

**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.

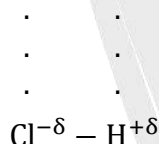
➤ **Types of Vander Waal's Forces****(1) Dipole-dipole interaction :**

The force of attraction between the oppositely charged poles of two polar molecules (for example :  $\text{H}_2\text{S}$ ,  $\text{HCl}$ ,  $\text{PH}_3$  etc.) is called dipole-dipole attraction.

- Two type of arrangements:

(a) Head to Tail (in gas):  $\text{H} - \text{Cl}^{-\delta} \dots \dots \text{H}^{+\delta} - \text{Cl}$  ( $E \propto 1/r^6$ )

- (b) Anti parallel (in solid and liquid):  $\text{H}^{+\delta} - \text{Cl}^{-\delta}$  ( $E \propto 1/r^3$ )



- (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  $\text{Cl}_2$  and  $\text{H}_2\text{O}$ .

- 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  $\text{F}_2$ ,  $\text{Cl}_2$ ,  $\text{N}_2$ , molecules and in noble gases.

**[Notation: upward arrow ( $\uparrow$ ) represent increasing value, down ward arrow ( $\downarrow$ ) represent decreasing value]**

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

## (Inorganic Chemistry)

(a) size

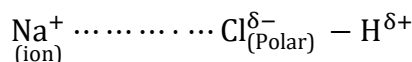
(b) molecular mass

(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  $\text{Na}^+$  and  $\text{Cl}_2$  molecule.

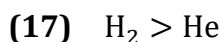
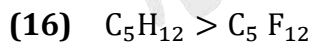
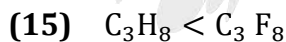
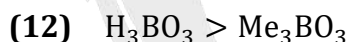
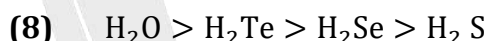
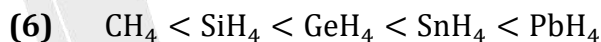
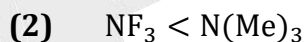
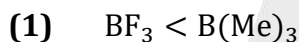
- Size of non-polar molecule increases, attraction force increases.



- 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



- Interaction energy relation with radius :

$$\text{Ion-dipole attraction} \propto \frac{1}{r^2}$$

$$\text{Dipole-dipole attraction (E}_k\text{)} \propto \frac{1}{r^3}$$

$$\text{Ion-induced dipole attraction} \propto \frac{1}{r^4}$$

$$\text{Dipole induced dipole attraction (E}_d\text{)} \propto \frac{1}{r^6}$$

$$\text{Instantaneous dipole-induced dipole attraction (E}_L\text{)} \propto \frac{1}{r^6}$$

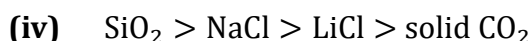
## (Inorganic Chemistry)

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

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

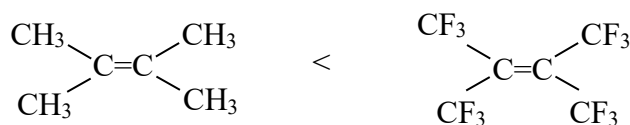
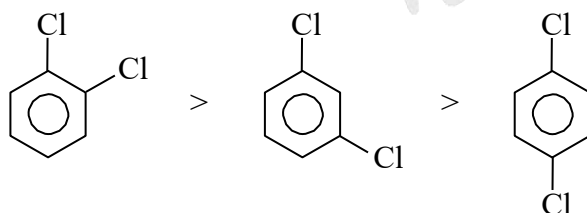
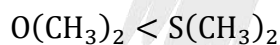
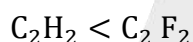
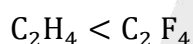
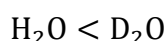
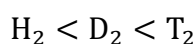
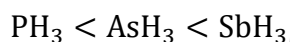
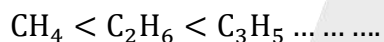
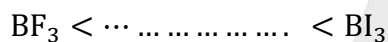
- Generally boiling point of ionic compound is greater than the covalent compound unless covalent compound do not have 3-D network like structure.

- **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)

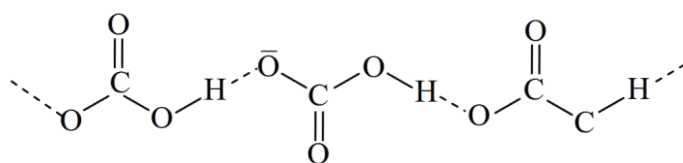
(Inorganic Chemistry)

• **Solved Example :**

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

Reason  $\rightarrow$   $\text{NaHCO}_3$  exist in polymer for  $\text{KHCO}_3$  exist in dimer form

$\text{NaHCO}_3$



[Massive hydrogen bonding]

$\text{KHCO}_3$



[Compact hydrogen bonding]

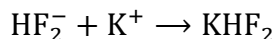
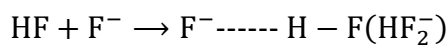
Q. Compound in which ion dipole interaction (H-bond) is present

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

(Inorganic Chemistry)

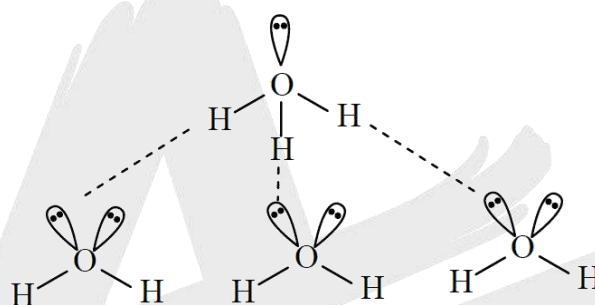
Q. KF & HF are soluble in each other why?

Due to ion dipole attraction

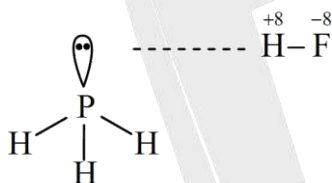


Identify the type of force of attraction :-

- (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)  $\text{H}_9\text{O}_4^+$  dipole-dipole, ion-dipole attraction & hydrogen bond



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



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

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

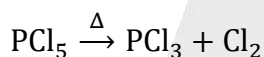


- (8)  $\text{C}_2\text{H}_5\text{NO}_2 > \text{C}_2\text{H}_6$  dipole-induced interaction  
Polar Non polar

## DO YOUR SELF - 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)  $\frac{1}{r^{12}}$
- 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)  $\text{CH}_3 - \text{CH}_2 - \text{Cl}$
- 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)
- Which of the following statements are INCORRECT?  
 (A)  $\text{BF}_3$  is more volatile than  $\text{BI}_3$   
 (B)  $\text{Xe(g)}$  has lesser interatomic forces than  $\text{Xe(s)}$   
 (C) The boiling point of  $\text{H}_2$  is lesser than He  
 (D)  $\text{OF}_2$  has higher boiling point than  $\text{CF}_4$
- Which of the following has Vander Waal's interaction with permanent dipole only ?  
 (A) Liquid-  $\text{NH}_3$  (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.

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

or

$$\frac{p-1}{p} \text{ Where } \theta \text{ is Bond Angle}$$

Equatorial

Axial

$$\theta = 120^\circ$$

$$\theta = 90^\circ$$

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

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

$$\% s = 33.33\%$$

$$\% s = 0$$

- 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)

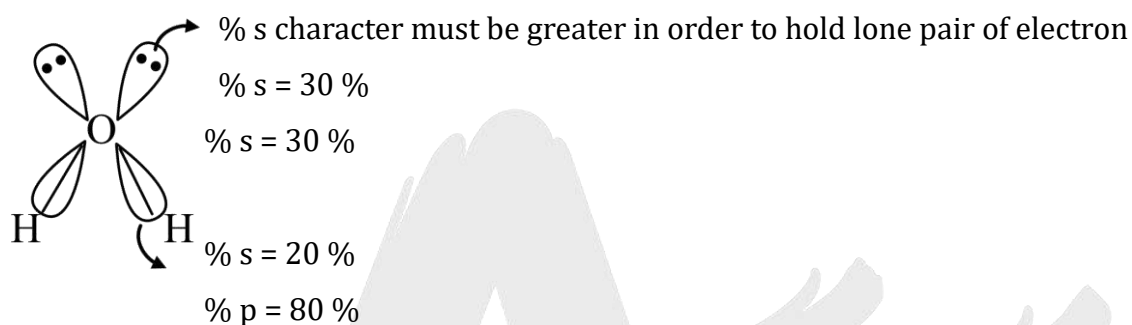
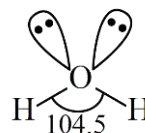
## (Inorganic Chemistry)

➤ **Type of hybridization**Equivalent hybridization =  $sp, sp^2, sp^3, sp^3d^2$ Non- equivalent hybridization =  $sp^3d, sp^3d^3$ Hybridisation in  $H_2O$  :-

$$\cos 104.5 = -0.25$$

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

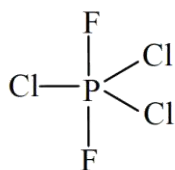
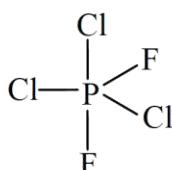
$$s = 20\%$$

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 to 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.**

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

**Ex.** Draw the geometry of  $PCl_3 F_2$ **Sol.**Correct  
StructureWrong  
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.  $F_3CH < Cl_3CH$

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

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

3. Compare the dipole moment ( $\mu$ ) for the given compound:

Ans.  $P(CH_3)_2(CF_3)_3 > P(CH_2)_3(CF_3)_2$

4. Compare P – F Bond Length in

Ans.  $PF_2(CH_3)_3 > PF_2(CF_3)_3$

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

Ans.  $H_2O_2 > O_2F_2$ .

6. Compare N – N Bond Length in

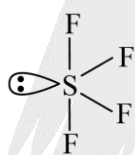
Ans. (a)  $N_2H_4 > N_2F_4$  (b)  $N_2H_2 > N_2F_4$

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

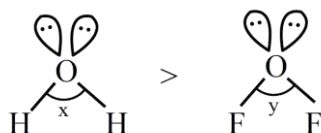
Ans.  $SF_4 > SOF_4$

• 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:  $H_2O < OCl_2$  ( $110.8^\circ$ )

$H_2O < OBr_2$  ( $111^\circ$ )

$H_2O < OI_2$  ( $112^\circ$ )



(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

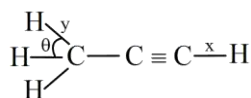
Ans.  $\text{O}_2\text{F}_2 > \text{OF}_2$

11. Which of the following is correct regarding  $\text{H}_2\text{CSF}_4$  ?

- (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  $\pi$ -bond present in axial plane (D) Maximum 6 atoms in one plane.

Ans. (B, C, D)

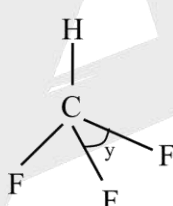
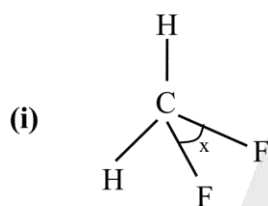
12. Select the correct statment for given compound :



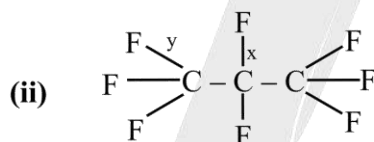
- (A)  $\theta > 109$  (B)  $\theta < 109$  (C)  $\theta = 109$  (D) Data is insufficient

Ans. (B)

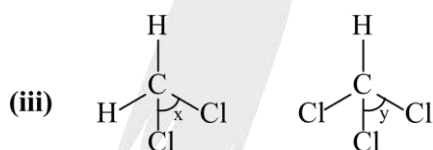
13. Compare x and y.



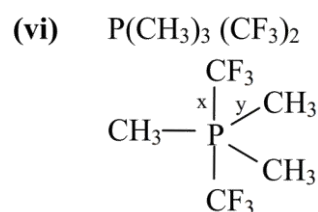
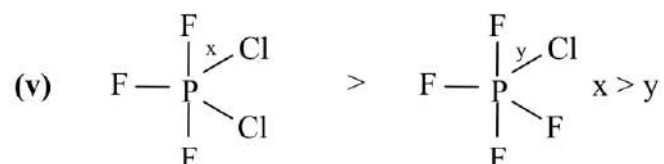
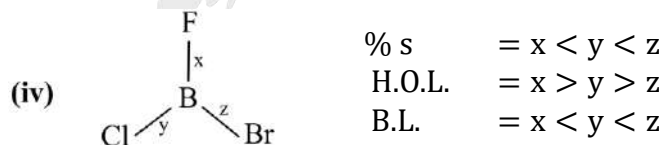
Ans.  $x < y$

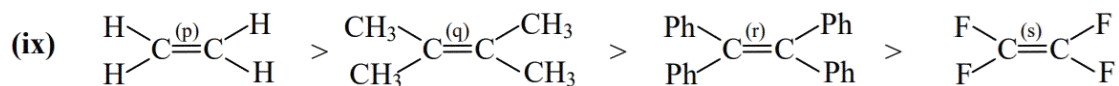
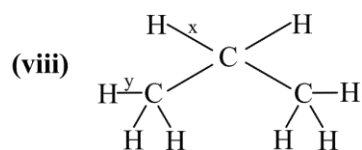
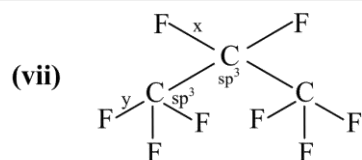


