ in which.

- | | |
|--|--|
| (A) $d_{\text{N}-\text{N}}(\text{salt}) > d_{\text{N}-\text{N}}(\text{N}_2\text{H}_4)$ | (B) $d_{\text{N}-\text{N}}(\text{salt}) < d_{\text{N}-\text{N}}(\text{N}_2\text{H}_4)$ |
| (C) $d_{\text{N}-\text{N}}(\text{salt}) = d_{\text{N}-\text{N}}(\text{N}_2\text{H}_4)$ | (D) Cannot be predicted |

BACK BONDING

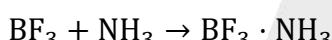
18. The approximate hybridisation of the oxygen atom in disiloxane, $(\text{SiH}_3)_2\text{O}$, is-

- | | | | |
|-------------------|-------------------|-----------------|-------------------|
| (A) sp^2 | (B) sp^3 | (C) sp | (D) sp^3 |
|-------------------|-------------------|-----------------|-------------------|

19. Which of the following will not form adduct ?

- | | |
|---|--|
| (A) $(\text{CH}_3)_2\text{O} + \text{BF}_3$ | (B) $(\text{SiH}_3)_2\text{O} + \text{BF}_3$ |
| (C) $\text{NH}_3 + \text{BF}_3$ | (D) $\text{CH}_3\text{NH}_2 + \text{BF}_3$ |

20. Select the correct statement about the reaction



- (A) Octet of ' N ' is incomplete in product
- (B) Octet of boron is complete in product
- (C) During the reaction total number of sigma bonds remain same in the reactant as well as in the product
- (D) Type of π -bond between boron and nitrogen is $2p_\pi - 2p_\pi$

21. Which of the following has highest bond energy ?

- | | |
|--------------------------------|--------------------------------|
| (A) C – F in (CF_4) | (B) C – Cl in (CCl_4) |
| (C) C – Br in (CBr_4) | (D) B-F in (BF_3) |

22. The incorrect statement regarding $\text{O}(\text{SiH}_3)_2$ and OCl_2 molecule is/are :

- (A) The strength of back bonding is more in $\text{O}(\text{SiH}_3)_2$ molecule than OCl_2 molecule
- (B) Si – $\widehat{\text{O}}$ – Si bond angle in $\text{O}(\text{SiH}_3)_2$ is greater than Cl – $\widehat{\text{O}}$ – Cl bond angle in OCl_2
- (C) The nature of back bond in both molecules is $2p_\pi - 3d_\pi$
- (D) Hybridisation of central O-atom in both molecules is same

23. The direction of back bonding from surrounding atom to central atom is observed in which of the following compound

- | | | | |
|---------------------------------|-----------------------------------|---------------------|---------------------------------|
| (A) $\bar{\text{C}}\text{Cl}_3$ | (B) $\bar{\text{C}}(\text{CN})_3$ | (C) $:\text{CCl}_2$ | (D) $[\text{B}(\text{OH})_4]^-$ |
|---------------------------------|-----------------------------------|---------------------|---------------------------------|

MULTICENTERED BOND / BRIDGE BONDING

SILICATE

ODD ELECTRON SPECIES

HYDROLYSIS

MOLECULE DOES NOT EXIST

- 41.** Which of the following molecule does not exist ?
(A) PbI_2 (B) VI_3 (C) ClF_7 (D) CuI

INERT PAIR EFFECT

- 42.** Which of the following statements is incorrect?

(A) Oxidizing power order: $\text{SiCl}_4 < \text{SnCl}_4 < \text{PbCl}_4$

(B) Ionic character order : $\text{CsBr} > \text{RbBr} > \text{KBr} > \text{NaBr} > \text{LiBr}$

(C) The ionic character of lead(II) halides decreases with increase in atomic no. of halogen

(D) The oxidation state of Tl in TlI_3 is +3 .

43. Statement-1: Hg_2^{2+} is good oxidising agent

Statement-2: 6s electrons are strongly attracted towards nucleus of Hg, due to poor shielding of 4f electrons

- (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
 - (B) Statement- 1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1
 - (C) Statement- 1 is true, statement- 2 is false.
 - (D) Statement- 1 is false, statement- 2 is true.

(Inorganic Chemistry)

- 44.** Statement-1: SnCl_4 doesn't exist and converts into SnCl_2 and Cl_2 spontaneously at room temperature
Statement-2: SnCl_4 is more stable than SnCl_2 .
 (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
 (B) Statement- 1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
 (C) Statement- 1 is true, statement- 2 is false.
 (D) Statement- 1 is false, statement- 2 is true.
- 45.** Which of the following substance has the largest negative lattice enthalpy ?
 (A) NaCl (B) CaBr_2 (C) NaBr (D) CaCl_2
- 46.** Choose the correct code for the following statements.
 I. The (-)ve value of ΔH for the dissolution of ionic compound is enough to predict the compound is soluble in water at any temperature.
 II. For the alkali metals carbonate, solubility order decreases down the group.
 III. For the alkali metals ozonide, the thermal stability order increases down the group.
 IV. For the alkaline earth metals nitride, the thermal stability order increases down the group.
 (A) T T F F (B) T F F T (C) T F T F (D) F T T F
- 47.** Out of the following which one has the highest values of covalent character?
 (A) ZnCl_2 (B) CdCl_2 (C) HgCl_2 (D) CuCl
- 48.** Compound having lowest Melting point.
 (A) BeCl_2 (B) MgCl_2 (C) CaCl_2 (D) SrCl_2
- 49.** Which of the following order is correct of the given property.
 (A) $\text{LiCl} > \text{NaCl} > \text{KCl} > \text{RbCl} > \text{CsCl}$: Thermal stability order
 (B) $\text{BeF}_2 < \text{MgF}_2 < \text{CaF}_2 < \text{SrF}_2 < \text{BaF}_2$: solubility order
 (C) $\text{NO}^{2-} > \text{NO}^- > \text{NO} = \text{NO}^{2+} > \text{NO}^+$: bond length order
 (D) $\text{BaO} > \text{SrO} > \text{CaO} > \text{BeO} > \text{MgO}$: basic character order
- 50.** Which of the following has highest covalent character.
 (A) CaCl_2 (B) ZnCl_2 (C) KCl (D) CuCl
- 51.** Which of the following order is CORRECT
 (A) $\text{BeF}_2 < \text{BaF}_2 \rightarrow$ Solubility
 (B) $\text{BeO} < \text{BeF}_2 \rightarrow$ Melting point
 (C) $\text{BeO} < \text{MgO} \rightarrow$ Acidic character
 (D) $\text{MgF}_2 < \text{AlF}_3 \rightarrow$ Covalent character

(Inorganic Chemistry)

52. Which of the following order is CORRECT about thermal stability.

- | | |
|---|-------------------------------------|
| (A) $\text{Li}_2\text{CO}_3 < \text{Cs}_2\text{CO}_3$ | (B) $\text{BeCO}_3 < \text{BaCO}_3$ |
| (C) $\text{LiNO}_3 < \text{CsNO}_3$ | (D) All of these |

53. Which of the following order is/are INCORRECT:-

- | |
|---|
| (A) $\text{NaF} < \text{MgF}_2 < \text{AlF}_3$ (Lattice energy) |
| (B) $\text{NaF} < \text{MgF}_2 < \text{AlF}_3$ (Melting point) |
| (C) $\text{NaF} < \text{MgF}_2 < \text{AlF}_3$ (Polarizing power of cation) |
| (D) $\text{NaF} < \text{MgF}_2 < \text{AlF}_3$ (% ionic character) |

54. The correct solubility order is/are :

- | | | | |
|---|-----------|-----------------|----------------|
| (I) $\text{CaCO}_3 > \text{SrCO}_3 > \text{BaCO}_3$ | | | |
| (II) $\text{Li}_2\text{CO}_3 < \text{Na}_2\text{CO}_3 < \text{K}_2\text{CO}_3$ | | | |
| (III) $\text{K}_2\text{CO}_3 < \text{Rb}_2\text{CO}_3 < \text{Cs}_2\text{CO}_3$ | | | |
| (IV) $\text{Na}_2\text{CO}_3 > \text{K}_2\text{CO}_3 > \text{Rb}_2\text{CO}_3$ | | | |
| (A) II, IV | (B) I, IV | (C) II, III, IV | (D) I, II, III |

MOLECULAR ORBITAL THEORY

55. Which of the following species have more number of electrons in bonding MO's as compared to antibonding MO's :-

- | | | | |
|--------------------|--------------------|------------------|------------------|
| (A) O_2^- | (B) N_2^+ | (C) C_2 | (D) All of these |
|--------------------|--------------------|------------------|------------------|

56. Which of the following statement is INCORRECT:-

- | |
|---|
| (A) KO_2 is paramagnetic in nature |
| (B) All halogens are coloured gases at room temperature |
| (C) O_2 is paramagnetic gas |
| (D) Bond order of OF is 1.5 |

57. Assuming that if Hund's rule is violated, then the paramagnetic specie is :

- | | | | |
|------------------|------------------|-------------------------|-------------------------|
| (A) B_2 | (B) O_2 | (C) NO^\ominus | (D) O_2^\oplus |
|------------------|------------------|-------------------------|-------------------------|

58. Among the following species, which has the minimum bond length?

- | | | | |
|------------------|------------------|------------------|--------------------|
| (A) B_2 | (B) C_2 | (C) F_2 | (D) O_2^- |
|------------------|------------------|------------------|--------------------|

59. During change of O_2 to O_2^- ion, the electron adds in which one of the following orbitals ?

- | | |
|-------------------------------------|---------------------------------|
| (A) $\sigma^* 2p_z$ orbital | (B) $\sigma 2p_z$ orbital |
| (C) $\pi^* 2p_x/\pi^* 2p_y$ orbital | (D) $\pi 2p_x/\pi 2p_y$ orbital |

60. The molecular orbital with highest energy in a nitrogen molecule is

- | | | | |
|-------------------|----------------|---------------------|----------------|
| (A) σ_{2p} | (B) π_{2p} | (C) σ^*_{2p} | (D) $\pi^* 2p$ |
|-------------------|----------------|---------------------|----------------|

(Inorganic Chemistry)