Ans.  $x > y$

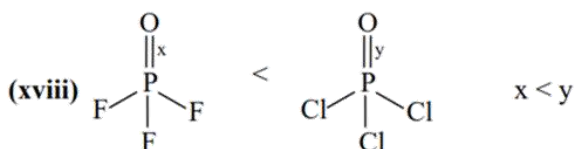
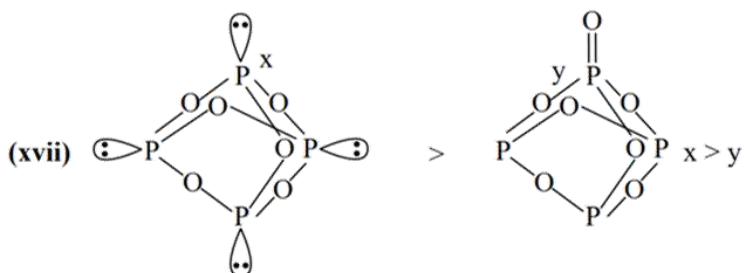
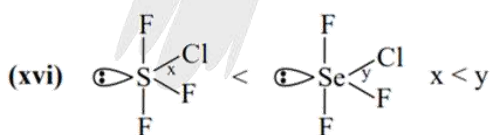
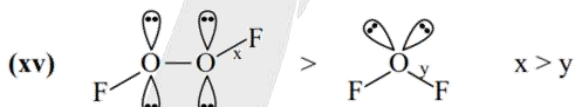
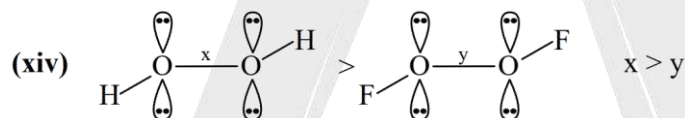
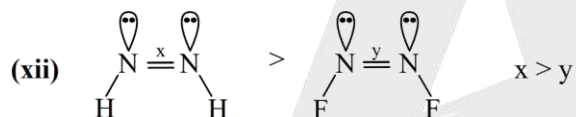
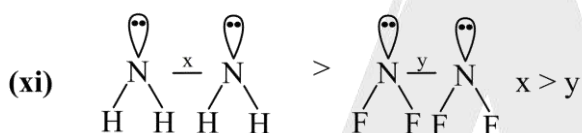


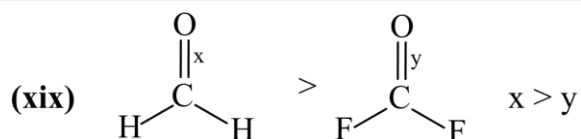
Ans.  $x > y$  (Steric Repulsion)



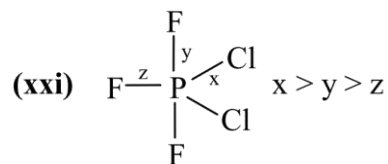
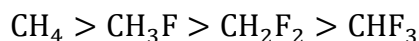


$$p > q > r > s$$





(xx) Compare CH bond length in  $\text{CH}_4$ ,  $\text{CH}_3\text{F}$ ,  $\text{CH}_2\text{F}_2$ ,  $\text{CHF}_3$



### 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  $90^\circ$ .

Group 15	Bond angle	Group 16	Bond angle
$\text{NH}_3$	$107^\circ 48'$	$\text{H}_2\text{O}$	$104^\circ 28'$
$\text{PH}_3$	$93^\circ 36'$	$\text{H}_2\text{S}$	$92^\circ$
$\text{AsH}_3$	$91^\circ 48'$	$\text{H}_2\text{Se}$	$91^\circ$
$\text{SbH}_3$	$91^\circ 18'$	$\text{H}_2\text{Te}$	$90.5^\circ$

- 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:  $\text{PH}_3$

**Explanation :**

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

Hence, hybridisation does not occur in  $\text{PH}_3$ .

Ex:  $\text{PH}_4^+$

Explanation:

$\text{sp}^3$  hybridisation.

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

Other example is  $\text{SiH}_4$

## (Inorganic Chemistry)

**Ex:**  $P_4$ 

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  $P_4$  ?

(A) 50

(B) 75

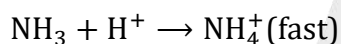
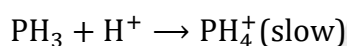
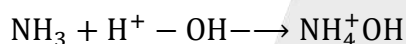
(C) 25

(D) 33.33

**Ans.** (B)**Ex:**  $P(SiH_3)_3$  (Tri silyl phosphine)**Explanation:**

No hybridisation

Geometry : Pyramidal

• **Effect on properties:****(a)** Formation of  $NH_4^+$  or  $PH_4^+$ **(b)** Solubility in water :  $NH_3 > PH_3$ **Que.** Compare bond angle(A)  $PF_3 < PCl_3$ (B)  $PF_3 > PH_3$ (C)  $BF_3 < BCl_3$ 

(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 :	$NH_3$	>	$PH_3$				

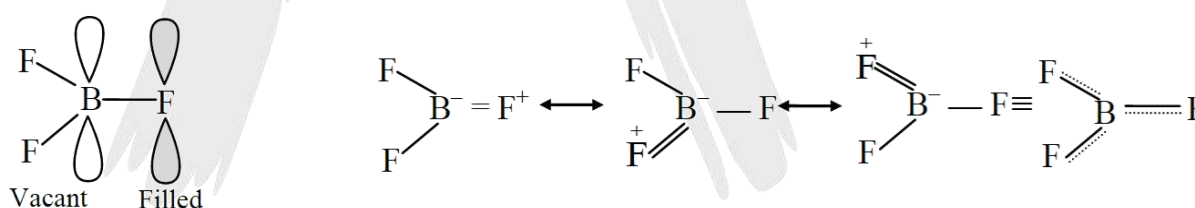
## DO YOUR SELF - 2

- 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.

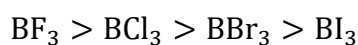
For example, in  $BF_3$  the boron atom completes its octet by accepting 2p-electrons of fluorine into 2p empty orbital.



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 :

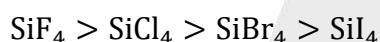
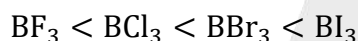


There is  $p\pi - p\pi$  back bonding in boron trihalide. The extent of back bonding decreases from  $BF_3$  to  $BI_3$  because of increasing size of p-orbitals participating in back bonding that is from 2p (in F) to 5p (in I).

Molecules	Type of back bonding	Shape
$\text{BF}_3$	$2p_\pi - 2p_\pi$	planar
$\text{N}(\text{CH}_3)_3$	no back bonding	pyramidal
$\text{N}(\text{SiH}_3)_3$	$2p_\pi - 3d_\pi$	planar
$\text{P}(\text{SiH}_3)_3$	No back bonding	pyramidal
$\text{CH}_3\text{NCS}$	No back bonding	bent
$\text{SiH}_3\text{NCS}$	$2p_\pi - 3d_\pi$	linear
$\text{N}(\text{GeH}_3)_3$	$2p_\pi - 4d_\pi$	planar
$\text{GeH}_3\text{NCS}$	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-:  $\text{CH}_2$  (Multiplicity = 3)

Singlet Carbene-:  $\text{CH}_2$  (Multiplicity = 1)

Triplet carbene is more stable than singlet carbene.

- **Dichlorocarbene- :  $\text{CCl}_2$**

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  $2p_\pi - 3d_\pi$  back bonding.

**Que.** Which is better proton donor acid between  $\text{CHF}_3$  and  $\text{CHCl}_3$  ?

**Ans.**  $\text{CHCl}_3$ , because  $\text{CCl}_3^-$  is stabilized by  $2p_\pi - 3d_\pi$  back bonding.

- **Effect of Back Bonding:**

a. Bond Length must be decrease.

b. Bond angle may be change

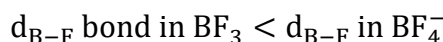
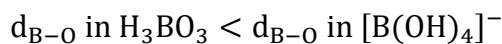
c. Hybridization may be change

- 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  $BF_4^-$

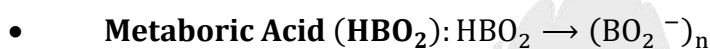
➤ **Some Important Order:**



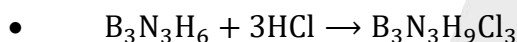
No back bonding in  $NCl_3$  due to its explosive nature.



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

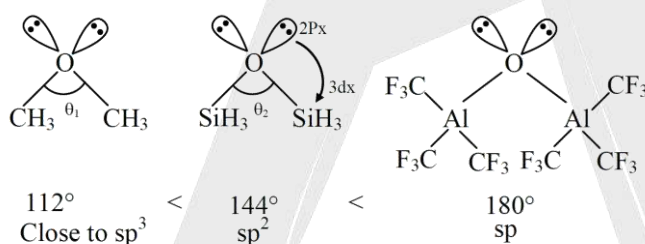


$B_3O_6^-$  is aromatic, planar, O and B are  $sp^2$  Hybridized

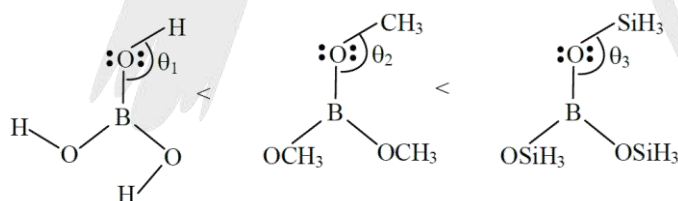


$2p_\pi - 2p_\pi$  back bonding involved in  $(BN)_x$

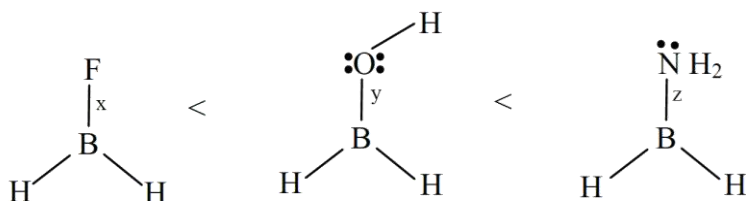
**Q.** Order of bond angle



**Q.** Order of bond angle :-

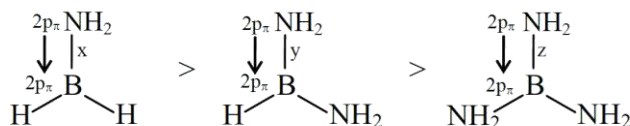


**Q.** Order of Strength Back Bonding :



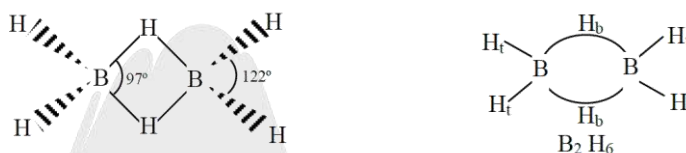
**Q.** Order of Strength Back Bonding :

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



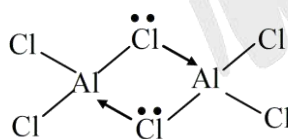
## (2) BRIDGE BONDING

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  $\text{B}_2\text{H}_6$ ,  $\text{Al}_2(\text{CH}_3)_6$ ,  $\text{BeH}_2$  (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  $\text{B}_2\text{H}_2$  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,  $\text{Ga}_2\text{H}_6$ .

But  $\text{Al}_2\text{Cl}_6$  have covalent bond only and there is no electron deficient bonding as depicted in the given structure.



(Bridging  $\text{Al} - \text{Cl} - \text{Al}$  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)  $\text{Al}_2\text{Cl}_6$  :**Information:-**

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

(B)  $\text{I}_2\text{Cl}_6$  :**Information:-**

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

(C)  $\text{B}_2\text{H}_6$  :**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)  $\text{Be}_2\text{Cl}_4$ **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

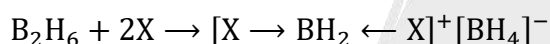
(F)  $Be_2H_4$  :

## Information:-

- Hybridisation of central atom =  $sp^3$
- Planarity:-Non- Planar
- **Borane:**

(a) **NidoBorane:**  $B_nH_{n+4}$  **Ex:**  $B_2H_6$  (di borane),  $B_3H_7$  (tri borane)

(b) **ArachnoBorane:**  $B_nH_{n+6}$  **Ex:**  $B_2H_8$  (di borane - 8),  $B_3H_9$  (tri borane - 9)

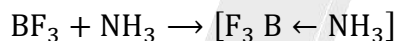


## DO YOUR SELF - 3

**Q.1**  $N(SiH_3)_3$  has -

- (A)  $sp^3$  hybridisation, pyramidal shape  
 (B)  $sp^2$  hybridisation, planar shape  
 (C)  $sp^3$  hybridisation, tetrahedral shape  
 (D)  $dsp^2$  hybridisation, square planar shape

**Q.2** Correct statement regarding this reaction



- (A) Hybridisation of N is changed  
 (B) Hybridisation of B is changed  
 (C)  $NH_3$  act as a lewis base  
 (D) (B) & (C) both

**Q.3** Shape of  $N(CH_3)_3$  is

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

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

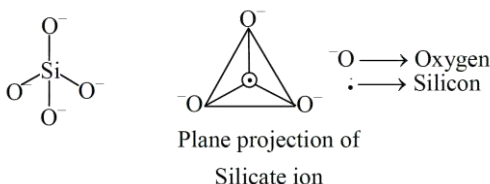
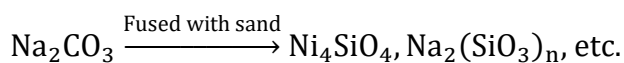
- (A)  $AlCl_3$  (B)  $AlH_3$  (C)  $BCl_3$  (D)  $ICl_3$

**Q.5** Which of the following represents  $(3C - 4e^-)$  Bridge bonding

- (A)  $Al_2Cl_6$  (B)  $BH_3$  (C)  $B_2H_6$  (D) none of these

**SILICATES**

- Silicates are metal derivatives of silicic acid,  $\text{H}_4\text{SiO}_4$  or  $\text{Si}(\text{OH})_4$ . Silicates are formed by heating metal oxide or metal carbonates with sand, e.g.



- Silicates have basic unit of  $\text{SiO}_4^{4-}$ , 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	$\text{SiO}_4^{4-}$
Pyro (closo)	1	3.5	$\text{Si}_2\text{O}_7^{6-}$
Cyclic (cyclo)	2	3	$(\text{SiO}_3)_n^{2n-}$ (n = finite)
Simple chain (pyroxene)	2	3	$(\text{SiO}_3)_n^{2n-}$ (n = infinite)
Double chain (amphibole)	(3,2) avg. = 2.5	$\frac{11}{4} = \left(\frac{5.5}{2}\right)$	$(\text{Si}_4\text{O}_{11})_n^{6n-}$
2D or (sheet or phyllo)	3	2.5	$(\text{Si}_2\text{O}_5)_n^{2n-}$
3D (tecto)	4	2	$(\text{SiO}_2)_n$

**ODD ELECTRON MOLECULES**

- If number of electron present in molecule are in odd number.

• **Example:-**

Odd electron molecule	$\text{NO}_2$	$\text{ClO}_3$	$\text{OF}$	$\text{O}_2^-$	$\text{ClO}_2$
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  $\sigma$  as well as  $\pi$  bond
- **Examples:**  $\text{NO}$ ,  $\text{O}_2^-$ ,  $\text{ClO}_2$  (Odd electron act as  $\pi$  bond)  
 $\text{N}_2^+$ ,  $\text{Li}_2^+$ ,  $\text{Na}_2^+$ , (Odd electron acts as  $\sigma$  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 develop 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
$\text{NO}_2$	$\text{sp}^2$	$\text{sp}^2$ hybrid orbital	Yes
$\text{ClO}_3$	$\text{sp}^3$	$\text{sp}^3$ hybrid orbital	Yes
$\text{CH}_3$	$\text{sp}^2$	p- orbital	Yes
$\text{CF}_3$	$\text{sp}^3$	$\text{sp}^3$ hybrid orbital	Yes
$\text{ClO}_2$	$\text{sp}^2$	3 d- orbital	No

- Bond order of Cl – O bond in  $\text{ClO}_2$  is 1.75.

➤ **Structure of odd  $e^-$  molecules**

- (1)  $\text{NO}_2$       Structure:-
- (2)  $\text{ClO}_2$       Structure:-
- (3)  $\text{ClO}_3$       Structure:-
- (4)  $\text{CH}_3$       Structure:-
- (5)  $\text{CF}_3$       Structure:-

Q. Which of the following statements is correct for  $\text{ClO}_2$

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)

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

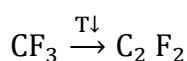
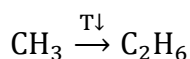
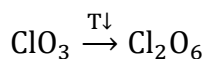
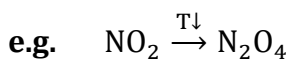
Explosive in nature

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

**Key point :-**

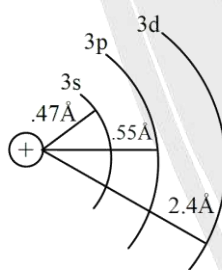
Species	Type of orbital (odd e')
$\text{NO}_2$	$\text{sp}^2$
$\text{CF}_3$	$\text{sp}^3$
$\text{ClO}_3$	$\text{sp}^3$
$\text{CH}_3$	Pure 'P'
$\text{ClO}_2$	d-orbital

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

#### Do not exist

$\text{PH}_5$

$\text{SH}_6$

$\text{SH}_4$

$\text{XeH}_2$

$\text{XeH}_4$

$\text{XeO}_2\text{H}_4$

$\text{XeO}_2\text{H}_2$

$\text{XeH}_6$

$\text{XeH}_5^+$

$\text{XeH}_5^-$

#### Exist

$\text{PF}_5$

$\text{SF}_6$

$\text{SF}_4$

$\text{XeF}_2$

$\text{XeF}_4$

$\text{XeO}_2\text{F}_4$

$\text{XeO}_2\text{F}_2$

$\text{XeF}_6$

$\text{XeF}_5^+$

$\text{XeF}_5^-$

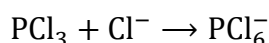
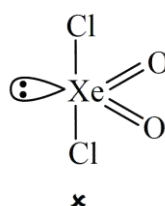
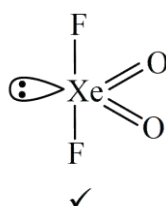
(Inorganic Chemistry)

2. Due to steric repulsion:

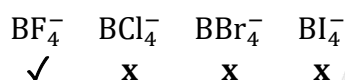
Ex.  $\text{BCl}_4^-$ ,  $\text{B}_2\text{Cl}_6$ ,  $\text{B}_2\text{Br}_6$ ,  $\text{B}_2\text{I}_6$ ,  $\text{B}_2\text{F}_6$ ,  $\text{SCl}_6$ ,  $\text{SBr}_6$ ,  $\text{SI}_6$ ,  $\text{ICl}_7$ ,  $\text{ClI}_7$ ,  $[\text{SiCl}_6]^{-2}$

Do not exist

Exist

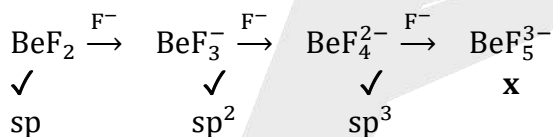


$\text{PCl}_6^-$  is possible but  $\text{PBr}_6^-$  does not exist  $\text{PBr}_2$  (combination of  $\text{PBr}_4^- + \text{PBr}_3^-$ ) possible but  $\text{PI}_2$  does not exist

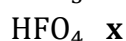
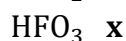
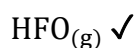
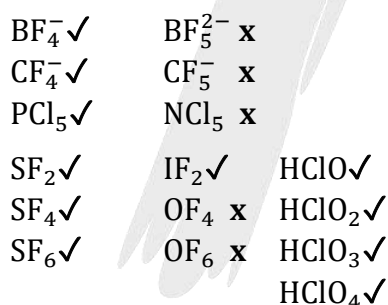


3. Due to absence of vacant orbital

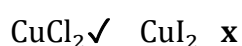
$\text{BeF}_2$ ,  $\text{BeF}_3^-$ ,  $\text{BeF}_4^{2-}$  are possible while  $\text{BeF}_5^{3-}$  due to absence of vacant orbital.



Other example :



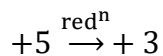
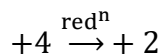
4. Due to reducing nature



**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



$BeF_5$  is possible

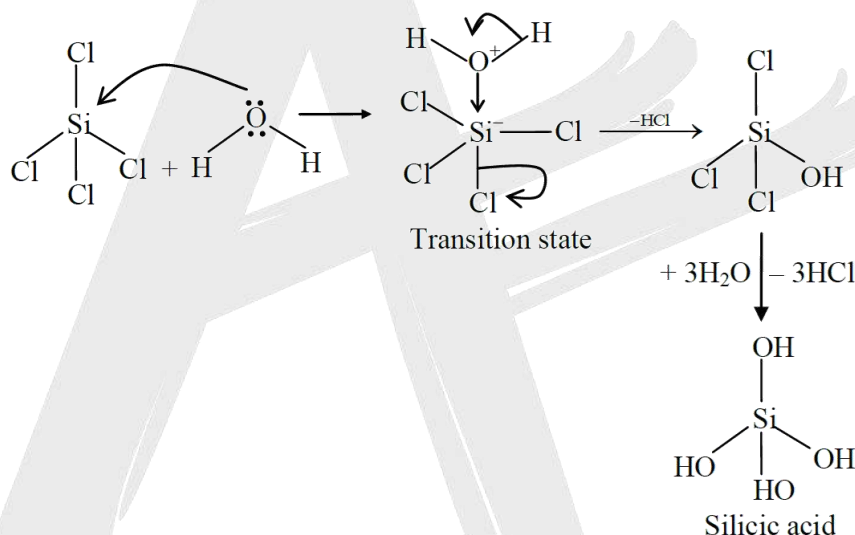
but  $BiCl_5$ ,  $BiBr_5$ ,  $BiI_5$  does not exist

Because  $BiF_5$  is strong O.A. as compared to other.

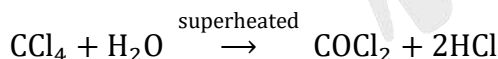
## HYDROLYSIS

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

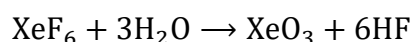
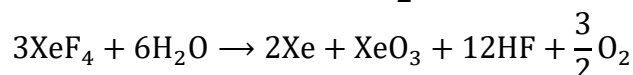
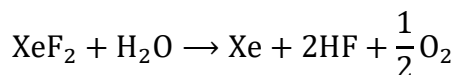
**Ex.** Hydrolysis of  $SiCl_4$



**Note:**  $CCl_4$ ,  $NF_3$ , is inert towards hydrolysis due to the absence of d orbital, but under drastic condition these molecules undergo hydrolysis.



**Note:** Hydrolysis of  $XeF_2$  &  $XeF_4$  takes place through redox reaction.



- Condition for  $SN^2$  :

- 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. ( $SF_6$  doesn'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  $\text{SN}^1$  mechanism)

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

• **Explanation:**

- (i) Product is oxyacid as well as hydric acids.
- (ii) Hybridisation of reactant is  $\text{sp}^3$  but that of transition state is  $\text{sp}^3 \text{ d}$ .
- (iii) Generally the oxyacid form of central atom and same oxidation state.
- (iv) Generally the hydric acid 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)  $\text{P} = \text{O} \gg \text{P} - \text{O}$  ( $\pi$ -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:**  $\text{AsCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{As}(\text{OH})_3 + 3\text{HCl}$

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

**Q.1.** Compare rate of hydrolysis?

- (i) (A)  $\text{MgCl}_2$  (B)  $\text{AlCl}_3$  (C)  $\text{CCl}_4$  (D)  $\text{SiCl}_4$  (E)  $\text{PCl}_5$

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

- (ii) (A)  $\text{SnCl}_2$  (B)  $\text{SnCl}_4$

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

- (iii) (A)  $\text{SnCl}_4$  (B)  $\text{SnMe}_4$

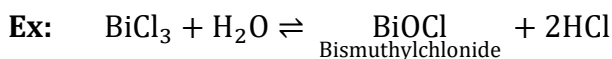
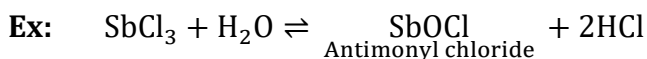
**Ans.**  $\text{SnCl}_4 > \text{SnMe}_4$

**Rate of hydrolysis order**

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



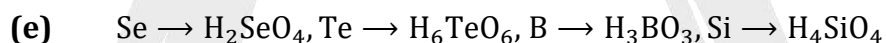
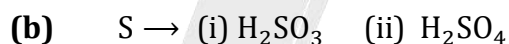
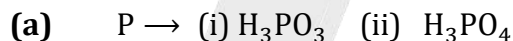
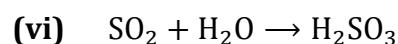
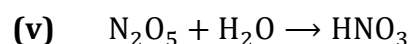
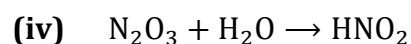
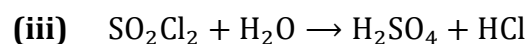
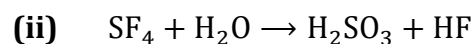
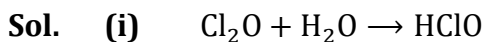
## (Inorganic Chemistry)

• **Note:**(i)  $\text{BeX}_2$  – Predominantly covalent ( $\text{X} = \text{F}, \text{Cl}, \text{Br}, \text{I}$ )(ii)  $\text{MgX}_2$  - Predominantly covalent ( $\text{X} = \text{Cl}, \text{Br}, \text{I}$ )(iii)  $\text{AlX}_3$  – Predominantly covalent ( $\text{X} = \text{Cl}, \text{Br}, \text{I}$ )(iv)  $\text{LiF}/\text{MgF}_2/\text{AlF}_3$  – Predominantly ionic**NOTE:** On adding acid, equation shifts backward and turbidity disappears.

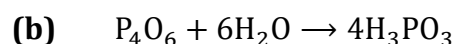
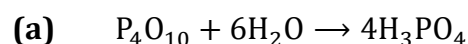
To distinguish between  $\text{SbO}^+$  and  $\text{BiO}^+$ , we add tartaric acid. Turbidity of  $\text{SbO}^+$  disappears but not of  $\text{BiO}^+$  this is used to distinguish between the two.

**Que.** Which of the following ions are present in  $\text{BiOCl}$  ?

- (A)  $\text{Bi}^+$                       (B)  $\text{BiO}^+$                       (C)  $\text{OCl}^-$                       (D)  $\text{Cl}^-$

**Ans.** (B, D)• **Remember:****Parent Oxyacid of following atoms:****Que.** Identify the product obtained on hydrolysis?

## • Addition and addition elimination reaction:



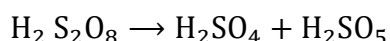
## (Inorganic Chemistry)

**Que.** Identify the product obtained on hydrolysis?

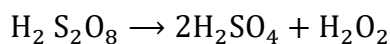
- Sol.**
- (i)  $P_4O_{10} + H_2O \rightarrow 4H_3PO_4$
  - (ii)  $P_4O_9 + H_2O \rightarrow 3H_3PO_4 + H_3PO_3$
  - (iii)  $P_4O_8 + H_2O \rightarrow 2H_3PO_4 + 2H_3PO_3$
  - (iv)  $P_4O_7 + H_2O \rightarrow H_3PO_4 + 3H_3PO_3$
  - (v)  $P_4O_6 + H_2O \rightarrow 4H_3PO_3$

**Ex:**  $H_2S_2O_8 + H_2O \rightarrow H_2O_2 + H_2SO_4$   
marshall's acid

(i) Partial hydrolysis of  $H_2 S_2O_8$



(ii) Complete hydrolysis of  $H_2 S_2O_8$



**Ex:**  $H_4P_2O_6 + H_2O \rightarrow H_3PO_4 + H_3PO_3$   
hypophosphoric acid

$H_4P_2O_6 + H_2O \rightarrow H_3PO_4 + H_3PO_3$   
Isohypophosphoric acid

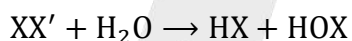
**Note:** Product obtained after hydrolysis of both given compound is same.

• **Important**

**Hydrolysis of Interhalogen compound**

- (i)  $ICl + H_2O \rightarrow HOI + HCl$
- (ii)  $IF_3 + H_2O \rightarrow HIO_2 + 3HF$
- (iii)  $BrF_5 + H_2O \rightarrow HBrO_3 + 5HF$
- (iv)  $IF_7 + H_2O \rightarrow HIO_4 + 7HF$

**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)

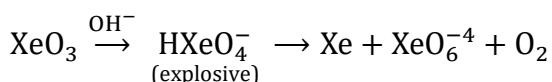
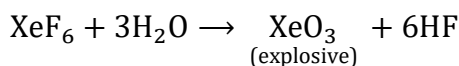
• **Important**

**Hydrolysis of noble gases compound**

- (i)  $XeF_2 + H_2O \rightarrow Xe + O_2 + HF$
- (ii)  $6XeF_4 + 12H_2O \rightarrow 4Xe + 2XeO_3 + 24HF + 3O_2$
- (iii) Hydrolysis of  $XeF_6$   

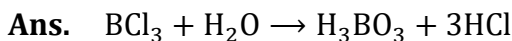
$$XeF_6 + 3H_2O \rightarrow XeO_3 + 6HF$$
(explosive)
- (iv) Alkaline hydrolysis of  $XeF_6$

## (Inorganic Chemistry)

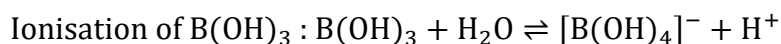


Two gaseous product Xe and O<sub>2</sub> are obtained during alkaline hydrolysis.