- 61.** According to Molecular orbital theory which of the following is correct ?
- LUMO level for C_2 molecule is σ_{2p_x} orbital
 - In C_2 molecules both the bonds are π bonds
 - In C_2^+ ion there is one σ and two π bonds
 - All the above are correct
- 62.** N_2 and O_2 are converted to monocations N_2^+ and O_2^+ respectively, which is wrong statement :
- In N_2^+ , the N – N bond weakens
 - In O_2^+ , the O – O bond order increases
 - In O_2^+ , the paramagnetism decrease
 - N_2^+ becomes diamagnetic
- 63.** Which of the following species absorb maximum energy in its HOMO-LUMO electronic transition?
- O_2
 - N_2^-
 - C_2
 - N_2
- MISCELLANEOUS**
- 64.** Molecule in which central atom has sp^3d^2 hybridization is present.
- IF_7
 - IO_6^{-5}
 - XeF_2
 - XeO_4
- 65.** Which of the following oxyacid has S-S linkage :
- $H_2S_2O_8$
 - $H_2S_2O_7$
 - $H_2S_2O_3$
 - All of the above
- 66.** Which of the following molecule/ion is planar and polar both:-
- NO_3^\ominus
 - NO_2^\ominus
 - PF_5
 - NH_3
- 67.** Choose the element which show maximum number of covalencies out of the given elements.
- F
 - N
 - C
 - Cl
- 68.** Which of the following order is correct against the property indicated:-
- $PH_4^+ < PCl_4^+ < PBr_4^+$ (bond angle)
 - $BF_3 < NF_3 < NH_3$ (dipole moment)
 - $CCl_4 < B(OH)_3 < PCl_5$ (number of valence electrons used for bonding by central atom)
 - $CH_4 < CCl_4 < CBr_4$ (order of bond polarity)
- 69.** Which of the following have different shape from the others :-
- NOF_3
 - XeO_4
 - $SOCl_2$
 - BF_4^\ominus
- 70.** Which of the following molecule/atom has lowest enthalpy of fusion ?
- H_2
 - He
 - Br_2
 - I_2



(Inorganic Chemistry)

71. Increasing order of stability of the +2 oxidation state of the ions ?
 (A) $\text{Ca}^{2+} < \text{Ba}^{2+} < \text{Sr}^{2+}$ (B) $\text{Pb}^{2+} < \text{Ge}^{2+} < \text{Sn}^{2+}$
 (C) $\text{Ge}^{2+} < \text{Sn}^{2+} < \text{Pb}^{2+}$ (D) $\text{Cu}^{2+} < \text{Au}^{2+} < \text{Ag}^{2+}$
72. Two hybrid orbitals have a bond angle of 120° . The percentage of s-character in the hybrid orbital is nearly:
 (A) 25% (B) 33% (C) 50% (D) 66%
73. Which of the following species has the same number of X – O – X linkage, where X = S or P ?
 (I) $\text{S}_4\text{O}_6^{2-}$ (II) S_3O_9 (III) $\text{S}_2\text{O}_5^{2-}$ (IV) $\text{P}_3\text{O}_9^{3-}$
 (A) II & IV (B) II & III (C) I & III (D) I & IV

ASSERTION -REASONING TYPE

In the following set of questions, a statement I is given and a corresponding statement II is given below it. Mark the correct answer as:

- (A) If both statement I and statement II are true and statement II is the correct explanation for statement I.
 (B) If both statement I and statement II are true but statement II is not the correct explanation for statement I.
 (C) If statement I is true but statement II is false.
 (D) If statement I is false but statement II is true.
74. **Statement I :** XeH_4 does not exist but XeF_4 exists.
Statement II : F is more electronegative than H and causes lesser extent of d orbital contraction as compared to that by H atom.
75. **Statement I :** $(\text{AlCl}_3)_2$ is not electron deficient $[\text{Al}(\text{CH}_3)_3]_2$ is electron deficient
Statement II : $(\text{AlCl}_3)_2$ possesses 3c - 2 e bond.
76. **Statement I :** $[\text{AlBr}_4]^-$ exists while the existence of $[\text{BBr}_4]^-$ is questionable.
Statement II : Al is larger in size as compared to B atom.
77. **Statement I :** $d_{\text{Mn}-\text{O}}$ in MnO_4 is less than that in MnO_4^{2-}
Statement II : The higher oxidation state of an element causes higher extent of d orbital contraction and forms more effective π bond with O atoms

**EXERCISE # II****WEAK FORCES**

- 1.** Which of the following option(s) is/are CORRECT?

Type of interaction distance-energy function

- | | |
|---|--|
| (A) dipole-dipole $\propto \frac{1}{r^3}$ | (B) H-bonding $\propto \frac{1}{r^3}$ |
| (C) Ion-dipole $\propto \frac{1}{r^2}$ | (D) London force $\propto \frac{1}{r^6}$ |

- 2.** The correct order of the boiling point is/are -

- | | |
|--|--|
| (A) He < Ne < Ar < Kr < Xe | (B) H ₂ < He |
| (C) H ₂ < D ₂ < T ₂ | (D) BF ₃ < BMe ₃ |

BENT'S AND DRAGO'S RULE

- 3.** Which of the following order is correct regarding %p-character ?

- | |
|---|
| (A) H ₂ S has higher p-character in S – H bond than the O – H bond in H ₂ O |
| (B) PH ₃ has higher p-character in P – H bond than the N – H bond in NH ₃ |
| (C) NH ₄ ⁺ has higher p-character in N – H bond than the P – H bond in PH ₄ ⁺ |
| (D) None of these |

- 4.** Which of the following statement(s) is/are CORRECT?

- | |
|--|
| (A) Axial bond length > equatorial bond length in PF ₅ |
| (B) axial bond length (P – F) < equatorial bond length (P – Cl) in PF ₂ Cl ₃ |
| (C) All P-F bond lengths are equal in PF ₅ |
| (D) axial bond length (P – F) > equatorial bond length (P – Cl) in PF ₂ Cl ₃ |

- 5.** Choose the correct angle order.

- | |
|--|
| (A) $\widehat{\text{H}}\text{PH}$ in PH ₄ ⁺ = $\widehat{\text{H}}\text{CH}$ in CH ₄ |
| (B) $\widehat{\text{HNH}}$ in NH ₃ < $\widehat{\text{H}}\text{PH}$ in PH ₃ |
| (C) $\widehat{\text{HNH}}$ in NH ₃ < $\widehat{\text{H}}\text{PH}$ in PH ₄ ⁺ |
| (D) $\widehat{\text{OSO}}$ in SO ₃ ²⁻ < $\widehat{\text{ONO}}$ in NO ₃ ⁻ |

- 6.** In which of the following back bonding is NOT possible -

- | | | | |
|--------------------------------------|-----------------------------------|--------------------------------------|----------------------------------|
| (A) N(CH ₃) ₃ | (B) BO ₃ ⁻³ | (C) P(CH ₃) ₃ | (D) BF ₄ ⁻ |
|--------------------------------------|-----------------------------------|--------------------------------------|----------------------------------|

BACK BONDING

- 7.** Molecule(s) in which maximum number of atoms in a plane may be ten.

- | | | | |
|---|---|---------------------------------------|--|
| (A) B ₂ Me ₄ H ₂ | (B) Al ₂ (CH ₃) ₆ | (C) N(SiH ₃) ₃ | (D) [Co(NH ₃) ₆] ³⁺ |
|---|---|---------------------------------------|--|

(Inorganic Chemistry)

8. Which of the following statement(s) is/are CORRECT -
- $[B_3O_6]^{3-}$ ion is non-planar but $B_3N_3H_6$ is planar
 - $(SiH_3)_3N$ is planar but $(SiH_3)_3P$ is pyramidal
 - H_3C-N C S is bent but SiH_3-NCS is linear
 - $(CH_3)_3N$ is pyramidal but $(GeH_3)_3N$ is planar
9. Which of the following statements is/are INCORRECT -
- CHF_3 is less acidic than $CHCl_3$
 - R_3C-O-H is more acidic than $R_3Si-O-H$
 - In BF_3 back bonding is possible but in CO back bonding is not possible
 - PH_3 is more basic than NH_3
10. Select the correct order of bond angle.
- | | |
|--------------------------|------------------------------|
| (A) $O(SiH_3)_2 > OCl_2$ | (B) $N(SiH_3)_3 > N(CH_3)_3$ |
| (C) $O(SiH_3)_2 < OCl_2$ | (D) $N(SiH_3)_3 < N(CH_3)_3$ |
11. In which of the following compounds, underlined atom can change their hybridisation due to back bonding :-
- $\underline{B}_3N_3H_6$
 - $\underline{N}(SiH_3)_3$
 - $O(\underline{SiH}_3)_2$
 - $H_3\underline{B}_3$

MULTICENTERED BOND

12. No X – X bond exists in which of the following compounds having general form of X_2H_6 ?
- B_2H_6
 - C_2H_6
 - Al_2H_6
 - Si_2H_6

13. Which of the following molecules have CORRECT indicated overlapping.

Molecule	Overlapping in the bridge bond (if any)
(A) Si_2Cl_6	$sp^3 - p - sp^3$
(B) Be_2H_4	$sp^2 - s - sp^2$
(C) Si_2H_6	$sp^3 - s - sp^3$
(D) B_2H_6	$sp^3 - s - sp^3$

14. In which of the following cases the number of corner oxygen shared per tetrahedron is '2' -

- Pyroxene chain silicate
- Amphibole chain silicate
- 5-membered cyclic silicate
- None of these

15. Select correct statement about NO_2 :

- It is odd electron specie
- $N - O$ bond order = 1.5
- Paramagnetic specie
- Isoelectronic with CO_2

16. The number of specie(s) which are not perfectly planar.

- $\dot{C}H_3$
- $\dot{C}F_3$
- $\dot{C}HF_2$
- $\dot{C}H_2F$

(Inorganic Chemistry)

17. Which of the following statement is CORRECT :-

- (A) The free electron of ClO_3 molecule is present in d-orbital of Cl-atom
- (B) The free electron of C_3 is present in sp^3 hybrid orbital
- (C) NO is polar
- (D) The free electron of ClO_2 molecule is present in d-orbital of Cl-atom

HYDROLYSIS

18. Which of the following compounds do not give free halogen acid (Hydrogen acid) on hydrolysis with excess water as a final product ?