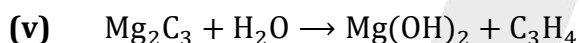
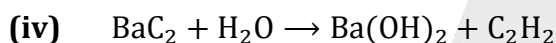
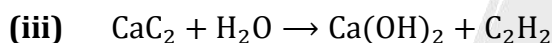
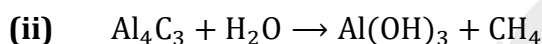
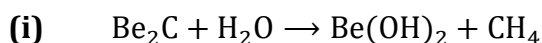
**Que.** Hydrolysis of BCl<sub>3</sub>



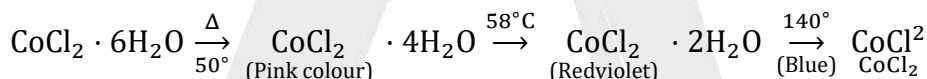
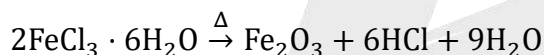
Product of hydrolysis of BCl<sub>3</sub> is H<sub>3</sub>BO<sub>3</sub> and HCl.



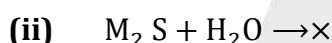
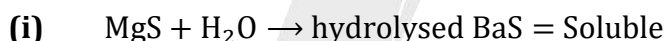
• **Hydrolysis of Carbide:**



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



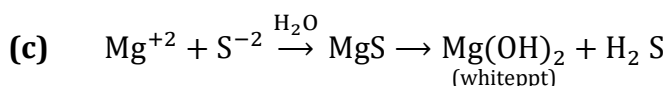
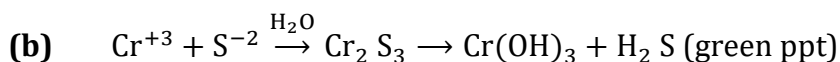
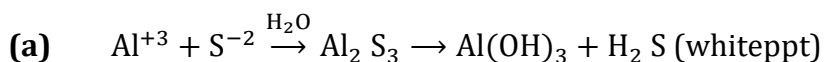
• **Sulphide:**



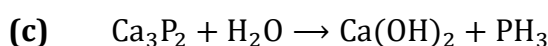
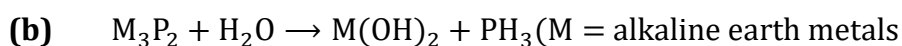
(where M = Alkali metal)

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

(iii) Exception:



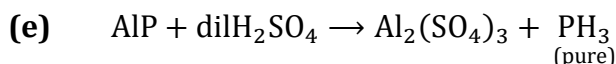
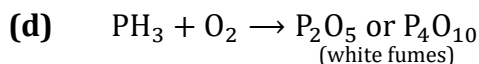
➤ **Phosphides:**



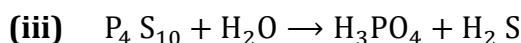
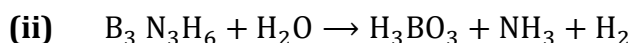
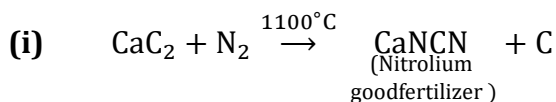
**(Inorganic Chemistry)**

**Note:**  $\text{Ca}_3\text{P}_2$  and  $\text{CaC}_2$  mixture used as Holme's signal.

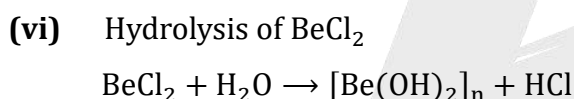
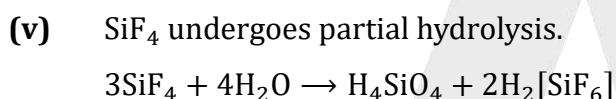
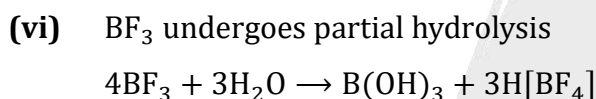
Impure  $\text{PH}_3$  is inflammable due to impurities.



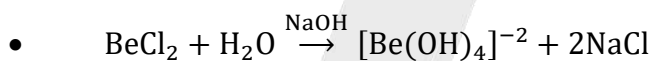
• **Important**



**Note:**  $\text{P}_4\text{O}_{10}$  and  $\text{P}_4\text{S}_{10}$  are isostructural



• **Alkaline hydrolysis of  $\text{BeCl}_2$**

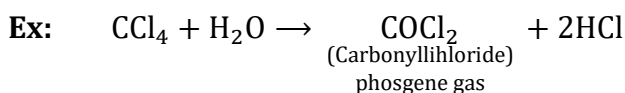
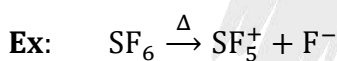


(vii) Rate of hydrolysis

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

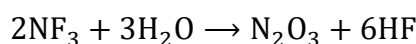
**Conclusion :** Size  $\uparrow$ , steric crowding  $\downarrow$ , rate of hydrolysis  $\uparrow$

•  **$\text{SN}^1$  / Drastic condition**



**Note:**  $\text{CCl}_4$  is a fire extinguisher but it is not used as fire extinguisher at high temperature because it forms  $\text{COCl}_2$

**Ex:** Hydrolysis of  $\text{NF}_3$  by  $\text{SN}^1$  mechanism:

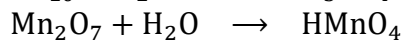
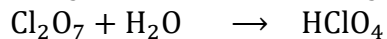
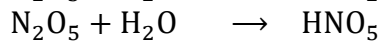


**Note:** Via  $\text{SN}^1$ , hydrolysis of  $\text{SF}_6$ ,  $\text{CCl}_4$ ,  $\text{NF}_3$  Can be done.

## (Inorganic Chemistry)

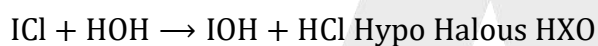
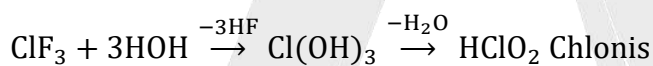
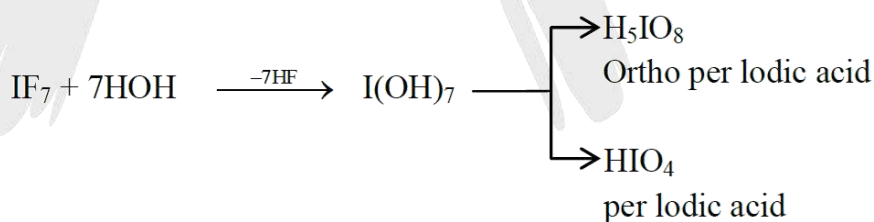
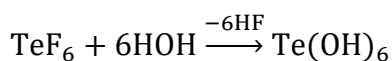
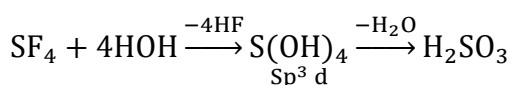
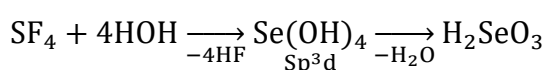
## • Other example

Hydrolysis of oxide

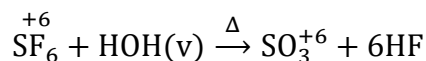
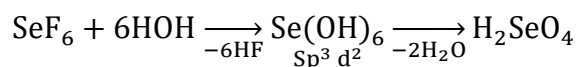


An example of disproportionation reaction requires bond combination of group number & oxidation state must be in odd & even.

## (1) AX type

(2) AX<sub>3</sub> type(3) AX<sub>5</sub> type(4) AX<sub>7</sub> type➤ Hydrolysis of TeF<sub>6</sub>➤ Hydrolysis of SF<sub>4</sub>➤ Hydrolysis of SeF<sub>4</sub>

## (Inorganic Chemistry)

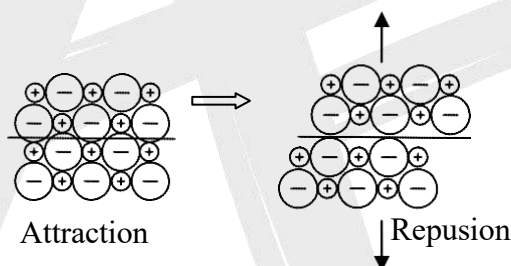
➤ **Hydrolysis of  $\text{SF}_6$** ➤ **Hydrolysis of  $\text{SeF}_6$** • **Some common name :**

$\text{KHSO}_5$	$\text{Na}_2\text{O}_2$	$(\text{H}_2\text{SO}_4)$
Oxone	solozone	oil of vitrol
	Or	
	Floccool	

**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)  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ ,  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  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  $\uparrow$ ,  $\phi$   $\uparrow$ , polarisation  $\uparrow$ , covalent character  $\uparrow$ , ionic character  $\downarrow$

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

## (2) Size of cation :

size  $\downarrow$ ,  $\phi$   $\uparrow$ , polarization  $\uparrow$ , covalent character  $\uparrow$ , ionic character  $\downarrow$

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

## (3) Size of anion :

size  $\uparrow$ , polarization  $\uparrow$ , covalent character  $\uparrow$ , ionic character  $\downarrow$

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

## (4) Charge on anion :

charge  $\uparrow$ , polarization  $\uparrow$ , covalent character  $\uparrow$ , ionic character  $\downarrow$

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 :  $ns^2np^6(8e^-)$

Ex.:  $\text{Na}^+ = 1s^22s^22p^6$

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

$\text{Cu}^{\oplus} = 1s^22s^22p^63s^23p^63d^{10}$

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:  $ns^2np^6nd^{10}(n+1)s^2(18+2e^-)$

$\text{Tl}^+ = [\text{Xe}]6s^24f^{14}5d^{10}$

**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 its +3 oxidation state. Pb shows +2 stable oxidation state and Bi shows +3 stable oxidation state.

- **For example:**

**Group 13**

B(+3)  
 Al(+3)  
 Ga(+3), (+1)  
 In(+3), (+1)  
 Tl(+3), (+1)

**Group 14**

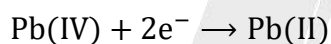
C(+4)  
 Si(+4)  
 Ge(+4), (+2)  
 Sn(+4), (+2)  
 Pb(+4), (+2)

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

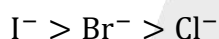
$\text{Pb}^{+2} > \text{Sn}^{+2} > \text{Ge}^{+2}$  (due to inert pair effect)

**Ex.**  $\text{PbCl}_4$  is stable at room temperature whereas  $\text{PbI}_4$  doesn't exist.

**Sol.** Due to inert pair effect Pb(+4) is less stable than Pb(+2). Hence it is very good oxidant.



Reducing abilities of halides follows the sequence



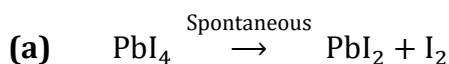
- Inert pair effect : order of stability**

**Due to inert pair effect :**

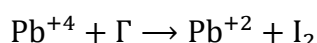
- (a)  $\text{Tl}^{+1} > \text{Tl}^{+3}$       (b)  $\text{Bi}^{+3} > \text{Bi}^{+5}$       (c)  $\text{Pb}^{+2} > \text{Pb}^{+4}$       (d)  $\text{Hg} > \text{Hg}^{+2}$
- (a)  $\text{Pb}^{+4} + 2\text{e}^- \xrightarrow{\text{(Oxidizing agent)}} \text{Pb}^{+2}$       (b)  $\text{T}^{+3} \xrightarrow{\text{(Oxidizing agent)}} 2\text{T}^0$       (c)  $\text{Bi}^{+5} \xrightarrow{\text{(Oxidizing agent)}} 2\text{e}^- \rightarrow \text{Bi}^{+3}$

**Note:**  $\text{PbO}_2$ ,  $\text{Pb}_2\text{O}_3$  ( $\text{PbO} + \text{PbO}_2$ ),  $\text{Pb}(\text{ClO}_4)$  are oxidizing agents because  $\text{Pb}^{+2}$  is more stable than  $\text{Pb}^{+4}$

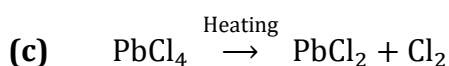
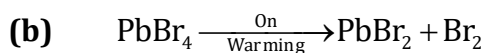
- Reducing power order  $\text{I}^- > \text{Br}^- > \text{Cl}^- > \text{F}^-$**



$\text{PbI}_4$  does not exist because  $\text{Pb}^{+4}$  act as oxidizing agent and  $\text{I}^-$  act as reducing agent.



## (Inorganic Chemistry)



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

**Note :** Only pentahalide of Bi is  $\text{BiF}_5$  is possible.  $[\text{F}^\ominus]$  is weak reducing agent ]

- $(a) \text{Cu}^{+2}_{(\text{O.A.})} + \text{I}^\ominus_{(\text{R.A.})} \rightarrow \text{Cu}_2\text{I}_2 + \text{I}_2$ 
 $(b) \text{Fe}^{+3}_{(\text{O.A.})} + \text{I}^\ominus_{(\text{R.A.})} \rightarrow \text{Fe}^{+2} + \text{I}_2$
- $(c) \text{Bi}^{+5}_{(\text{O.A.})} + \text{I}^\ominus_{(\text{R.A.})} \rightarrow \text{Bi}^{+3} + \text{I}_2$ 
 $(d) \text{Tl}^{+3}_{(\text{O.A.})} + 3\text{I}^\ominus_{(\text{R.A.})} \rightarrow \text{Tl}^+ + \text{I}_2$

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

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

Stability of higher oxidation state ↓ down the group

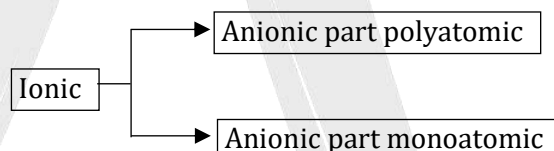
$\text{CX}_4 > \text{SiX}_4 > \text{GeX}_4 > \text{SnX}_4 > \text{PbX}_4$  (Where X is F, Cl, Br, I)

Stability of lower oxidation state ↑ 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:**

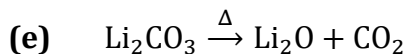
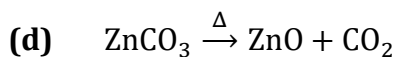
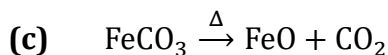
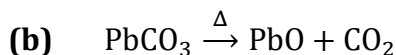
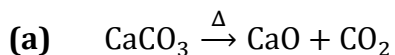
Order of Thermal stability:

- (a)  $\text{Li}_2\text{CO}_3 < \text{Na}_2\text{CO}_3 < \text{K}_2\text{CO}_3 < \text{Rb}_2\text{CO}_3 < \text{Cs}_2\text{CO}_3$
- (b)  $\text{BeCO}_3 < \text{MgCO}_3 < \text{CaCO}_3 < \text{SrCO}_3 < \text{BaCO}_3$
- (c)  $\text{Li}_2\text{SO}_4 < \text{Na}_2\text{SO}_4 < \text{K}_2\text{SO}_4 < \text{Rb}_2\text{SO}_4 < \text{Cs}_2\text{SO}_4$
- (d)  $\text{BeSO}_4 < \text{MgSO}_4 < \text{CaSO}_4 < \text{SrSO}_4 < \text{BaSO}_4$
- (e)  $\text{LiNO}_3 < \text{NaNO}_3 < \text{KNO}_3 < \text{RbNO}_3 < \text{CsNO}_3$
- (f)  $\text{Be}(\text{NO}_3)_2 < \text{Mg}(\text{NO}_3)_2 < \text{Ca}(\text{NO}_3)_2 < \text{Sr}(\text{NO}_3)_2 < \text{Ba}(\text{NO}_3)_2$
- (g)  $\text{NaHCO}_3 < \text{KHCO}_3 < \text{RbHCO}_3 < \text{CsHCO}_3$
- (h)  $\text{Be}(\text{HCO}_3)_2 < \text{Mg}(\text{HCO}_3)_2 < \text{Ca}(\text{HCO}_3)_2 < \text{Sr}(\text{HCO}_3)_2 < \text{Ba}(\text{HCO}_3)_2$

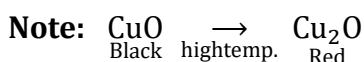
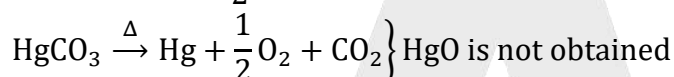
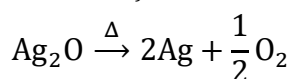
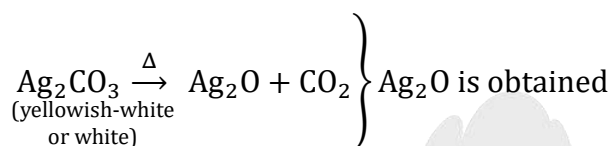
**Note:** Na, K, Rb, Cs carbonate do not decompose on heating, they melt at high temperature.

## (Inorganic Chemistry)

- Heating effect of carbonate:**



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



- Thermal stability of ionic compound having monoatomic anion :**



$$\text{L.E} = Kq_1q_2/r^2(r_c + r_a)$$

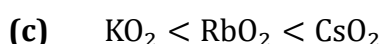
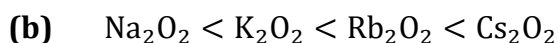
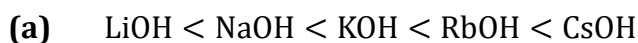
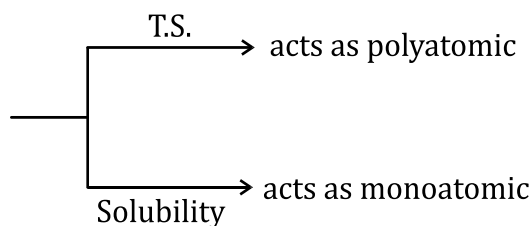
$$\Rightarrow \text{L.E.} \propto \text{charge} \quad \text{L.E.} \propto \frac{1}{\text{size}}$$

$$\Rightarrow \text{Charge} \uparrow, \text{L.E.} \uparrow \Rightarrow \text{size} \uparrow, \text{L.E.} \downarrow$$

$$\text{Thermal stability} \propto \text{Lattice energy}$$



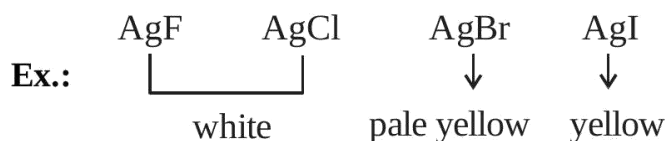
- Important :**



## (Inorganic Chemistry)

- Colour of Ionic compound :**

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



**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 :**  $\phi$  of :

	$\text{Be}^{+2} > \text{Al}^{+3}$
	6.4          6
Hydrate Size	$\text{Ba}_{(\text{aq.})}^{+2} > \text{Al}_{(\text{aq.})}^{+3}$
Ionic Mobility	$\text{Be}_{(\text{aq.})}^{+2} < \text{Al}_{(2\text{q.})}^{+3}$

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

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

**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 :**  $\text{Br}^-/\text{I}^-$  : They follow trend of polyatomic

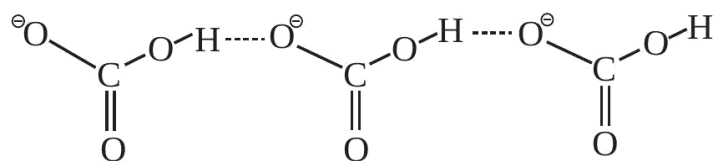
- (a)  $\text{LiBr} > \text{NaBr} > \text{KBr} > \text{RbBr} > \text{CsBr}$
- (b)  $\underline{\text{NaI}} > \text{LiI} > \text{KI} > \text{RbI} > \text{CsI}$

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

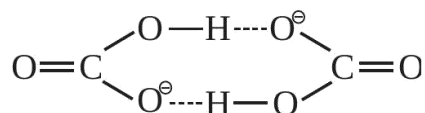
- (a)  $\text{Li}_2\text{O} < \text{Na}_2\text{O} < \text{K}_2\text{O} < \text{Rb}_2\text{O} < \text{Cs}_2\text{O}$
- (b)  $\text{Li}_2\text{CO}_3 < \text{Na}_2\text{CO}_3 < \text{K}_2\text{CO}_3 < \text{Rb}_2\text{CO}_3 < \text{Cs}_2\text{CO}_3$
- (c)  $\text{NaHCO}_3 < \text{KHCO}_3 < \text{RbHCO}_3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

(Inorganic Chemistry)

- Reason: Massive H bonding in  $\text{NaHCO}_3$  (Sparingly Soluble)

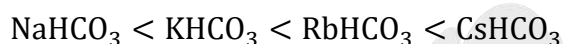


Compact H-bonding in  $\text{KHCO}_3$ ,  $\text{RbHCO}_3$ ,  $\text{CsHCO}_3$  (Completely Soluble)

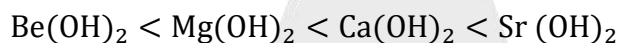


Que. Find order of  $K_{sp}$ .

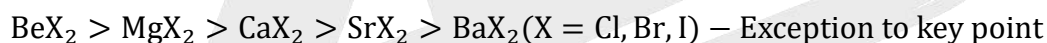
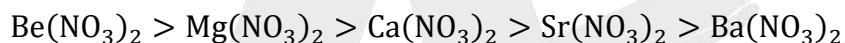
Solubility  $\uparrow$ ,  $K_{sp}$   $\uparrow$



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



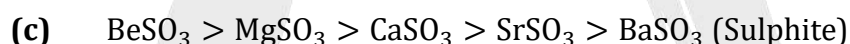
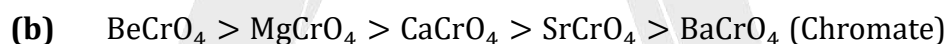
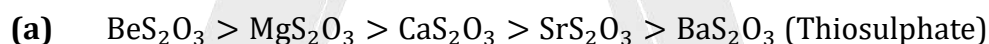
But if number of polyatomic anion  $>$  number of cation, then solubility  $\downarrow$  down the group.



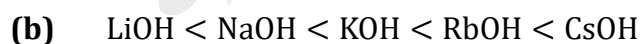
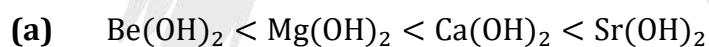
- Key point : (For Cases I to IV)

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

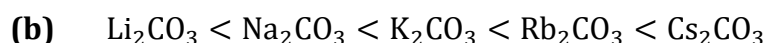
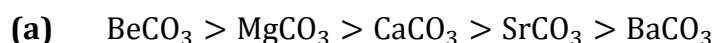
- Alkaline earth metals :



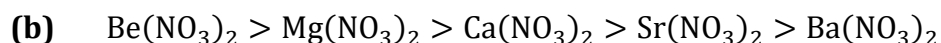
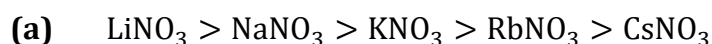
- Hydroxide :



- Carbonate :



- Nitrate :



## (Inorganic Chemistry)

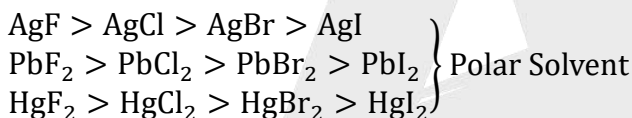
## • Other example

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

## • 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):



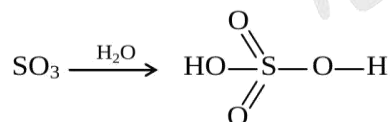
## NATURE OF OXIDE

## • 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

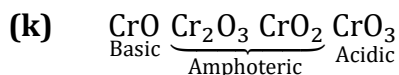
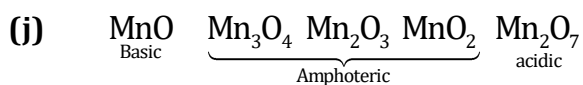
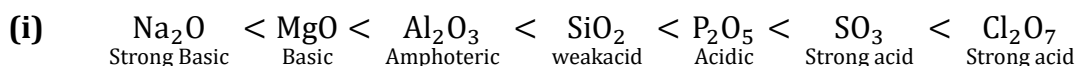
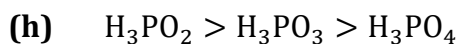
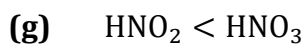
## • Nature of non-metallic oxides :



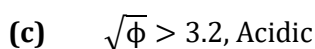
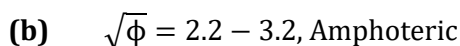
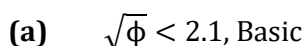
## • E.N of non-metal ↑, acidic nature ↑

- (a)  $\text{CO}_2 > \text{SiO}_2$   
 (b)  $\text{CO} < \text{CO}_2$  positive charge ↑, EN ↑, acidic nature ↑  
 (c)  $\text{SO}_2 < \text{SO}_3$   
 (d)  $\text{N}_2\text{O} < \text{NO} < \text{N}_2\text{O}_3 < \text{N}_2\text{O}_4 < \text{N}_2\text{O}_5$   
 (e)  $\text{H}_2\text{SO}_3 < \text{H}_2\text{SO}_4$   
 (f)  $\text{HClO} < \text{HClO}_2 < \text{HClO}_3 < \text{HClO}_4$

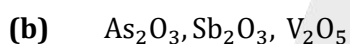
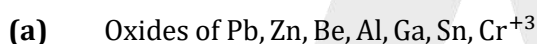
## (Inorganic Chemistry)



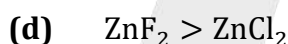
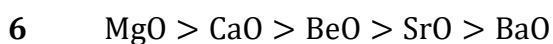
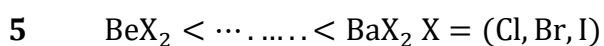
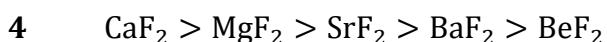
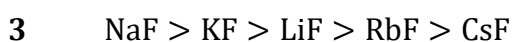
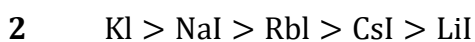
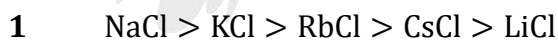
## • Rule:

**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

- In which of the following species the bonds are non-directional ?  
(A)  $\text{NCl}_3$  (B)  $\text{RbCl}$  (C)  $\text{BeCl}_2$  (D)  $\text{BCl}_3$
- Out of following which one has least value of melting point  
(A)  $\text{LiCl}$  (B)  $\text{BeCl}_2$  (C)  $\text{MgCl}_2$  (D)  $\text{CaCl}_2$
- Out of following which one has maximum ionic character -  
(A)  $\text{NaCl}$  (B)  $\text{KCl}$  (C)  $\text{CaCl}_2$  (D)  $\text{MgCl}_2$
- Which of the following has highest melting point -  
(A)  $\text{NaCl}$  (B)  $\text{NaI}$  (C)  $\text{NaBr}$  (D)  $\text{NaF}$
- Among  $\text{LiCl}$ ,  $\text{BeCl}_2$ ,  $\text{BCl}_3$  and  $\text{CCl}_4$ , 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)

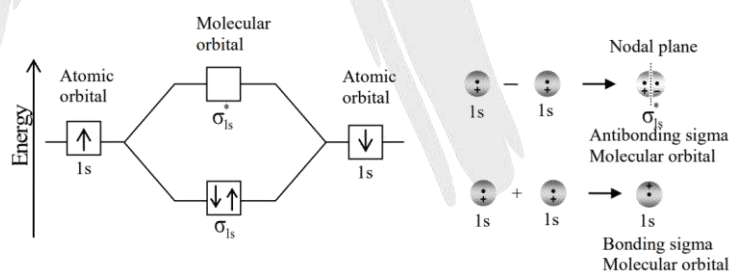
➤ Given by Hunds &amp; Mulliken

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

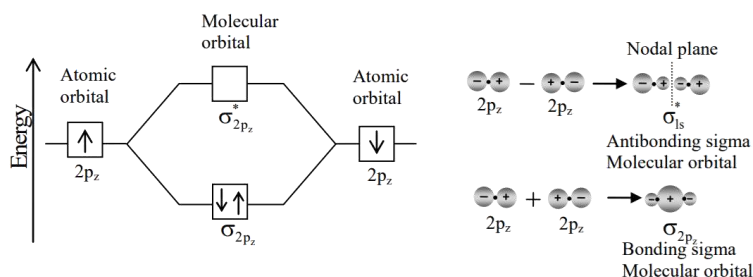
## Types of molecular orbitals

Molecular orbitals of diatomic molecules are designated as  $\sigma$  (sigma),  $\pi$  (pie),  $\delta$  (delta) etc.In this nomenclature, the sigma ( $\sigma$ ) molecular orbitals are symmetrical around the inter molecular axis (assumed to be z-axis) while pi ( $\pi$ ) molecular orbitals are not symmetrical.