- (A) NCl_3
- (B) PCl_3
- (C) SiCl_4
- (D) BF_3

MOLECULE DOES NOT EXIST

19. Which of the following species do not exist in nature.

- (A) PI_5 (TBP form)
- (B) PbI_4
- (C) HFO_3
- (D) ICl_7

20. Which of the following do/does not exist ?

- (A) SH_6
- (B) HFO_4
- (C) FeI_3
- (D) HClO_3

INERT PAIR EFFECT

21. Which of the following have $(18 + 2)$ electron configuration ?

- (A) Pb^{2+}
- (B) Cd^{2+}
- (C) Bi^{3+}
- (D) S^{-2}

22. Which of following stability order is/are correct due to inert pair effect.

- (A) $\text{Hg} > \text{Hg}^{2+}$
- (B) $\text{Bi}^{3+} < \text{Bi}^{5+}$
- (C) $\text{Pb}^{2+} > \text{Pb}^{4+}$
- (D) $\text{Fe}^{2+} < \text{Fe}^{3+}$

IONIC COMPOUND

23. Which of the following order is/are CORRECT :-

- (A) $\text{MgCO}_3 < \text{BaCO}_3$ (Thermal stability)
- (B) $\text{LiF} < \text{CsF}$ (Solubility)
- (C) $\text{Li}_3\text{N} > \text{K}_3\text{N}$ (Thermal stability)
- (D) $\text{MgSO}_3 > \text{BaSO}_3$ (Solubility)

24. Select the CORRECT order against the mentioned property :-

- (A) $\text{NaNO}_3 < \text{KNO}_3 < \text{RbNO}_3$ (Thermal stability)
- (B) $\text{NaF} > \text{KF} > \text{RbF}$ (Covalent nature)
- (C) $\text{Si} - \text{O} < \text{P} - \text{O} < \text{S} - \text{O} < \text{Cl} - \text{O}$ (π -bond strength)
- (D) $\text{F}_2 < \text{Cl}_2 < \text{Br}_2 < \text{I}_2$ (Bond length)



(Inorganic Chemistry)

25. Correct order of solubility in water will be?

- (A) LiCl > NaCl > KCl < RbCl < CsCl (B) $\text{Li}_2\text{CO}_3 < \text{Na}_2\text{CO}_3 < \text{K}_2\text{CO}_3$
 (C) LiF < NaF < KF < RbF (D) $\text{BeCO}_3 < \text{MgCO}_3 < \text{CaCO}_3$

26. Which of the following will give metal oxide on heating?

- (A) CaCO_3 (B) AgNO_3 (C) K_2CO_3 (D) Li_2CO_3

27. Which of the following order is/are CORRECT :-

- (A) $\text{NaCl} < \text{LiCl}$ (melting point) (B) $\text{CaF}_2 > \text{CaO}$ (lattice energy)
 (C) $\text{LiNO}_3 < \text{NaNO}_3$ (thermal stability) (D) $\text{Be}_3\text{N}_2 > \text{Ba}_3\text{N}_2$ (thermal stability)

MOLECULAR ORBITAL THEORY

28. Which of the following have identical bond order?

- (A) O_2^{2+} (B) NO^+ (C) CN^- (D) CN^+

29. Assuming that if Hund's rule is violated, then the diamagnetic specie(s) is/are :

- (A) B_2 (B) O_2 (C) N_2 (D) O_2^\oplus

30. The paramagnetic molecule(s) which have non fractional bond order :-

- (A) O_2 (B) O_2^\ominus (C) N_2^{2-} (D) B_2

MISCELLANEOUS

31. Bond angles which are associated with sp^3d^3 hybridization.

- (A) 90° (B) 120° (C) 180° (D) 72°

32. Which of following statement is/are CORRECT for ClOF_3 ?

- (A) In hybridisation central atom uses its d_{xy} orbital
 (B) In π -bond formation central atom uses its 'p' orbital
 (C) The shape of molecule is see-saw
 (D) The molecule is non-planar

33. Which of the following species are planar as well as polar.

- (A) I_3^+ (B) NO_2^- (C) PCl_3 (D) BO_3^{3-}



EXERCISE - III

INTEGER TYPE

1. Which of the following pairs have dipole-dipole interaction?
 $(BF_3 + BF_3), (CCl_4 + Na^+)(HCl + HCl), (CHCl_3 + CHCl_3), (K^+ + HCl), (Na^+ + Cl^-)$
2. Find the number of molecules in which axial orbital length is higher than equatorial orbital length of central atom : $PCl_5, PCl_3 F_2, PF_4 Cl, PCl_2 F_3, PF_5$
3. Find the total number of $2C - 2e^-$ bond in $Al_2(C_6H_5)_6$ (excluding π bond)
Fill your answer as sum of digits till you get the single digit answer.
4. Find the number of molecules, which do not have hybridisation, according to Drago's rule.
 $PH_3, SH_2, AsH_3, H_2Se, SiH_4$
5. $6XeF_4 + 12H_2O \rightarrow 4X + 2Y + 24HF + 3O_2$
 In above reaction find the difference of oxidation state in central atom of X and Y.
6. Total number of molecules in which bridge bond formed by $sp^3 - s^- sp^3$ type overlap
 $B_2H_6, Al_2(CH_3)_6, I_2Cl_6, Al_2H_6, Si_2Cl_6$
7. Among the following total number of planar molecules/ions is.
 $H_3O^+, I_3^\oplus, NO_2^\ominus, ClF_3, XeF_2, ICl_4^\oplus, OCl_2$
8. For the given compounds, number of compounds which undergo complete hydrolysis in presence of excess amount of water in ordinary condition :
 $SF_4, XeF_2, BiCl_3, NF_3, NCl_3, POCl_3, BF_3$
9. Find out the number (s) of molecule in which bond angle around under line atom is 120° :-
 $H_3\overline{B}O_3, \underline{P}(SiH_3)_3, \overset{+}{N}(SiH_3)_3, \overline{CH}_3, \underline{N}(CH_3)_3, \underline{Sn}Cl_3^-$
10. Find the number of chemical species which undergoes hydrolysis through redox reaction.
 $XeF_2, XeF_4, XeF_6, SF_4, PCl_3, PCl_5$
11. Find the maximum number of F atom(s) in one plane in XeF_5^+ :-
12. Find the number of molecules which are polar
 $PCl_3 F_2, PCl_2 F_3, P(CH_3)_3(CF_3)_2, P(CH_3)_2(CF_3)_3$
13. Ratio of sp^3 and sp^2 hybridized atoms in the anionic part of Borax is
(if ans is 12: 4 then represented as 124 and fill your answer as sum of digits (excluding decimal places) till you get the single digit)
14. Number of species having bond order 2 will be?
 $O_2^{+2}, N_2^{+2}, N_2^{-2}, O_2^+, N_2^+, C_2, B_2^{-2}$
15. Find the total number of $2C - 2e^-$ bond in $Al_2(C_6H_5)_6$ (excluding π bond)
 Fill your answer as sum of digits till you get the single digit answer.

EXERCISE - IV

Paragraph for Question 1 to 2

Bent's rule can be stated as follows. "The central atom projects the hybrid orbitals of less s-character" towards more electronegative atom.

1. Which of the following statement is CORRECT ?
 - (A) CH_3F is not perfect tetrahedral
 - (B) PCl_3F_2 has got a trigonal bipyramidal (T.B.P) shape.
 - (C) In PCl_3F_2 , the two fluorine atoms preferably are positioned in the axial directions.
 - (D) All are correct
2. Which of the following order is CORRECT ?

(A) $d_{\text{C}-\text{H}}$ in $\text{CH}_3\text{Cl} > d_{\text{C}-\text{H}}$ in CH_3F	(B) $d_{\text{C}-\text{H}}$ in $\text{CH}_3\text{Cl} < d_{\text{C}-\text{H}}$ in CH_3F
(C) $\overline{\text{H}}\text{P}\overline{\text{H}}(\text{PH}_3) > \overline{\text{H}}\text{P}\overline{\text{H}}(\text{PH}_4^+)$	(D) $\text{H}-\overset{\circ}{\text{C}}-\text{H}$ in $\text{CH}_4 > \text{F}-\overset{\circ}{\text{C}}-\text{F}$ in CF_4

Paragraph for Question 3 to 4

Back bonding is a type of sideways overlapping.

3. Which of the following molecule has $2p_\pi - 3d_\pi$ back bonding.

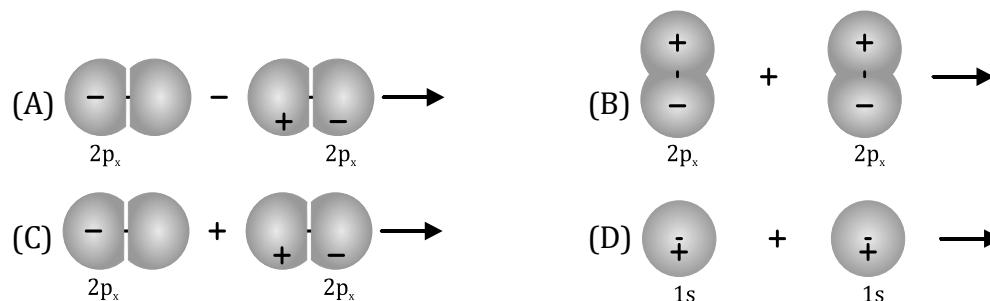
(A) PCl_3	(B) CCl_3^-	(C) BCl_3	(D) $(\text{BO}_2^-)_3$
--------------------	----------------------	--------------------	-------------------------
4. Which of the following has CORRECT order of strength of back bonding.

(A) $\text{BF}_3 > \text{BCl}_3$	(B) $\text{O}(\text{SiH}_3)_2 > \text{S}(\text{SiH}_3)_2$
(C) $\text{N}(\text{SiH}_3)_3 < \text{NH}_2\text{SiH}_3$	(D) All are correct

Paragraph for Question 5 to 6

Qualitatively, the formation of molecular orbitals can be understood in terms of the constructive or destructive interference of the electron waves of the combining atoms. In the formation of bonding molecular orbital, the two electron waves of the bonding atoms reinforce each other due to constructive interference while in the formation of antibonding molecular orbital, the electron waves cancel each other due to destructive interference.

5. Which of the following combinations give(s) antibonding sigma molecular orbital if z-axis is the internuclear axis ?



6. Which of the following specie does not exist :-

(A) HeH^+	(B) Be_2	(C) C_2^{2-}	(D) NO^+
--------------------	-------------------	-----------------------	-------------------

Paragraph for Question 7 to 8

According to Bent's Rule, which states : more electronegative substituents prefer hybrid orbitals having less s-character and more electropositive substituents prefer hybrid orbitals having more s-character

7. Among the following, which has/have equatorial bonds becomes stronger and shorter than the axial bonds ?
 (A) PCl_5 (B) ClF_3 (C) SF_4 (D) All of these
8. Which of the following has CORRECT order of their indicating properties?
 (A) $\text{F} - \hat{\text{C}} - \text{F}(\text{CH}_2\text{F}_2) > \text{H} - \hat{\text{C}} - \text{H}(\text{CH}_4)$; bond angle
 (B) $\text{PH}_3 < \text{PF}_3$; bond angle
 (C) $\text{POF}_3 < \text{POCl}_3$; P – O bond strength
 (D) All of these

Paragraph for Question 9 to 10

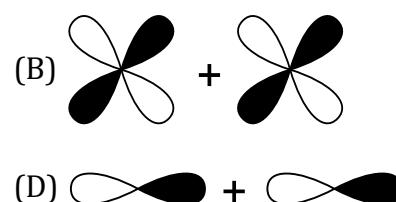
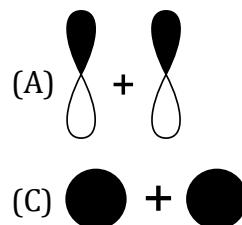
When a substance undergoes nucleophilic substitution reaction and the nucleophile is solvent itself, then the reaction is known as solvolysis, if the solvent used is water then the reaction is called as hydrolysis.

9. The product(s) of hydrolysis of NCl_3 is/are :-
 (A) HNO_2 (B) HCl (C) NH_3 (D) HOCl
10. Which of the following compounds on hydrolysis produce oxyacid having basicity three in water :-
 (A) PCl_5 (B) AsCl_3 (C) PCl_3 (D) BCl_3

Paragraph for Question 11 to 12

Molecular orbital theory is based on linear combination of atomic orbitals (LCAO). According to LCAO when respective atomic orbitals of the atoms interact, they undergo constructive and destructive interference giving two types of molecular orbital i.e. bonding and antibonding molecular orbitals respectively.

11. Which of the following overlapping result underade molecular orbital.



12. Which of the following property does not change when O_2 is converted to O_2^- :-
 (A) Magnetic behaviour (B) Magnetic moment
 (C) Bond order (D) Number of bonding electron



Paragraph for Question Nos. 13 to 15

Bridge bonding is a specific kind of bonding in pages of chemistry. In general σ -bond pair delocalisation is very difficult. But electron deficiency of the central atom forces to delocalise and forms this kind of bond.

- 13.** The state of hybridisation of central atom in dimer form of both BH_3 and BeH_2 is
 (A) sp^2, sp (B) sp^3, sp^2 (C) sp^3, sp^3 (D) sp^2, sp^3
- 14.** Which of the following molecule has complete octet
 (A) B_2H_6 (B) Al_2Cl_6 (C) Be_2Cl_4 (D) BeH_2
- 15.** Which of the following is/are electron deficient compounds?
 (A) NaBH_4 (B) B_2H_6 (C) Al_2Cl_6 (D) $\text{BeCl}_{2(s)}$

MATCHING LIST

- | | |
|------------------------------------|-----------------------------|
| 16. List I (Species) | List II (Bond order) |
| (P) O_2^- | (1) 2.5 |
| (Q) N_2^+ | (2) 1.0 |
| (R) H_2^+ | (3) 1.5 |
| (S) B_2 | (4) 0.5 |
- Code:** (P) (Q) (R) (S)
- | | | | |
|-------|---|---|---|
| (A) 2 | 3 | 4 | 1 |
| (C) 3 | 1 | 2 | 4 |
- | | | | |
|-------|-----|-----|-----|
| (P) | (Q) | (R) | (S) |
| (B) 2 | 1 | 4 | 2 |
| (D) 4 | 1 | 2 | 3 |

- | | |
|---|----------------|
| 17. List I (Unit of silicate) | |
| (P) $\text{Si}_2\text{O}_7^{6-}$ | (1) |
| (Q) $(\text{Si}_2\text{O}_{5.5})_n^{-3}$ | (2) 1 |
| (R) SiO_2 | (3) 2.5 (avg.) |
| (S) $(\text{Si}_2\text{O}_5)^{2-}$ | (4) 4 |
- Code:** (P) (Q) (R) (S)
- | | | | |
|-------|---|---|---|
| (A) 2 | 3 | 4 | 1 |
| (C) 2 | 3 | 1 | 4 |
- | | | | |
|-------|-----|-----|-----|
| (P) | (Q) | (R) | (S) |
| (B) 3 | 1 | 2 | 4 |
| (D) 4 | 2 | 3 | 1 |

- 18.** Match column-I with column-II :-
- | | |
|---------------------|------------------------------------|
| List I | List II |
| (P) BF_3 | (1) Exist in dimeric form |
| (Q) AlCl_3 | (2) Effective back bond is present |
| (R) SiO_2 | (3) Acts as lewis acid |
| (S) CO | (4) Exist in polymeric form |

- Code:** (P) (Q) (R) (S)
- | | | | |
|-------|---|---|---|
| (A) 3 | 2 | 4 | 1 |
| (C) 3 | 1 | 4 | 2 |
- | | | | |
|-------|-----|-----|-----|
| (P) | (Q) | (R) | (S) |
| (B) 1 | 2 | 4 | 3 |
| (D) 1 | 2 | 3 | 4 |

**MATRIX MATCH****19. Column-I**

- (A) BF_3
- (B) BCl_3
- (C) H_3BO_3
- (D) $\text{B}(\text{OCH}_3)_3$

Column-II

- (P) Intra molecular lewis acid-base interaction
- (Q) $2p_{\pi} - 3p_{\pi}$ back bond
- (R) Lewis acid
- (S) Incomplete octet of central atom boron
- (T) sp^2 hybridisation of boron

20. Column-I

- (A) HCl and HCl
- (B) HCl and C_6H_6
- (C) Na^+ and NH_3
- (D) K^+ and CCl_4

Column-II

- (P) dipole - dipole
- (Q) Ion-dipole
- (R) Ion-induced dipole - dipole
- (S) induced dipole
- (T) London dispersion force



EXERCISE - V

NATIONAL STANDARD EXAMINATION IN CHEMISTRY (NSEC) STAGE-I

1. Which of the following pairs has the strongest hydrogen bonding between themselves?
[NSEC-2002]

(A) SiH ₄ and SiF ₄	(B) CH ₄ and CH ₃ OH
(C) CH ₃ COCH ₃ and CHCl ₃	(D) HCO ₂ H and CH ₃ CO ₂ H

2. The number of hydrogen bonds formed by each H₂O molecule in an ice crystal is :
[NSEC-2003]

(A) 6	(B) 4	(C) 2	(D) 3
-------	-------	-------	-------

3. The molecule with non-zero dipole moment is
[NSEC-2004]

(A) BF ₃	(B) PCl ₃	(C) SiCl ₄	(D) CIF ₅
---------------------	----------------------	-----------------------	----------------------

4. Bond orders of NO and NO⁺ are respectively
[NSEC-2004]

(A) 2.5 and 3	(B) 2 and 4	(C) 3.5 and 2.5	(D) 4 and 2
---------------	-------------	-----------------	-------------

5. The molecular orbital with highest energy in a nitrogen molecule is
[NSEC-2004]

(A) σ _{2p}	(B) π _{2p}	(C) σ [*] 2p	(D) π [*] 2p
---------------------	---------------------	-----------------------	-----------------------

6. The substance that has the lowest boiling point is
[NSEC-2004]

(A) HCl	(B) H ₂ S	(C) PH ₃	(D) SiH ₄
---------	----------------------	---------------------	----------------------

7. The compound in which H-bonding is not possible is:
[NSEC-2005]

(A) CH ₃ OCH ₃	(B) H ₂ O	(C) CH ₃ CH ₂ OH	(D) CH ₃ COOH
--------------------------------------	----------------------	--	--------------------------

8. In solid CuSO₄.5H₂O, copper is coordinated to
[NSEC-2005]

(A) One water molecule	(B) three water molecules
(C) Five water molecules	(D) four water molecules.

9. In thiosulphuric acid H₂S₂O₃, the oxidation states of sulphur atoms are
[NSEC-2006]

(A) +II, +II	(B) 0, +IV	(C) +I, +III	(D) -II, +VI.
--------------	------------	--------------	---------------

10. Lewis dot structures of compounds of representative elements normally follow the octet rule.
Which of the following does not obey the octet rule?
[NSEC-2006]

(A) CO ₃ ²⁻	(B) O ₃	(C) SO ₂	(D) I ₃ ⁻
-----------------------------------	--------------------	---------------------	---------------------------------

11. Considering z-axis to be the internuclear axis, the combination of orbitals on Li and Cl atoms respectively, that can lead to a stable sigma bond
[NSEC-2006]

(A) 2 s and 3p _y	(B) 1 s and 3p _y	(C) 1 s and 3p _z	(D) 2 s and 3p _z .
-----------------------------	-----------------------------	-----------------------------	-------------------------------

12. The structures of AlCl₃ and PCl₃ can be described as
[NSEC-2006]

(A) Both planar	(B) Both pyramidal
(C) Planar and pyramidal respectively	(D) pyramidal and planar respectively.



(Inorganic Chemistry)

13. The hybrid orbitals used by chlorine in ClF_3 molecule are of the type [NSEC-2006]
 (A) sp^3 (B) sp^2 (C) sp^2d (D) sp^3d
14. The non-linear molecule is [NSEC-2006]
 (A) SO_2 (B) CO_2 (C) HCN (D) C_2H_2
15. Which of the following pairs is a Lewis acid & a Lewis base ? [NSEC-2006]
 (A) Cl^- & Ag^+ (B) NH_3 & BF_3 (C) SO_4^{2-} & HSO_4^- (D) H^+ & OH^-
16. Trisilylamine $\text{N}(\text{Si}(\text{CH}_3)_3)_3$ is [NSEC-2006]
 (A) acidic (B) basic (C) neutral (D) amphoteric
17. Which type of bond exists between the two boron atoms in a diborane molecule ? [NSEC-2007]
 (A) 2-Center-2-electron (B) 3-Center-2-electron
 (C) 3-Center-3-electron (D) 4-Center-4-electron
18. According to Molecular Orbital Theory, the oxygen molecule is- [NSEC-2007]
 (A) Diamagnetic (B) Paramagnetic
 (C) Ferromagnetic (D) non magnetic
19. In which of the following pairs are both molecules polar? [NSEC-2008]
 (A) O_2 and H_2O (B) BF_3 and PCl_3 (C) SO_2 and SCl_2 (D) CS_2 and NO_2
20. The species containing the maximum number of lone pairs in the central atom is: [NSEC-2009]
 (A) ClO_3^- (B) XeF_4 (C) SF_4 (D) I_3^-
21. The electron-pair geometry of the central oxygen atom of ozone is - [NSEC-2009]
 (A) linear (B) trigonal planar
 (C) tetrahedral (D) trigonal bipyramidal
22. The sequence of molecular orbitals for the carbide ion (C_2^{2-}) is - [NSEC-2009]
 (A) $\sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \pi 2p^4$
 (B) $\sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \pi 2p^4 \sigma 2p^2$
 (C) $\sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \pi 2p^4 \sigma 2p^2 \pi^* 2p^2$
 (D) $\sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \pi 2p^4 \sigma 2p^2 \pi^* 2p^4$
23. The change in hybridization of aluminium when Al_2Cl_6 decomposes in the gas phase is: [NSEC-2010]
 (A) $\text{sp}^2 \rightarrow \text{sp}^3$ (B) $\text{sp} \rightarrow \text{sp}^2$ (C) $\text{sp} \rightarrow \text{sp}^3$ (D) $\text{sp}^3 \rightarrow \text{sp}^2$



(Inorganic Chemistry)