## (a) s-s combination of orbitals

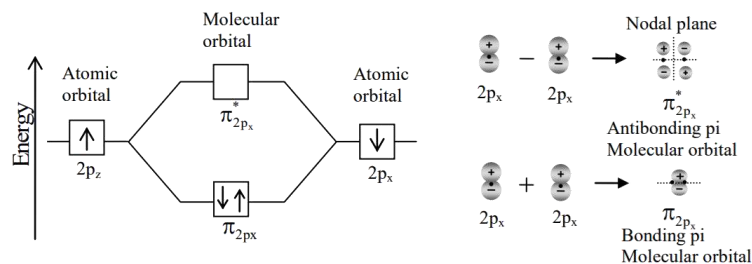


## (b) p-p combination of orbital(end to end overlap)

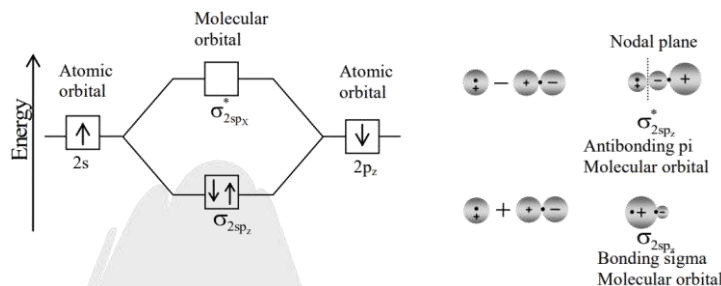




(c) p-p combination of orbitals (side by side overlap)



(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 N<sub>2</sub> (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 O<sub>2</sub> and F<sub>2</sub> (molecule having > 14 electrons)

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

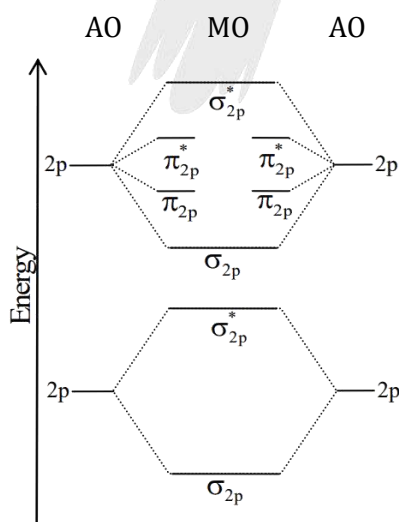
$\sigma^*, \pi^*$  = antibonding molecular orbital

$\sigma, \pi$  = bonding molecular orbital

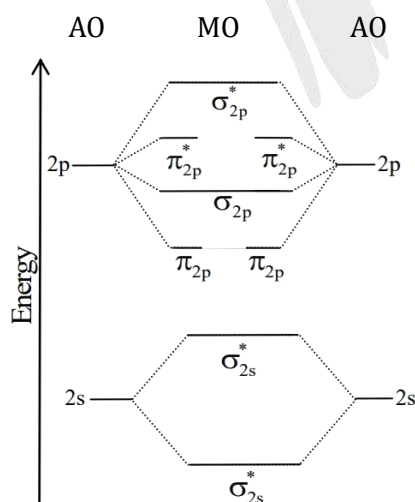
**Ex.** Why molecular orbitals have different order of energy in N<sub>2</sub> & O<sub>2</sub> ?

**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  $\sigma_{sp}$  and  $\pi_{2p}$  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  $\uparrow$  stability of molecule  $\uparrow$  bond length  $\downarrow$

**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 ( $\mu$ ).
- $\mu = \sqrt{n(n+2)}$  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:

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

- **For Axial:** After two rotation from  $180^\circ$ , 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.

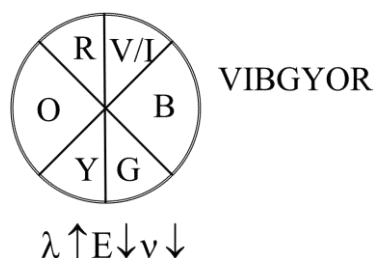
**HOMO:** Highest occupied molecular orbital

**LUMO:** Lowest unoccupied molecular orbital

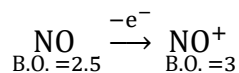
## (Inorganic Chemistry)

In  $F_2$  molecule HOMO is ABMOIn  $O_2$  molecule HOMO is ABMOIn  $N_2$  molecule HOMO is BMO

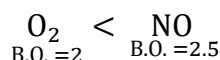
In CO molecule HOMO is NBMO

• **Note :**

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



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



3.  $\text{CO}$                        $\text{CO}^+$

**Bond order:**                      3                      >                      3

**Bond length:**                      1.128 Å                      1.115 Å

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

**DO YOUR SELF - 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)  $\sigma_{2P_z}$                       (C)  $\pi_{2P_x}$                       (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 ?

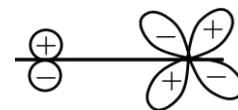
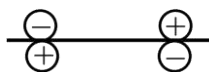
(A) s-orbital p-orbital

(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

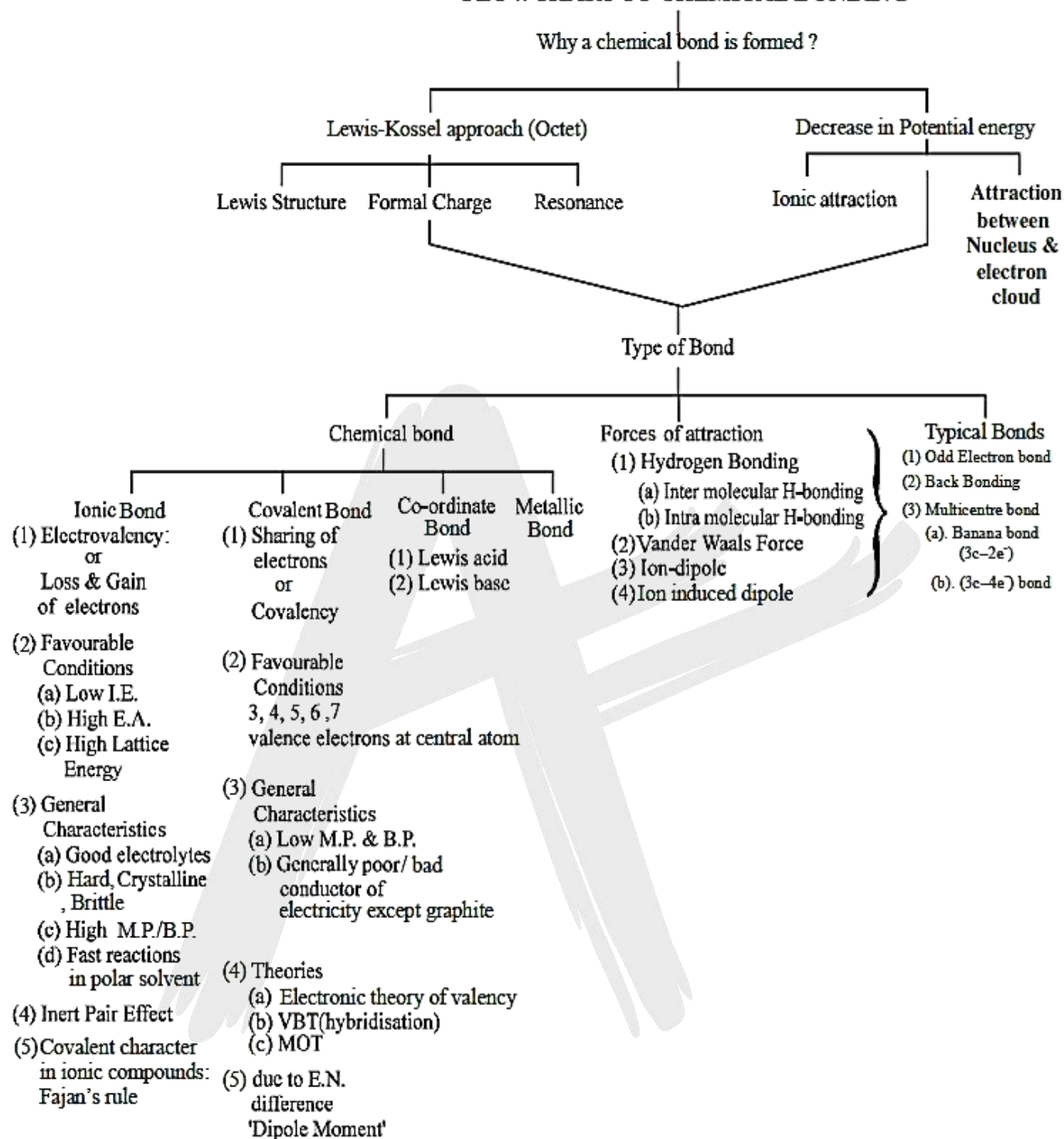
**Do your self - 4**

1. B    2. B    3. B    4. D    5. C

**Do your self - 5**

1. B    2. C    3. B    4. B    5. D

# FLOWCHART TO CHEMICAL BONDING



## EXERCISE – I

## WEAK FORCES

1. The correct order of boiling point of  $\text{NCl}_3$ ,  $\text{NClF}_2$ ,  $\text{NF}_3$  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 Vander 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.

## (Inorganic Chemistry)

8. Which of the following interaction is present in  $\text{XeFe}_6 \cdot 6\text{H}_2\text{O}$
- (A) Keesom force (B) Debye force  
(C) Ion-dipole (D) None of these

## BENT'S RULE AND DRAGO'S

9. Which of the following order of bond angle is CORRECT.
- (A)  $\text{NH}_3 < \text{PH}_3 < \text{AsH}_3 < \text{SbH}_3$   
(B)  $\text{H}_2\text{O} < \text{H}_2\text{S} < \text{H}_2\text{Se} < \text{H}_2\text{Te}$   
(C)  $\text{OF}_2 < \text{H}_2\text{O} < \text{Cl}_2\text{O}$   
(D)  $\text{SiF}_4 < \text{SiCl}_4 < \text{SiBr}_4 < \text{SiI}_4$
10. Calculate the percentage of p character in the orbital occupied by the lone pair of electrons in water molecule. [Given :  $\widehat{\text{HOH}}$  is  $104.5^\circ$  and  $\cos(104.5^\circ) = -0.25$ ]
- (A) 80% (B) 20% (C) 70% (D) 75%
11. Which of the following statement is correct for  $\text{F}_3\text{C} - \text{CF}_2 - \text{CF}_3$  ?
- (A) All C-F bond lengths are identical.  
(B) Two C - F bond attached to middle carbon atom are longer as compared to the other C - F bond at the terminal carbon.  
(C) Two C-F bonds attached to the middle carbon atom are shorter as compared to the other C - F bond at the terminal carbon.  
(D) None of these
12. The correct order of  $d_{\text{C-H}}$  in the following option is
- (A)  $\text{CHF}_3 = \text{CH}_2\text{F}_2 = \text{CH}_3\text{F}$  (B)  $\text{CHF}_3 > \text{CH}_2\text{F}_2 > \text{CH}_3\text{F}$   
(C)  $\text{CH}_2\text{F}_2 > \text{CH}_3\text{F} > \text{CHF}_3$  (D)  $\text{CH}_3\text{F} > \text{CH}_2\text{F}_2 > \text{CHF}_3$
13. The strongest P - O bond is found in the molecule
- (A)  $\text{F}_3\text{PO}$  (B)  $\text{Cl}_3\text{PO}$  (C)  $\text{Br}_3\text{PO}$  (D)  $(\text{CH}_3)_3\text{PO}$
14. Consider the following compounds :
- (I)  $\text{ClF}_3$  (II)  $\text{BrF}_3$
- The order of the angles between axial and equatorial bond pairs is
- (A) I > II (B) I < II (C) I = II (D) none
15. Out of  $\text{C}_2\text{H}_6$ ,  $\text{C}_2\text{H}_4$  and  $\text{C}_2\text{H}_2$ . Compound which have highest C - C bond length is :-
- (A)  $\text{C}_2\text{H}_4$   
(B)  $\text{C}_2\text{H}_2$   
(C)  $\text{C}_2\text{H}_6$   
(D) All have equal C-C bond length

## (Inorganic Chemistry)

16. The correct sequence for polarity of the following molecule

1. Benzene      2. Inorganic Benzene      3.  $\text{PCl}_3\text{F}_2$       4.  $\text{PCl}_2\text{F}_3$

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

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

17.  $\text{N}_2\text{H}_4$  reacts with conc.  $\text{H}_2\text{SO}_4$  to produce a salt  $[\text{NH}_3 - \text{NH}_3]^{+2}\text{SO}_4^{-2}$  in which.