24. The species that contains maximum number of electrons in the antibonding molecular orbitals is : [NSEC-2010]
- (A) O_2^{2-} (B) O_2 (C) O_2^- (D) O_2^+
25. The compound that has the highest ionic character associated with the X-Cl bond is [NSEC-2010]
- (A) PCl_5 (B) BCl_3 (C) CCl_4 (D) $SiCl_4$
26. According to VSEPR theory the shape of IF_5 molecule will be: [NSEC-2011]
- (A) Tetrahedral (B) trigonal bipyramidal
 (C) Square pyramid (D) Trigonal planar
27. The compound that does not have a π bond is: [NSEC-2011]
- (A) SO_2 (B) SF_6 (C) O_2 (D) SO_3
28. The species in which the central atom uses sp^2 hybrid orbitals is [NSEC-2012]
- (A) PH_3 (B) NH_3 (C) CH_3^+ (D) SbH_3
29. In which of the following ion/molecule, the 'S' atom does not assume sp^3 hybridization ? [NSEC-2012]
- (A) SO_4^{2-} (B) SF_4 (C) SF_2 (D) S_8
30. Which of the following compounds has the least tendency to form hydrogen bonds between molecules? [NSEC-2012]
- (A) NH_3 (B) NH_2OH (C) HF (D) CH_3F
31. The bond order of NO^+ ion is: [NSEC-2012]
- (A) 1 (B) 2 (C) 2.5 (D) 3
32. Which of the following molecular structures is NOT possible? [NSEC-2012]
- (A) OF_2 (B) SF_2 (C) OF_4 (D) SF_4
33. The species having highest bond energy is [NSEC-2014]
- (A) O_2 (B) O_2^+ (C) O_2^- (D) O_2^{2-}
34. The structure of a molecule of $N(SiMe_3)_3$ is [NSEC-2015]
- (A) Pyramidal with angle close to 110°
 (B) T-shaped with angle 90°
 (C) Bent T-shaped with angle close to 89°
 (D) Trigonal planar with bond angle close to 120°
35. The order of $p\pi - d\pi$ interaction in the compounds containing bond between Si/P/S/Cl and oxygen is in the order [NSEC-2015]
- (A) $P > Si > Cl > S$ (B) $Si < P < S < Cl$
 (C) $S < Cl < P < Si$ (D) $Si > P > S > Cl$

**EXERCISE - JEE - MAIN**

1. Which one of the following molecules is expected to exhibit diamagnetic behaviour ? [AIEEE-2013]
 (A) C_2 (B) N_2 (C) O_2 (D) S_2

2. In which of the following pairs of molecules/ions, both the species are not likely to exist ? [JEE-M-2013]
 (A) H_2^+, He_2^{2-} (B) H_2^-, He_2^{2-} (C) H_2^{2+}, He (D) H_2^-, He_2^{2+}

3. Stability of the species Li_2 , Li_2^- and Li_2^+ increases in the order of : - [JEE-M-2013]
 (A) $Li_2 < Li_2^+ < Li_2^-$ (B) $Li_2^- < Li_2^+ < Li_2$
 (C) $Li_2 < Li_2^- < Li_2^+$ (D) $Li_2^- < Li_2 < Li_2^+$

4. Which one of the following properties is not shown by NO ? [JEE-M-2014]
 (A) It combines with oxygen to form nitrogen dioxide
 (B) Its bond order is 2.5
 (C) It is diamagnetic in gaseous state
 (D) It is a neutral oxide

5. The correct order of thermal stability of hydroxides is : [JEE-M-2015 (on line)]
 (A) $Ba(OH)_2 < Sr(OH)_2 < Ca(OH)_2 < Mg(OH)_2$
 (B) $Mg(OH)_2 < Sr(OH)_2 < Ca(OH)_2 < Ba(OH)_2$
 (C) $Mg(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Ba(OH)_2$
 (D) $Ba(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Mg(OH)_2$

6. Which of the alkaline earth metal halides given below is essentially covalent in nature : - [JEE-M-2015 (on line)]
 (A) $SrCl_2$ (B) $CaCl_2$ (C) $BeCl_2$ (D) $MgCl_2$

7. Which one of the following alkaline earth metal sulphates has its hydration enthalpy greater than its lattice enthalpy ? [JEE-M-2015]
 (A) $BaSO_4$ (B) $SrSO_4$ (C) $CaSO_4$ (D) $BeSO_4$

8. The intermolecular interaction that is dependent on the inverse cube of distance between the molecules is : - [JEE-M-2015]
 (A) London force (B) Hydrogen bond
 (C) ion-ion interaction (D) ion-dipole interaction

9. Which one has the highest boiling point ? [JEE-M-2015]
 (A) Kr (B) Xe (C) He (D) Ne

10. Which intermolecular force is most responsible in allowing xenon gas to liquefy? [JEE (MAIN) ONLINE 2016]

(Inorganic Chemistry)

- 21.** Which of following is a Lewis acid? [JEE Main online - 2018]
(A) PH_3 (B) $\text{B}(\text{CH}_3)_3$ (C) NaH (D) NF_3

22. (I) (II)

In hydrogen azide (above) the bond orders of bonds (I) and (II) are

[JEE Main online - 2018]

- (I) (II) (I) (II) (I) (II) (I) (II)
 (A) $\leq 2 \geq 2$ (B) $\geq 2 < 2$ (C) $\geq 2 \geq 2$ (D) $\leq 2 \leq 2$

- 23.** The decreasing order of bond angles in BF_3 , NH_3 , PF_3 and I_3^- is :

[JEE Main online - 2018]

- (A) $\text{I}_3^- > \text{NH}_3 > \text{PF}_3 > \text{BF}_3$ (B) $\text{I}_3^- > \text{BF}_3 > \text{NH}_3 > \text{PF}_3$
(C) $\text{BF}_3 > \text{I}_3^- > \text{PF}_3 > \text{NH}_3$ (D) $\text{BF}_3 > \text{NH}_3 > \text{PF}_3 > \text{I}_3^-$

24. Xenon hexafluoride on partial hydrolysis produces compounds 'X' and 'Y'. Compounds 'X' and 'Y' and the oxidation state of Xe are respectively:

[JEE Main online - 2018]

- (A) $\text{XeO}_2(+4)$ and $\text{XeO}_3(+6)$
(B) $\text{XeOF}_4(+6)$ and $\text{XeO}_3(+6)$
(C) $\text{XeO}_2\text{F}_2(+6)$ and $\text{XeO}_2(+4)$
(D) $\text{XeOF}_4(+6)$ and $\text{XeO}_2\text{F}_2(+6)$

25. Among the oxides of nitrogen : N_2O_3 , N_2O_4 and N_2O_5 ; the molecule(s) having N - N bond is/are:

[JEE Main online - 2018]

- 26.** Which of the following conversions involves change in both shape and hybridisation?

[JEE Main online - 2018]

- (A) $\text{NH}_3 \rightarrow \text{NH}_4^+$ (B) $\text{CH}_4 \rightarrow \text{C}_2\text{H}_6$
 (C) $\text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+$ (D) $\text{BF}_3 \rightarrow \text{BF}_4^-$

27. A group 13 element 'X' reacts with chlorine gas to produce a compound XCl_3 is electron deficient and easily reacts with NH_3 to form $\text{Cl}_3\text{X} \leftarrow \text{NH}_3$ adduct; however, XCl_3 does not dimerize. X is:

[JEE Main online - 2018]

- 28.** Which of the following best describes the diagram below of a molecular orbital?

[JEE Main online - 2018]

29. In KO_2 , the nature of oxygen species and the oxidation state of oxygen atom are, respectively:

[JEE Main online - 2018]



(Inorganic Chemistry)

47. The number of bonds between sulphur and oxygen atoms in $S_2O_8^{2-}$ and the number of bonds between sulphur and sulphur atoms in rhombic sulphur, respectively, are :

[JEE Main online - 2020]

- (A) 4 and 6 (B) 8 and 8 (C) 4 and 8 (D) 8 and 6

48. The predominant intermolecular forces present in ethyl acetate, a liquid, are :

[JEE Main online - 2020]

- (A) London dispersion, dipole-dipole and hydrogen bonding [JEE Main online - 2020]
 (B) hydrogen bonding and London dispersion
 (C) Dipole-dipole and hydrogen bonding
 (D) London dispersion and dipole-dipole

49. Arrange the following bonds according to their average bond energies in descending order :



[JEE Main online - 2020]

- (A) $C - F > C - Cl > C - Br > C - I$
 (B) $C - Cl > C - Br > C - I > C - F$
 (C) $C - I > C - Br > C - Cl > C - F$
 (D) $C - Br > C - I > C - Cl > C - F$

50. If the magnetic moment of a dioxygen species is 1.73 B.M, it may be :

[JEE Main online - 2020]

- (A) O_2^- or O_2^+
 (B) O_2 or O_2^-
 (C) O_2 or O_2^+
 (D) O_2, O_2^- or O_2^+

51. The acidic, basic and amphoteric oxides, respectively, are:

[JEE Main online - 2020]

- (A) MgO, Cl_2O, Al_2O_3
 (B) N_2O_3, Li_2O, Al_2O_3
 (C) Cl_2O, CaO, P_4O_{10}
 (D) Na_2O, SO_3, Al_2O_3

52. The number of sp^2 hybrid orbitals in a molecule of benzene is :

[JEE Main online - 2020]

- (A) 6 (B) 24 (C) 18 (D) 12

53. The sum of the total number of bonds between chromium and oxygen atoms in chromate and dichromate ions is _____ .

[JEE Main online - 2020]



(Inorganic Chemistry)

54. Which of the following are isostructural pairs? [JEE Main 2021]

- | | |
|--|---|
| (A) SO_4^{2-} and CrO_4^{2-} | (B) SiCl_4 and TiCl_4 |
| (C) NH_3 and NO_3^- | (D) BCl_3 and BrCl_3 |
| (A) A and C only | (B) A and B only |
| (C) B and C only | (D) C and D only |

55. The correct shape and I-I-I bond angles respectively in I_3^- ion are : [JEE Main 2021]

- (A) Trigonal planar; 120°
- (B) Distorted trigonal planar; 135° and 90°
- (C) Linear; 180°
- (D) T-shaped; 180° and 90°

56. According to molecular orbital theory, the species among the following that does not exist is:

- | | | | |
|---------------------|---------------------|-----------------------|-------------------|
| (A) He_2^- | (B) He_2^+ | (C) O_2^{2-} | (D) Be_2 |
|---------------------|---------------------|-----------------------|-------------------|
- [JEE Main 2021]

57. Which among the following species has unequal bond lengths?

- | | | | |
|--------------------|--------------------|---------------------|-------------------|
| (A) XeF_4 | (B) SiF_4 | (C) BF_4^- | (D) SF_4 |
|--------------------|--------------------|---------------------|-------------------|

58. Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R.

Assertion A : Dipole-dipole interactions are the only non-covalent interactions, resulting in hydrogen bond formation

Reason R : Fluorine is the most electronegative element and hydrogen bonds in HF are symmetrical In the light of the above statements, choose the most appropriate answer from the options given below : [JEE Main 2021]

- (A) A is false but R is true
- (B) Both A and R are true and R is the correct explanation of A
- (C) A is true but R is false
- (D) Both A and R are true and R is not the correct explanation of A

59. Match List-I with List-II. [JEE Main 2021]

List-I (Molecule) **List-II (Bond order)**

- | | |
|-------------------|---------|
| (a) Ne_2 | (i) 1 |
| (b) N_2 | (ii) 2 |
| (c) F_2 | (iii) 0 |
| (d) O_2 | (iv) 3 |

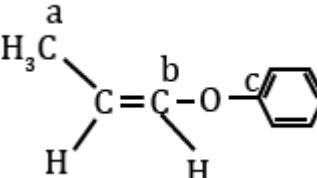
Choose the correct answer from the options given below:

[JEE Main 2021]

- (A) (a) - (iii), (b) - (iv), (c) - (i), (d) - (iii)
 (B) (a) - (i), (b) - (ii), (c) - (iii), (d) - (iv)
 (C) (a) - (ii), (b) - (i), (c) - (iv), (d) - (iii)
 (D) (a) - (iv), (b) - (iii), (c) - (ii), (d) - (i)

60. AX is a covalent diatomic molecule where A and X are second row elements of periodic table. Based on Molecular orbital theory, the bond order of AX is 2.5. The total number of electrons in AX is ____ (Round off to the Nearest Integer). **[JEE Main 2021]**

61. In the following molecules,



Hybridisation of carbon a, b and c respectively are : **[JEE Main 2021]**

(A) sp^3 , sp , sp (B) sp^3 , sp^2 , sp
 (C) sp^3 , sp^2 , sp^2 (D) sp^3 , sp , sp^2

62. The number of species below that have two lone pairs of electrons in their central atom is ____ (Round off to the Nearest integer) SF_4 , BF_4^- , CIF_3 , AsF_3 , PCl_5 , BrF_5 , XeF_4 , SF_6 **[JEE Main 2021]**

63. Identify the species having one π -bond and maximum number of canonical forms from the following : **[JEE Main 2021]**

(A) SO_3 (B) O_2 (C) SO_2 (D) CO_3^{2-}

64. Given below are two statements: One is labelled as Assertion A and the other labelled as Reason R.
[JEE Main 2021]
 Assertion A : Lithium halides are somewhat covalent in nature.
 Reason R : Lithium possess high polarisation capability.
 In the light of the above statements, choose the most appropriate answer from the options given below:
 (A) A is true but R is false
 (B) A is false but R is true
 (C) Both A and R are true but R is NOT the correct explanation of A
 (D) Both A and R are true and R is the correct explanation of A

65. The total number of electrons in all bonding molecular orbitals of O_2^{2-} is ____ (Round off to the nearest integer) **[JEE Main 2021]**



(Inorganic Chemistry)

66. Match List I with List II :

[JEE Main 2022]

List-I (molecule)	List-II (hybridization; shape)
A. XeO_3	I. $\text{sp}^3 \text{ d}$; linear
B. XeF_2	II. sp^3 ; pyramidal
C. XeOF_4	III. $\text{sp}^3 \text{ d}^3$; distorted octahedral
D. XeF_6	IV. $\text{sp}^3 \text{ d}^2$; square pyramidal

Choose the correct answer from the options given below:

(A) A-II, B-I, C-IV, D-III

(B) A-II, B-IV, C-III, D-I

(C) A-IV, B-II, C-III, D-I

(D) A-IV, B-II, C-I, D-III

67. The total number of acidic oxides from the following list is: NO , N_2O , B_2O_3 , N_2O_5 , CO , SO_3 , P_4O_{10}

(A) 3

(B) 4

(C) 5

(D) 6

[JEE Main 2022]

68. Arrange the following in increasing order of their covalent character.

[JEE Main 2022]

(A) CaF_2 (B) CaCl_2 (C) CaBr_2 (D) CaI_2

Choose the correct answer from the options given below.

(A) $\text{B} < \text{A} < \text{C} < \text{D}$ (B) $\text{A} < \text{B} < \text{C} < \text{D}$ (C) $\text{A} < \text{B} < \text{D} < \text{C}$ (D) $\text{A} < \text{C} < \text{B} < \text{D}$

69. The number of molecule(s) or ion(s) from the following having non-planar structure is

 NO_3^- , H_2O_2 , BF_3 , PCl_3 , XeF_4

[JEE Main 2022]

 SF_4 , XeO_3 , PH_4^+ , SO_3 , $[\text{Al}(\text{OH})_4]^-$

70. Based upon VSEPR theory, match the shape (geometry) of the molecules in List-I with the

[JEE Main 2022]

molecules in List-II and select the most appropriate option

List-I (Shape)

List-II (Molecules)

(A) T-shaped

(I) XeF_4

(B) Trigonal planar

(II) SF_4

(C) Square planar

(III) ClF_3

(D) See-saw

(IV) BF_3

(A) (A) - I, (B) - (II), (C) - (III), (D) - (IV)

(B) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

(C) (A) - (III), (B) - (IV), (C) - (II), (D) - (I)

(D) (A) - (IV), (B) - (III), (C) - (I), (D) - (II)



(Inorganic Chemistry)

71. Consider the species CH_4 , NH_4^+ and BH_4^- . Choose the correct option with respect to the three species: [JEE Main 2022]

- (A) They are isoelectronic and only two have tetrahedral structures
- (B) They are isoelectronic and all have tetrahedral structures
- (C) Only two are isoelectronic and all have tetrahedral structures
- (D) Only two are isoelectronic and only two have tetrahedral structures

72. What is the number of unpaired electron(s) in the highest occupied molecular orbital of the following species : N_2 : N_2^+ ; O_2 ; O_2^+ ? [JEE Main 2023]

- (A) 0,1,2,1
- (B) 2,1,2,1
- (C) 0,1,0,1
- (D) 2,1,0,1

73. **Statement I :-** Dipole moment is a vector quantity and by convention it is depicted by a small arrow with tail on the negative centre and head pointing towards the positive centre.

Statement II :- The crossed arrow of the dipole moment symbolizes the direction of the shift of charges in the molecules.

In the light of the above statements, choose the most appropriate answer from the options given below :- [JEE Main 2023]

- (A) Both Statement I and Statement II are correct.
- (B) Statement I is incorrect but Statement II is correct.
- (C) Both Statement I and Statement II are incorrect.
- (D) Statement I is correct but Statement II is incorrect.

74. The number of given orbitals which have electron density along the axis is _____

$p_x, p_y, p_z, d_{xy}, d_{yz}, d_{xz}, d_{z^2}, d_{x^2-y^2}$

[JEE Main 2023]

75. Match List I with List II

LIST-I (molecules/ions)		LIST-II (No. of lone pairs of e^- on central atom)	
(A)	IF_7	I.	Three
(B)	ICl_4^-	II.	One
(C)	XeF_6	III.	Two
(D)	XeF_2	IV.	Zero

Choose the correct answer from the options given below:

[JEE Main 2023]

- (A) A – II, B – III, C – IV, D – I
- (B) A – IV, B – III, C – II, D – I
- (C) A – II, B – I, C – IV, D – III
- (D) A – IV, B – I, C – II, D – III



76. Match List I with List II

[JEE Main 2023]

List I	List II
A. XeF_4	I. See - saw
B. SF_4	II. Square planar
C. NH_4^+	III. Bent T-shaped
D. BrF	IV. Tetrahedral

Choose the correct answer from the options given below:

(A) A-IV, B-III, C-II, D-I

(B) A-II, B-I, C-III, D-IV

(C) A-IV, B-I, C-II, D-III

(D) A-II, B-I, C-IV, D-III

77. Amongst the following, the number of species having the linear shape is _____.

 $\text{XeF}_2, \text{I}_3^+, \text{C}_3\text{O}_2, \text{I}_3^-, \text{CO}_2, \text{SO}_2, \text{BeCl}$ and BCl_2^\ominus

[JEE Main 2023]

**EXERCISE – JEE – ADVANCED**

1. The molecules that will have dipole moment are : [IIT-1992]

(A) 2, 2-dimethylpropane	(B) trans-pent-2-ene
(C) cis-hex-3-ene	(D) 2, 2, 3, 3-tetramethylbutane
2. Which of the following have identical bond order ? [IIT-1992]

(A) CN^-	(B) O_2^-	(C) NO^+	(D) CN^+
-------------------	--------------------	-------------------	-------------------
3. Among the following the one that is polar and has the central atom with sp^2 hybridisation is: [IIT-1997]

(A) H_2CO_3	(B) SiF_4	(C) BF_3	(D) HClO_2
-----------------------------	--------------------	-------------------	---------------------
4. Which of the following is soluble in water ? [IIT-98]

(A) CS_2	(B) $\text{C}_2\text{H}_5\text{OH}$	(C) CCl_4	(D) CHCl_3
-------------------	-------------------------------------	--------------------	---------------------
5. The correct order of hybridization of the central atom in the following species NH_3 , $[\text{PtCl}_4]^{2-}$, PCl_5 and BCl_3 is : [IIT-2001]

(A) dsp^2 , sp^3 d, sp^2 and sp^3	(B) sp^3 , dsp^2 , sp^3 d, sp^2
(C) dsp^2 , sp^2 , sp^3 , sp^3 d	(D) dsp^2 , sp^3 , sp^2 , sp^3 d
6. The common features among the species CN^- , CO and NO^+ are : [IIT-2001]

(A) bond order three and isoelectronic
(B) bond order three and weak field ligands
(C) bond order two and π -acceptors
(D) isoelectronic and weak field ligands
7. Which of the following molecular species has unpaired electron(s)? [JEE-2002]

(A) N_2	(B) F_2	(C) O_2^-	(D) O_2^{2-}
------------------	------------------	--------------------	-----------------------
8. According to molecular orbital theory which of the following statement about the magnetic character and bond order is correct regarding O_2^+ [JEE-2004]

(A) Paramagnetic and Bond order $< \text{O}_2$
(B) Paramagnetic and Bond order $> \text{O}_2$
(C) Diamagnetic and Bond order $< \text{O}_2$
(D) Diamagnetic and Bond order $> \text{O}_2$
9. Among the following, the paramagnetic compound is [JEE-2007]

(A) Na_2O_2	(B) O_3	(C) N_2O	(D) KO_2
-----------------------------	------------------	--------------------------	-------------------
10. The species having bond order different from that in CO is [JEE-2007]

(A) NO^-	(B) NO^+	(C) CN^-	(D) N_2
-------------------	-------------------	-------------------	------------------

- 11.** **Statement-1 :** In water, orthoboric acid behaves as a weak monobasic acid. **[JEE-2007]**
Statement-2 : In water, orthoboric acid acts as a proton donor.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.
(C) Statement-1 is True, Statement-2 is False.
(D) Statement-1 is False, Statement-2 is True.