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

## BACK BONDING

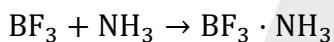
18. The approximate hybridisation of the oxygen atom in disiloxane,  $(\text{SiH}_3)_2\text{O}$ , is-

- (A)  $\text{sp}^2$       (B)  $\text{sp}^3$       (C)  $\text{sp}$       (D)  $\text{sp}^3$

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  $\pi$ -bond between boron and nitrogen is  $2p_\pi - 2p_\pi$

21. Which of the following has highest bond energy ?

- (A) C - F in  $(\text{CF}_4)$       (B) C - Cl in  $(\text{CCl}_4)$   
 (C) C - Br in  $(\text{CBr}_4)$       (D) B-F in  $(\text{BF}_3)$

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

- (A) The strength of back bonding is more in  $\text{O}(\text{SiH}_3)_2$  molecule than  $\text{OCl}_2$  molecule  
 (B)  $\text{Si} - \hat{\text{O}} - \text{Si}$  bond angle in  $\text{O}(\text{SiH}_3)_2$  is greater than  $\text{Cl} - \hat{\text{O}} - \text{Cl}$  bond angle in  $\text{OCl}_2$   
 (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

24. Which of the following molecule has  $3C - 4e^-$  bond ?  
 (A)  $Al_2Cl_6$  (B)  $Be_2Cl_4$   
 (C)  $I_2Cl_6$  (D) All are having  $3C - 4e^-$  bond
25. In which of the following molecules/species all following characteristics are found ?  
 (a) Tetrahedral hybridisation  
 (b) Hybridisation can be considered to have taken place with the help of empty orbital(s).  
 (c) All bond lengths are identical i.e. all A – B bond lengths are identical.  
 (A)  $B_2H_6$  (B)  $Al_2Cl_6$  (C)  $BeCl_2(g)$  (D)  $BF_4^-$
26. The number of three centre two electron bonds in a molecule of diborane is :-  
 (A) 0 (B) 2 (C) 4 (D) 6
27. Which of the following ligand is not responsible for symmetrical bond cleavage in  $B_2H_6$  ?  
 (A)  $Me_2S$  (B)  $H^-$  (C) THF (D)  $NH_3$
28. Which of the following have both  $3c - 2e^\ominus$  and  $2c - 2e^\ominus$  type of bond ?  
 (A)  $BeH_2(s)$  (B)  $BeCl_2(s)$  (C)  $Al_2H_6$  (D)  $Si_2Cl_6$
29. Which of the following molecule have  $3C - 4e^-$  bond as well as planar geometry ?  
 (A)  $Al_2Br_6$  (B)  $Al_2I_6$  (C)  $I_2Cl_6$  (D)  $(AlH_3)_n$

## SILICATE

30. A cyclic silicate anion is represented as  $[Si_3O_9]^{n-}$ . The value of 'n' is  
 (A) 3 (B) 4 (C) 6 (D) 8
31. In which of following silicate structure, the number of corner shared per tetrahedron is '2'.  
 (A) Four membered cyclic silicate (B) Pyrosilicate  
 (C) Orthosilicate (D) 2D-Silicate
32. If four  $SiO_4$  units are forming single chain type arrangement then find the total number of unshared 'O' atom.  
 (A) 10 (B) 6 (C) 2 (D) 8
33. Thortvetite,  $Sc_2Si_2O_7$  is :  
 (A) a pyrosilicate (B) a sheet silicate  
 (C) an orthosilicate (D) an amphibole silicate

## ODD ELECTRON SPECIES

34. Find the odd electron specie in which odd electron is present in pure 'p' atomic orbital.  
 (A)  $\dot{N}O_2$  (B)  $\dot{Cl}O_2$  (C)  $\dot{C}_3$  (D)  $\dot{C}H_3$

## HYDROLYSIS

35. Which of the following is an uncommon hydrolysis product of  $\text{XeF}_2$  and  $\text{XeF}_4$  ?  
 (A) Xe (B)  $\text{XeO}_3$  (C) HF (D)  $\text{O}_2$
36. In which of the following reactions is INCORRECT according to its products formed.  
 (A)  $\text{PCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_3 + 3\text{HCl}$  (B)  $\text{NCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{NH}_3 + 3\text{HOCl}$   
 (C)  $\text{ICl} + \text{H}_2\text{O} \rightarrow \text{HClO} + \text{HI}$  (D)  $\text{N}_2\text{O}_4 + \text{H}_2\text{O} \rightarrow \text{HNO}_3 + \text{HNO}_2$
37. Which of the following compound produce only oxyacid on hydrolysis :-  
 (A)  $\text{IF}_7$  (B)  $\text{XeF}_6$  (C)  $\text{P}_4\text{O}_6$  (D)  $\text{CrO}_2\text{Cl}_2$
38. Which of the following compound does not undergoes in partial hydrolysis ?  
 (A)  $\text{BF}_3$  (B)  $\text{SiF}_4$  (C)  $\text{SbCl}_3$  (D)  $\text{NCl}_3$
39. The correct increasing order of extent of hydrolysis is :  
 (A)  $\text{CCl}_4 < \text{MgCl}_2 < \text{AlCl}_3 < \text{SiCl}_4 < \text{PCl}_5$  (B)  $\text{CCl}_4 < \text{AlCl}_3 < \text{MgCl}_2 < \text{PCl}_5 < \text{SiCl}_4$   
 (C)  $\text{CCl}_4 < \text{SiCl}_4 < \text{PCl}_5 < \text{AlCl}_3 < \text{MgCl}_2$  (D)  $\text{CCl}_4 < \text{PCl}_5 < \text{SiCl}_4 < \text{AlCl}_3 < \text{MgCl}_2$
40.  $\text{XeF}_6$  on complete hydrolysis gives:  
 (A) Xe (B)  $\text{XeO}_2$  (C)  $\text{XeO}_3$  (D)  $\text{XeO}_4$

## MOLECULE DOES NOT EXIST

41. Which of the following molecule does not exist ?  
 (A)  $\text{PbI}_2$  (B)  $\text{VI}_3$  (C)  $\text{ClF}_7$  (D)  $\text{CuI}$

## 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  $\text{TlI}_3$  is +3 .
43. **Statement-1:**  $\text{Hg}_2^{2+}$  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:**  $\text{SnCl}_4$  doesn't exist and converts into  $\text{SnCl}_2$  and  $\text{Cl}_2$  spontaneously at room temperature  
**Statement-2:**  $\text{SnCl}_4$  is more stable than  $\text{SnCl}_2$ .  
 (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)  $\text{NaCl}$  (B)  $\text{CaBr}_2$  (C)  $\text{NaBr}$  (D)  $\text{CaCl}_2$
46. Choose the correct code for the following statements.  
**I.** The (-)ve value of  $\Delta H$  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)  $\text{ZnCl}_2$  (B)  $\text{CdCl}_2$  (C)  $\text{HgCl}_2$  (D)  $\text{CuCl}$
48. Compound having lowest Melting point.  
 (A)  $\text{BeCl}_2$  (B)  $\text{MgCl}_2$  (C)  $\text{CaCl}_2$  (D)  $\text{SrCl}_2$
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)  $\text{CaCl}_2$  (B)  $\text{ZnCl}_2$  (C)  $\text{KCl}$  (D)  $\text{CuCl}$
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)  $\text{O}_2^-$  (B)  $\text{N}_2^+$  (C)  $\text{C}_2$  (D) All of these
56. Which of the following statement is INCORRECT:-  
 (A)  $\text{KO}_2$  is paramagnetic in nature  
 (B) All halogens are coloured gases at room temperature  
 (C)  $\text{O}_2$  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)  $\text{B}_2$  (B)  $\text{O}_2$  (C)  $\text{NO}^\ominus$  (D)  $\text{O}_2^\oplus$
58. Among the following species, which has the minimum bond length?  
 (A)  $\text{B}_2$  (B)  $\text{C}_2$  (C)  $\text{F}_2$  (D)  $\text{O}_2^-$
59. During change of  $\text{O}_2$  to  $\text{O}_2^-$  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)  $\sigma_{2p}$  (B)  $\pi_{2p}$  (C)  $\sigma^*_{2p}$  (D)  $\pi^*_{2p}$

## (Inorganic Chemistry)

61. According to Molecular orbital theory which of the following is correct ?  
 (A) LUMO level for  $C_2$  molecule is  $\sigma_{2p_x}$  orbital  
 (B) In  $C_2$  molecules both the bonds are  $\pi$  bonds  
 (C) In  $C_2^2$  ion there is one  $\sigma$  and two  $\pi$  bonds  
 (D) 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 :  
 (A) In  $N_2^+$ , the N – N bond weakens  
 (B) In  $O_2^+$ , the O – O bond order increases  
 (C) In  $O_2^+$ , the paramagnetism decrease  
 (D)  $N_2^+$  becomes diamagnetic
63. Which of the following species absorb maximum energy in its HOMO-LUMO electronic transition?  
 (A)  $O_2$  (B)  $N_2^-$  (C)  $C_2$  (D)  $N_2$

## MISCELLANEOUS

64. Molecule in which central atom has  $sp^3d^2$  hybridization is present.  
 (A)  $IF_7$  (B)  $IO_6^{5-}$  (C)  $XeF_2$  (D)  $XeO_4$
65. Which of the following oxyacid has S-S linkage :  
 (A)  $H_2S_2O_8$  (B)  $H_2S_2O_7$   
 (C)  $H_2S_2O_3$  (D) All of the above
66. Which of the following molecule/ion is planar and polar both;-  
 (A)  $NO_3^-$  (B)  $NO_2^-$  (C)  $PF_5$  (D)  $NH_3$
67. Choose the element which show maximum number of covalencies out of the given elements.  
 (A) F (B) N (C) C (D) Cl
68. Which of the following order in correct against the property indicated:-  
 (A)  $PH_4^+ < PCl_4^+ < PBr_4^+$  (bond angle)  
 (B)  $BF_3 < NF_3 < NH_3$  (dipole moment)  
 (C)  $CCl_4 < B(OH)_3 < PCl_5$  (number of valence electrons used for bonding by central atom)  
 (D)  $CH_4 < CCl_4 < CBr_4$  (order of bond polarity)
69. Which of the following have different shape from the others :-  
 (A)  $NOF_3$  (B)  $XeO_4$  (C)  $SOCl_2$  (D)  $BF_4^-$
70. Which of the following molecule/atom has lowest enthalpy of fusion ?  
 (A)  $H_2$  (B) He (C)  $Br_2$  (D)  $I_2$

## (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  $120^\circ$ . 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)  $\text{S}_3\text{O}_9$  (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 :**  $\text{XeH}_4$  does not exist but  $\text{XeF}_4$  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 :**  $d_{\text{Mn-O}}$  in  $\text{MnO}_4$  is less than that in  $\text{MnO}_4^{2-}$   
**Statement II :** The higher oxidation state of an element causes higher extent of d orbital contraction and forms more effective  $\pi$  bond with O atoms

## EXERCISE # II

## WEAK FORCES

- 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  $\propto \frac{1}{r^6}$
- The correct order of the boiling point is/are -  
 (A) He < Ne < Ar < Kr < Xe (B) H<sub>2</sub> < He  
 (C) H<sub>2</sub> < D<sub>2</sub> < T<sub>2</sub> (D) BF<sub>3</sub> < BMe<sub>3</sub>

## BENT'S AND DRAGO'S RULE

- Which of the following order is correct regarding %p-character ?  
 (A) H<sub>2</sub> S has higher p-character in S – H bond than the O – H bond in H<sub>2</sub>O  
 (B) PH<sub>3</sub> has higher p-character in P – H bond than the N – H bond in NH<sub>3</sub>  
 (C) NH<sub>4</sub><sup>+</sup> has higher p-character in N – H bond than the P – H bond in PH<sub>4</sub><sup>+</sup>  
 (D) None of these
- Which of the following statement(s) is/are CORRECT?  
 (A) Axial bond length > equatorial bond length in PF<sub>5</sub>  
 (B) axial bond length (P – F) < equatorial bond length (P – Cl) in PF<sub>2</sub>Cl<sub>3</sub>  
 (C) All P-F bond lengths are equal in PF<sub>5</sub>  
 (D) axial bond length (P – F) > equatorial bond length (P – Cl) in PF<sub>2</sub>Cl<sub>3</sub>
- Choose the correct angle order.  
 (A)  $\widehat{\text{HPH}}$  in PH<sub>4</sub><sup>+</sup> =  $\widehat{\text{HCH}}$  in CH<sub>4</sub>  
 (B)  $\widehat{\text{HNNH}}$  in NH<sub>3</sub> <  $\widehat{\text{HPH}}$  in PH<sub>3</sub>  
 (C)  $\widehat{\text{HNNH}}$  in NH<sub>3</sub> <  $\widehat{\text{HPH}}$  in PH<sub>4</sub><sup>+</sup>  
 (D)  $\widehat{\text{OSO}}$  in SO<sub>3</sub><sup>2-</sup> <  $\widehat{\text{ONNO}}$  in NO<sub>3</sub><sup>-</sup>
- In which of the following back bonding is NOT possible -  
 (A) N(CH<sub>3</sub>)<sub>3</sub> (B) BO<sub>3</sub><sup>-3</sup> (C) P(CH<sub>3</sub>)<sub>3</sub> (D) BF<sub>4</sub><sup>-</sup>

## BACK BONDING

- Molecule(s) in which maximum number of atoms in a plane may be ten.  
 (A) B<sub>2</sub>Me<sub>4</sub>H<sub>2</sub> (B) Al<sub>2</sub>(CH<sub>3</sub>)<sub>6</sub> (C) N(SiH<sub>3</sub>)<sub>3</sub> (D) [Co(NH<sub>3</sub>)<sub>6</sub>]<sup>3+</sup>



## (Inorganic Chemistry)

8. Which of the following statement(s) is/are CORRECT -  
 (A)  $[B_3O_6]^{-3}$  ion is non-planar but  $B_3N_3H_6$  is planar  
 (B)  $(SiH_3)_3N$  is planar but  $(SiH_3)_3P$  is pyramidal  
 (C)  $H_3C - NCS$  is bent but  $SiH_3 - NCS$  is linear  
 (D)  $(CH_3)_3N$  is pyramidal but  $(GeH_3)_3N$  is planar
9. Which of the following statements is/are INCORRECT -  
 (A)  $CHF_3$  is less acidic than  $CHCl_3$   
 (B)  $R_3C - O - H$  is more acidic than  $R_3Si - O - H$   
 (C) In  $BF_3$  back bonding is possible but in  $CO$  back bonding is not possible  
 (D)  $PH_3$  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 :-  
 (A)  $B_3N_3H_6$  (B)  $\underline{N}(SiH_3)_3$  (C)  $O(\underline{Si}H_3)_2$  (D)  $H_3\underline{B}_3$