12. **Statement-1 :** Pb^{+4} compounds are stronger oxidizing agents than Sn^{4+} compounds
Statement-2 : The higher oxidation states for the group 14 elements are more stable for the heavier members of the group due to 'inert pair effect'. **[JEE-2008]**
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.
(C) Statement-1 is True, Statement-2 is False.
(D) Statement-1 is False, Statement-2 is True.

13. Match each of the diatomic molecules/ions in Column I with its property/properties in Column II. **[JEE-2009]**

Column I	Column II
(A) B_2	(P) Paramagnetic
(B) N_2	(Q) undergoes oxidation
(C) O_2^-	(R) Undergoes reduction
(D) O_2	(S) Bond order ≥ 2
	(T) Mixing of 's' and 'p' orbitals

14. In the reaction $2\text{X} + \text{B}_2\text{H}_6 \rightarrow [\text{BH}_2(\text{X})_2]^+[\text{BH}_4]^-$ the amine(s) X is (are) **[JEE-2009]**
(A) NH_3 (B) CH_3NH_2 (C) $(\text{CH}_3)_2\text{NH}$ (D) $(\text{CH}_3)_3\text{N}$

15. The species having pyramidal shape is **[JEE-2010]**
(A) SO_3 (B) BrF_3 (C) SiO_3^{2-} (D) OsF_2

16. Assuming that Hund's rule is violated, the bond order and magnetic nature of the diatomic molecule B_2 is **[JEE-2010]**
(A) 1 and diamagnetic (B) 0 and diamagnetic
(C) 1 and paramagnetic (D) 0 and paramagnetic

17. The value of n in the molecular formula $\text{Be}_n\text{Al}_2\text{Si}_6\text{O}_{18}$ is **[JEE-2010]**

- 18.** The total number of diprotic acids among the following is [JEE-2010]

H₃PO₄ H₂SO₄ H₂CO₃ H₂S₂O₇
H₃BO₃ H₃PO₂ H₂CrO₄ H₂SO₃

19. Among the following, the number of elements showing only one non-zero oxidation state is O, Cl, F, N, P, Sn, Tl, Na, Ti [JEE-2010]

20. Assuming 2s-2p mixing is NOT operative, the paramagnetic species among the following is : [JEE Adv. 2014]

(A) Be₂ (B) B₂ (C) C₂ (D) N₂

21. Match the orbital overlap figures shown in List-I with the description given in List-II and select the correct answer using the code given below the lists. [JEE Adv. 2014]

List-I	List-II
(P)	(1) p – dπ antibonding
(Q)	(2) d – dσ bonding
(R)	(3) d – dσ antibonding

Code: (P) (Q) (R) (S) (P) (Q) (R) (S)

(A) 2 1 3 4 (B) 4 3 1 2
(C) 2 3 1 4 (D) 4 1 3 2

22. Three moles of B₂H₆ are completely reacted with methanol. The number of moles of boron containing product formed is - [JEE Adv. 2015]

23. When O₂ is adsorbed on a metallic surface, electron transfer occurs from the metal to O₂. The TRUE statement (s) regarding this adsorption is (are) [JEE Adv. 2015]

(A) O₂ is physisorbed
(B) heat is released
(C) occupancy of π*_{2p} of O₂ is increased
(D) bond length of O₂ is increased

24. According to Molecular Orbital Theory, [JEE Adv. 2016]

(A) C₂²⁻ is expected to be diamagnetic
(B) O₂²⁺ is expected to have a longer bond length than O₂
(C) N₂⁺ and N₂⁻ have the same bond order
(D) He₂⁺ has the same energy as two isolated He atoms

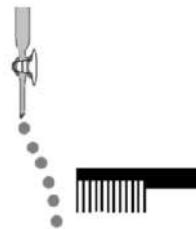
25. The order of the oxidation state of the phosphorus atom in H₃PO₂, H₃PO₄, H₃PO₃, and H₄P₂O₆ is [JEE Adv. 2017]

(A) H₃PO₄ > H₃PO₂ > H₃PO₃ > H₄P₂O₆ (B) H₃PO₃ > H₃PO₂ > H₃PO₄ > H₄P₂O₆
(C) H₃PO₄ > H₄P₂O₆ > H₃PO₃ > H₃PO₂ (D) H₃PO₂ > H₃PO₃ > H₄P₂O₆ > H₃PO₄



(Inorganic Chemistry)

- 26.** The correct statement(s) about the oxoacid, HClO_4 and HClO is(are) [JEE Adv. 2017]
- (A) HClO_4 is more acidic than HClO because of the resonance stabilization of its anion
 - (B) HClO_4 is formed in the reaction between Cl_2 and H_2O
 - (C) The central atom in both HClO_4 and HClO is sp^3 hybridized
 - (D) The conjugate base of HClO_4 is weaker base than H_2O
- 27.** The colour of the X_2 molecules of group 17 elements changes gradually from yellow to violet down the group. This is due to [JEE Adv. 2017]
- (A) the physical state of X_2 at room temperature changes from gas to solid down the group
 - (B) Decrease in HOMO-LUMO gap down the group
 - (C) decrease in $\pi^* - \sigma^*$ gap down the group
 - (D) decrease in ionization energy down the group
- 28.** Among the following, the correct statement(s) is (are) [JEE Adv. 2017]
- (A) $\text{Al}(\text{CH}_3)_3$ has the three-centre two-electron bonds in its dimeric structure
 - (B) AlCl_3 has the three-centre two-electron bonds in its dimeric structure
 - (C) BH_3 has the three-centre two-electron bonds in its dimeric structure
 - (D) The Lewis acidity of BCl_3 is greater than that of AlCl_3
- 29.** The option(s) with only amphoteric oxides is (are) [JEE Adv. 2017]
- | | |
|--|--|
| (A) Cr_2O_3 , BeO , SnO , SnO_2 | (B) ZnO , Al_2O_3 , PbO , PbO_2 |
| (C) NO , B_2O_3 , PbO , SnO_2 | (D) Cr_2O_3 , CrO , SnO , PbO |
- 30.** Among H_2 , He_2^+ , Li_2 , Be_2 , B_2 , C_2 , N_2 , O_2^- , and F_2 the number of diamagnetic species is (Atomic number H = 1, He = 2, Li = 3, Be = 4, B = 5, C = 6, N = 7, O = 8, F = 9) [JEE Adv. 2017]
- 31.** The sum of the number of lone pairs of electrons on each central atom in the following species is $[\text{TeBr}_6]^{2-}$, $[\text{BrF}_2]^+$, SNF_3 and $[\text{XeF}_3]^-$ (Atomic number: N = 7, F = 9, S = 16, Br = 35, Te = 52, Xe = 54) [JEE Adv. 2017]
- 32.** Each of the following options contains a set of four molecules. Identify the option(s) where all four molecules possess permanent dipole moment at room temperature. [JEE Adv. 2019]
- | | |
|--|--|
| (A) NO_2 , NH_3 , POCl_3 , CH_3Cl | (B) BeCl_2 , CO_2 , BCl_3 , CHCl_3 |
| (C) SO_2 , $\text{C}_6\text{H}_5\text{Cl}$, H_2Se , BrF_5 | (D) BF_3 , O_3 , SF_6 , XeF_6 |
- 33.** Among B_2H_6 , $\text{B}_3\text{N}_3\text{H}_6$, N_2O , N_2O_4 , $\text{H}_2\text{S}_2\text{O}_3$ and $\text{H}_2\text{S}_2\text{O}_8$, the total number of molecules containing covalent bond between two atoms of the same kind is _____. [JEE Adv. 2019]
- 34.** Consider the following compounds in the liquid form : O_2 , HF , H_2O , NH_3 , H_2O_2 , CCl_4 , CHCl_3 , C_6H_6 , $\text{C}_6\text{H}_5\text{Cl}$. [JEE Adv. 2020]
- When a charged comb is brought near their flowing stream, how many of them show deflection as per the following figure?



35. For diatomic molecules, the correct statement(s) about the molecular orbitals formed by the overlap of two $2p_z$ orbitals is(are) [JEE Adv. 2022]

- (A) σ orbital has a total of two nodal planes.
- (B) σ^* orbital has one node in the xz -plane containing the molecular axis.
- (C) π orbital has one node in the plane which is perpendicular to the molecular axis and goes through the center of the molecule.
- (D) π^* orbital has one node in the xy -plane containing the molecular axis.

**ANSWER KEY****EXERCISE - I**

- | | | | | | | | | | | | | | |
|-----|---|-----|---|-----|---|-----|---|-----|---|-----|---|-----|---|
| 1. | A | 2. | B | 3. | D | 4. | C | 5. | C | 6. | D | 7. | D |
| 8. | B | 9. | C | 10. | C | 11. | B | 12. | D | 13. | A | 14. | A |
| 15. | C | 16. | B | 17. | B | 18. | A | 19. | B | 20. | B | 21. | D |
| 22. | D | 23. | C | 24. | D | 25. | D | 26. | B | 27. | D | 28. | C |
| 29. | C | 30. | C | 31. | A | 32. | A | 33. | A | 34. | D | 35. | B |
| 36. | C | 37. | C | 38. | D | 39. | A | 40. | C | 41. | C | 42. | D |
| 43. | A | 44. | D | 45. | D | 46. | C | 47. | C | 48. | A | 49. | C |
| 50. | B | 51. | D | 52. | D | 53. | D | 54. | D | 55. | D | 56. | B |
| 57. | D | 58. | B | 59. | C | 60. | C | 61. | D | 62. | D | 63. | D |
| 64. | B | 65. | C | 66. | B | 67. | D | 68. | B | 69. | C | 70. | B |
| 71. | C | 72. | B | 73. | A | 74. | C | 75. | A | 76. | A | 77. | A |

EXERCISE - II

- | | | | | | | | | | |
|-----|------|-----|-----|-----|------|-----|------|-----|-----|
| 1. | ABCD | 2. | ACD | 3. | AB | 4. | AB | 5. | ACD |
| 6. | ACD | 7. | AB | 8. | BCD | 9. | BCD | 10. | AB |
| 11. | BD | 12. | AC | 13. | BD | 14. | AC | 15. | ABC |
| 16. | BCD | 17. | BCD | 18. | AD | 19. | ABCD | 20. | ABC |
| 21. | AC | 22. | AC | 23. | ABCD | 24. | ABCD | 25. | ABC |
| 26. | AD | 27. | CD | 28. | ABC | 29. | ABC | 30. | ACD |
| 31. | ACD | 32. | CD | 33. | AB | | | | |

EXERCISE - III

- | | | | | | | | | | | | | | |
|-----|---|----|---|-----|---|-----|---|-----|---|-----|---|-----|---|
| 1. | 2 | 2. | 5 | 3. | 7 | 4. | 4 | 5. | 6 | 6. | 2 | 7. | 6 |
| 8. | 4 | 9. | 2 | 10. | 2 | 11. | 4 | 12. | 2 | 13. | 4 | 14. | 4 |
| 15. | 7 | | | | | | | | | | | | |

EXERCISE - IV

- | | | | | | | | | | | | | | |
|-----|--|-----|----|-----|----|-----|----|-----|----|-----|---|-----|---|
| 1. | D | 2. | A | 3. | B | 4. | D | 5. | A | 6. | B | 7. | D |
| 8. | B | 9. | CD | 10. | AB | 11. | AD | 12. | AD | 13. | B | 14. | B |
| 15. | B | 16. | B | 17. | A | 18. | C | | | | | | |
| 19. | A P, R, S, T; B P, Q, R, S ;T; C P, R, S, T ; D P, R, S, T | | | | | | | | | | | | |
| 20. | A P, S, T; B Q, R, S ; C P, R, S ; D Q | | | | | | | | | | | | |

**EXERCISE - V**

- | | | | | | | | | | | | | | |
|-----|---|-----|---|-----|---|-----|---|-----|---|-----|---|-----|---|
| 1. | D | 2. | B | 3. | B | 4. | A | 5. | C | 6. | D | 7. | A |
| 8. | D | 9. | D | 10. | D | 11. | D | 12. | C | 13. | D | 14. | A |
| 15. | D | 16. | C | 17. | B | 18. | B | 19. | C | 20. | D | 21. | B |
| 22. | B | 23. | D | 24. | A | 25. | D | 26. | C | 27. | B | 28. | C |
| 29. | B | 30. | D | 31. | D | 32. | C | 33. | C | 34. | B | 35. | D |
| 36. | B | | | | | | | | | | | | |

EXERCISE - JEE MAIN

- | | | | | | | | | | | | | | |
|-----|---|-----|----|-----|---|-----|----|-----|---|-----|---|-----|---|
| 1. | B | 2. | C | 3. | B | 4. | C | 5. | C | 6. | C | 7. | D |
| 8. | B | 9. | B | 10. | B | 11. | D | 12. | B | 13. | D | 14. | C |
| 15. | D | 16. | A | 17. | D | 18. | C | 19. | A | 20. | B | 21. | B |
| 22. | A | 23. | B | 24. | D | 25. | D | 26. | D | 27. | A | 28. | D |
| 29. | B | 30. | C | 31. | C | 32. | C | 33. | C | 34. | C | 35. | D |
| 36. | A | 37. | D | 38. | C | 39. | D | 40. | A | 41. | B | 42. | B |
| 43. | B | 44. | A | 45. | D | 46. | A | 47. | B | 48. | D | 49. | A |
| 50. | A | 51. | B | 52. | C | 53. | 12 | 54. | B | 55. | C | 56. | D |
| 57. | D | 58. | C | 59. | A | 60. | 15 | 61. | C | 62. | 2 | 63. | D |
| 64. | D | 65. | 10 | 66. | A | 67. | B | 68. | B | 69. | 3 | 70. | B |
| 71. | B | 72. | A | 73. | D | 74. | 5 | 75. | B | 76. | D | 77. | 5 |

EXERCISE - JEE - ADVANCED

- | | | | | | | | | | | | | | |
|-----|---|-----|----|-----|-----|-----|----|-----|-------|-----|------|-----|----|
| 1. | BC | 2. | AC | 3. | A | 4. | B | 5. | B | 6. | A | 7. | C |
| 8. | B | 9. | D | 10. | A | 11. | C | 12. | C | | | | |
| 13. | A - P, Q, R, T; B - Q, R, S, T; C - P, Q, R; D - P, Q, R, S | | | | | | | | | | | | |
| 14. | BC | 15. | D | 16. | A | 17. | 3 | 18. | 6 | 19. | 2 | 20. | C |
| 21. | C | 22. | 6 | 23. | BCD | 24. | AC | 25. | C | 26. | ACD | 27. | BC |
| 28. | ACD | 29. | AB | 30. | 6 | 31. | 6 | 32. | 1 & 3 | 33. | 4.00 | 34. | 6 |
| 35. | AD | | | | | | | | | | | | |

**HINT AND SOLUTIONS****EXERCISE - JEE - ADVANCED**

- 24.** (A) C_2^{-2} Total no. of electrons = 14 so it is diamagnetic
 (B) O_2^{2-} Bond order = 3; O_2 Bond order = 2
 \therefore Bond length in O_2^{2+} is less than bond length in O_2 .
 (C) Bond order of N_2^+ = 2.5
 Bond order of He_2^+ = 1/2
 \therefore Some energy is released during the formation of He_2^+ from two isolated He atoms.

- 25.** Let oxidation states of phosphorus in H_3PO_2 , H_3PO_4 , H_3PO_3 and $\text{H}_4\text{P}_2\text{O}_6$ be w, x, y and z respectively.

Thus, in H_3PO_2 :

$$3 \times (+1) + w + 2 \times (-2) = 0 \quad \therefore w = +1$$

In H_3PO_4 :

$$3 \times (+1) + x + 4 \times (-2) = 0 \quad \therefore x = +5$$

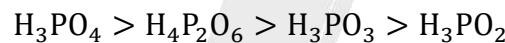
In H_3PO_3 :

$$3 \times (+1) + y + 3 \times (-2) = 0 \quad \therefore y = +3$$

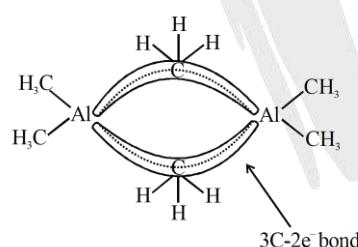
In $\text{H}_4\text{P}_2\text{O}_6$:

$$4 \times (+1) + 2z + 6 \times (-2) = 0 \quad \therefore z = +4$$

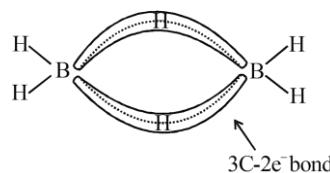
Thus, the order of oxidation state is :



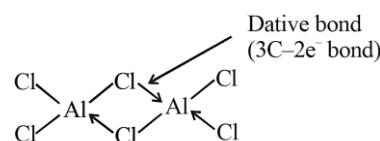
- 28** (A) Structure of $\text{Al}_2(\text{CH}_3)_6$



- (B) Structure of B_2H_6



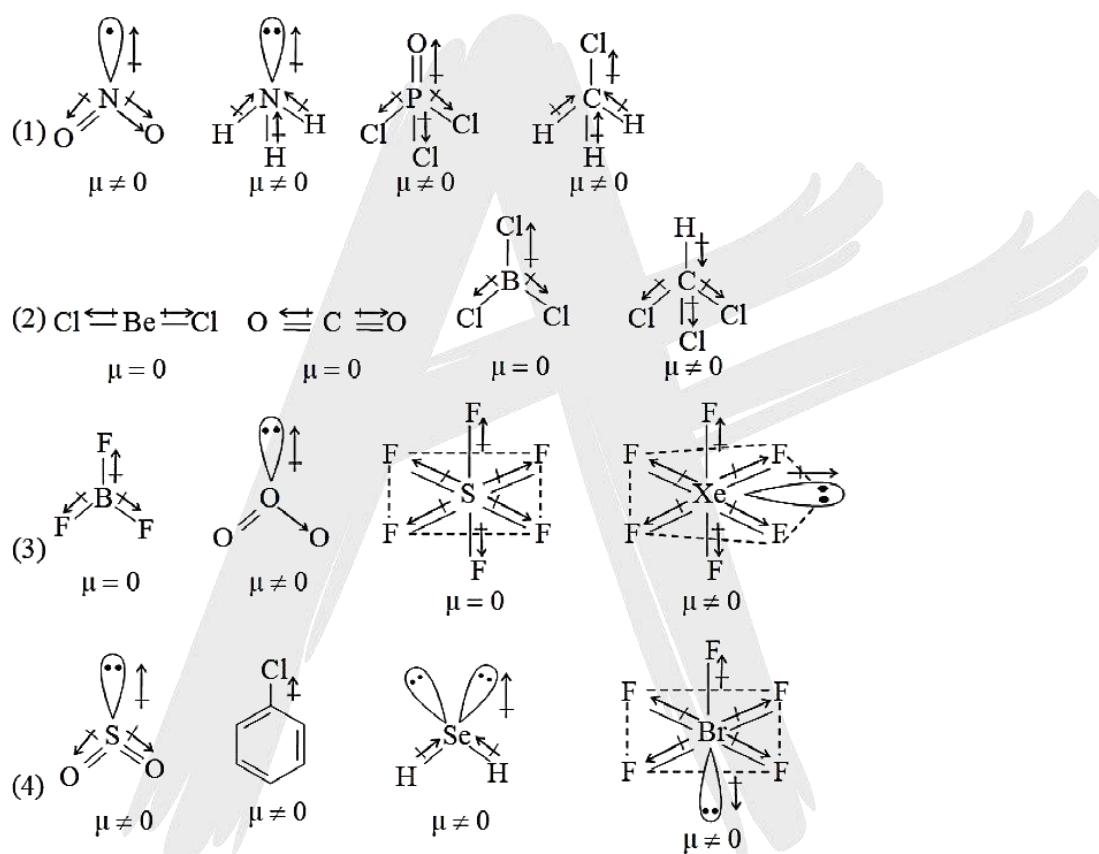
- (C) Structure of Al_2Cl_6



(Inorganic Chemistry)

31. H_2 : $\sigma 1s^2$ (Diamagnetic)
 He_2^+ : $\sigma 1s^2, \sigma^* 1s^1$ (Paramagnetic)
 Li_2 : $\sigma 1s^2, \sigma^+ 1s^2, \sigma 2s^2$ (Diamagnetic)
 Be_2 : $\sigma 1s^2, \sigma^* 1s^2, \sigma^* 2s^2$ (Diamagnetic)
 B_2 : $\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \pi 2p_x^1 = \pi 2p_y^1$ (Paramagnetic)
 C_2 : $\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_s^2 = \pi 2p_y^2$ (Diamagnetic)
 N_2 : $\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2, \sigma 2p_z^2$ (Diamagnetic)
 O_2^- : $\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^2 = \pi^* 2p_y^1$ (Paramagnetic)
 F_2 : $\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, \pi 2p_s^2 = \pi 2p_y^2, \pi^* 2p_s^2 = \pi^* 2p_y^2$ (Diamagnetic)

32.



33.