## MULTICENTERED BOND

12. No  $X - X$  bond exists in which of the following compounds having general form of  $X_2H_6$  ?  
 (A)  $B_2H_6$  (B)  $C_2H_6$  (C)  $Al_2H_6$  (D)  $Si_2H_6$
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' -  
 (A) Pyroxene chain silicate (B) Amphibole chain silicate  
 (C) 5-membered cyclic silicate (D) None of these
15. Select correct statement about  $NO_2$  :  
 (A) It is odd electron specie (B)  $N - O$  bond order = 1.5  
 (C) Paramagnetic specie (D) Isoelectronic with  $CO_2$
16. The number of specie(s) which are not perfectly planar.  
 (A)  $\dot{C}H_3$  (B)  $\dot{C}F_3$  (C)  $\dot{C}HF_2$  (D)  $\dot{C}H_2F$



## (Inorganic Chemistry)

17. Which of the following statement is CORRECT :-
- (A) The free electron of  $\text{ClO}_3$  molecule is present in d-orbital of Cl-atom
- (B) The free electron of  $\dot{\text{C}}_3$  is present in  $\text{sp}^3$  hybrid orbital
- (C) NO is polar
- (D) The free electron of  $\text{ClO}_2$  molecule is present in d-orbital of Cl-atom

## HYDROLYSIS

18. Which of the following compounds do not give free halogen acid (Hydra acid) on hydrolysis with excess water as a final product ?
- (A)  $\text{NCl}_3$                       (B)  $\text{PCl}_3$                       (C)  $\text{SiCl}_4$                       (D)  $\text{BF}_3$

## MOLECULE DOES NOT EXIST

19. Which of the following species do not exist in nature.
- (A)  $\text{PI}_5$  (TBP form)    (B)  $\text{PbI}_4$                       (C)  $\text{HFO}_3$                       (D)  $\text{ICl}_7$
20. Which of the following do/does not exist ?
- (A)  $\text{SH}_6$                       (B)  $\text{HFO}_4$                       (C)  $\text{FeI}_3$                       (D)  $\text{HClO}_3$

## INERT PAIR EFFECT

21. Which of the following have  $(18 + 2)$  electron configuration ?
- (A)  $\text{Pb}^{2+}$                       (B)  $\text{Cd}^{2+}$                       (C)  $\text{Bi}^{3+}$                       (D)  $\text{S}^{-2}$
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)  $\text{Si} - \text{O} < \text{P} - \text{O} < \text{S} - \text{O} < \text{Cl} - \text{O}$  ( $\pi$ -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)  $\text{LiCl} > \text{NaCl} > \text{KCl} < \text{RbCl} < \text{CsCl}$  (B)  $\text{Li}_2\text{CO}_3 < \text{Na}_2\text{CO}_3 < \text{K}_2\text{CO}_3$   
 (C)  $\text{LiF} < \text{NaF} < \text{KF} < \text{RbF}$  (D)  $\text{BeCO}_3 < \text{MgCO}_3 < \text{CaCO}_3$
26. Which of the following will give metal oxide on heating?  
 (A)  $\text{CaCO}_3$  (B)  $\text{AgNO}_3$  (C)  $\text{K}_2\text{CO}_3$  (D)  $\text{Li}_2\text{CO}_3$
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)  $\text{O}_2^{2+}$  (B)  $\text{NO}^+$  (C)  $\text{CN}^-$  (D)  $\text{CN}^+$
29. Assuming that if Hund's rule is violated, then the diamagnetic specie(s) is/are :  
 (A)  $\text{B}_2$  (B)  $\text{O}_2$  (C)  $\text{N}_2$  (D)  $\text{O}_2^+$
30. The paramagnetic molecule(s) which have non fractional bond order :-  
 (A)  $\text{O}_2$  (B)  $\text{O}_2^-$  (C)  $\text{N}_2^{2-}$  (D)  $\text{B}_2$

## MISCELLANEOUS

31. Bond angles which are associated with  $\text{sp}^3 \text{d}^3$  hybridization.  
 (A)  $90^\circ$  (B)  $120^\circ$  (C)  $180^\circ$  (D)  $72^\circ$
32. Which of following statement is/are CORRECT for  $\text{ClOF}_3$  ?  
 (A) In hybridisation central atom uses its  $\text{d}_{xy}$  orbital  
 (B) In  $\pi$ -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)  $\text{I}_3^+$  (B)  $\text{NO}_2^-$  (C)  $\text{PCl}_3$  (D)  $\text{BO}_3^{3-}$

## EXERCISE - III

## INTEGER TYPE

- Which of the following pairs have dipole-dipole interaction?  
( $\text{BF}_3 + \text{BF}_3$ ), ( $\text{CCl}_4 + \text{Na}^+$ )( $\text{HCl} + \text{HCl}$ ), ( $\text{CHCl}_3 + \text{CHCl}_3$ ), ( $\text{K}^+ + \text{HCl}$ ), ( $\text{Na}^+ + \text{Cl}^-$ )
- Find the number of molecules in which axial orbital length is higher than equatorial orbital length of central atom :  $\text{PCl}_5$ ,  $\text{PCl}_3 \text{ F}_2$ ,  $\text{PF}_4\text{Cl}$ ,  $\text{PCl}_2 \text{ F}_3$ ,  $\text{PF}_5$
- Find the total number of  $2\text{C} - 2\text{e}^-$  bond in  $\text{Al}_2(\text{C}_6\text{H}_5)_6$  (excluding  $\pi$  bond)  
**Fill your answer as sum of digits till you get the single digit answer.**
- Find the number of molecules, which do not have hybridisation, according to Drago's rule.  
 $\text{PH}_3$ ,  $\text{SH}_2$ ,  $\text{AsH}_3$ ,  $\text{H}_2\text{Se}$ ,  $\text{SiH}_4$
- $6\text{XeF}_4 + 12\text{H}_2\text{O} \rightarrow 4\text{X} + 2\text{Y} + 24\text{HF} + 3\text{O}_2$   
In above reaction find the difference of oxidation state in central atom of X and Y.
- Total number of molecules in which bridge bond formed by  $\text{sp}^3 - \text{s}^- \text{sp}^3$  type overlap  
 $\text{B}_2\text{H}_6$ ,  $\text{Al}_2(\text{CH}_3)_6$ ,  $\text{I}_2\text{Cl}_6$ ,  $\text{Al}_2\text{H}_6$ ,  $\text{Si}_2\text{Cl}_6$
- Among the following total number of planar molecules/ions is.  
 $\text{H}_3\text{O}^+$ ,  $\text{I}_3^\oplus$ ,  $\text{NO}_2^\ominus$ ,  $\text{ClF}_3$ ,  $\text{XeF}_2$ ,  $\text{ICl}_4^\oplus$ ,  $\text{OCl}_2$
- For the given compounds, number of compounds which undergo complete hydrolysis in presence of excess amount of water in ordinary condition :  
 $\text{SF}_4$ ,  $\text{XeF}_2$ ,  $\text{BiCl}_3$ ,  $\text{NF}_3$ ,  $\text{NCl}_3$ ,  $\text{POCl}_3$ ,  $\text{BF}_3$
- Find out the number (s) of molecule in which bond angle around under line atom is  $120^\circ$  :-  
 $\text{H}_3\text{BO}_3$ ,  $\underline{\text{P}}(\text{SiH}_3)_3$ ,  $\underline{\text{N}}(\text{SiH}_3)_3$ ,  $\text{CH}_3^+$ ,  $\underline{\text{N}}(\text{CH}_3)_3$ ,  $\underline{\text{SnCl}}_3^-$
- Find the number of chemical species which undergoes hydrolysis through redox reaction.  
 $\text{XeF}_2$ ,  $\text{XeF}_4$ ,  $\text{XeF}_6$ ,  $\text{SF}_4$ ,  $\text{PCl}_3$ ,  $\text{PCl}_5$
- Find the maximum number of F atom(s) in one plane in  $\text{XeF}_5^+$ :-
- Find the number of molecules which are polar  
 $\text{PCl}_3 \text{ F}_2$ ,  $\text{PCl}_2 \text{ F}_3$ ,  $\text{P}(\text{CH}_3)_3(\text{CF}_3)_2$ ,  $\text{P}(\text{CH}_3)_2(\text{CF}_3)_3$
- Ratio of  $\text{sp}^3$  and  $\text{sp}^2$  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)**
- Number of species having bond order 2 will be?  
 $\text{O}_2^{+2}$ ,  $\text{N}_2^{+2}$ ,  $\text{N}_2^{-2}$ ,  $\text{O}_2^+$ ,  $\text{N}_2^+$ ,  $\text{C}_2$ ,  $\text{B}_2^{-2}$
- Find the total number of  $2\text{C} - 2\text{e}^-$  bond in  $\text{Al}_2(\text{C}_6\text{H}_5)_6$  (excluding  $\pi$  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.

- Which of the following statement is CORRECT ?  
 (A)  $\text{CH}_3\text{F}$  is not perfect tetrahedral  
 (B)  $\text{PCl}_3\text{F}_2$  has got a trigonal bipyramidal (T.B.P) shape.  
 (C) In  $\text{PCl}_3\text{F}_2$ , the two fluorine atoms preferably are positioned in the axial directions.  
 (D) All are correct
- Which of the following order is CORRECT ?  
 (A)  $d_{\text{C-H}}$  in  $\text{CH}_3\text{Cl} > d_{\text{C-H}}$  in  $\text{CH}_3\text{F}$  (B)  $d_{\text{C-H}}$  in  $\text{CH}_3\text{Cl} < d_{\text{C-H}}$  in  $\text{CH}_3\text{F}$   
 (C)  $\text{H}\text{P}\text{H}(\text{PH}_3) > \text{H}\text{P}\text{H}(\text{PH}_4^+)$  (D)  $\text{H}-\text{C}-\text{H}$  in  $\text{CH}_4 > \text{F}-\text{C}-\text{F}$  in  $\text{CF}_4$

## Paragraph for Question 3 to 4

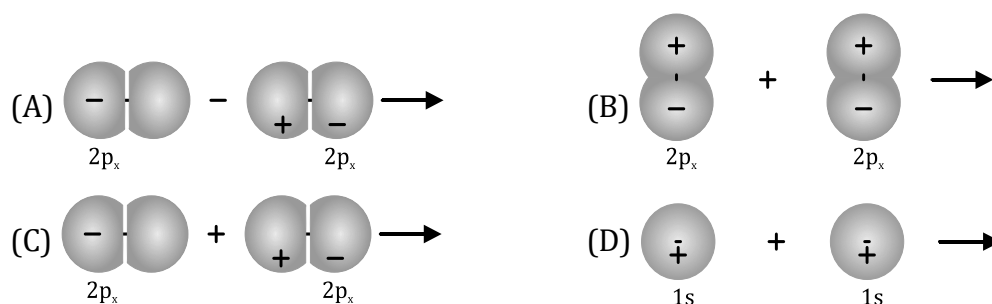
Back bonding is a type of sideways overlapping.

- Which of the following molecule has  $2p_\pi - 3d_\pi$  back bonding.  
 (A)  $\text{PCl}_3$  (B)  $\text{CCl}_3^-$  (C)  $\text{BCl}_3$  (D)  $(\text{BO}_2^-)_3$
- 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.

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



- Which of the following specie does not exist :-  
 (A)  $\text{HeH}^+$  (B)  $\text{Be}_2$  (C)  $\text{C}_2^{2-}$  (D)  $\text{NO}^+$

## 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)  $\text{PCl}_5$  (B)  $\text{ClF}_3$  (C)  $\text{SF}_4$  (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

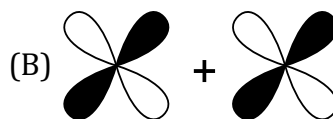
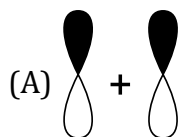
When a substance undergoes nucleophilic substitution reaction and the nucleophile is solvent itself, then the reaction is known as solvolysis, if the solvent used is water then the reaction is called as hydrolysis.

9. The product(s) of hydrolysis of  $\text{NCl}_3$  is/are :-  
 (A)  $\text{HNO}_2$  (B)  $\text{HCl}$  (C)  $\text{NH}_3$  (D)  $\text{HOCl}$
10. Which of the following compounds on hydrolysis produce oxyacid having basicity three in water :-  
 (A)  $\text{PCl}_5$  (B)  $\text{AsCl}_3$  (C)  $\text{PCl}_3$  (D)  $\text{BCl}_3$

## 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 undergoes 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 ungerade molecular orbital.



12. Which of the following property does not change when  $\text{O}_2$  is converted to  $\text{O}_2^-$  :-  
 (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  $\sigma$ -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  $\text{BH}_3$  and  $\text{BeH}_2$  is  
 (A)  $\text{sp}^2, \text{sp}$  (B)  $\text{sp}^3, \text{sp}^2$  (C)  $\text{sp}^3, \text{sp}^3$  (D)  $\text{sp}^2, \text{sp}^3$
14. Which of the following molecule has complete octet  
 (A)  $\text{B}_2\text{H}_6$  (B)  $\text{Al}_2\text{Cl}_6$  (C)  $\text{Be}_2\text{Cl}_4$  (D)  $\text{BeH}_2$
15. Which of the following is/are electron deficient compounds?  
 (A)  $\text{NaBH}_4$  (B)  $\text{B}_2\text{H}_6$  (C)  $\text{Al}_2\text{Cl}_6$  (D)  $\text{BeCl}_2(\text{s})$

## MATCHING LIST

## 16. List I (Species)

- (P)  $\text{O}_2^-$   
 (Q)  $\text{N}_2^+$   
 (R)  $\text{H}_2^+$   
 (S)  $\text{B}_2$

## List II (Bond order)

- (1) 2.5  
 (2) 1.0  
 (3) 1.5  
 (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)  $\text{Si}_2\text{O}_7^{6-}$   
 (Q)  $(\text{Si}_2\text{O}_{5.5}^{-3})_n$   
 (R)  $\text{SiO}_2$   
 (S)  $(\text{Si}_2\text{O}_5^{2-})$

- (1)  
 (2) 1  
 (3) 2.5 (avg.)  
 (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

- (P)  $\text{BF}_3$   
 (Q)  $\text{AlCl}_3$   
 (R)  $\text{SiO}_2$   
 (S) CO

## List II

- (1) Exist in dimeric form  
 (2) Effective back bond is present  
 (3) Acts as lewis acid  
 (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)  $\text{BF}_3$   
(B)  $\text{BCl}_3$   
(C)  $\text{H}_3\text{BO}_3$   
(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)  $\text{sp}^2$  hybridisation of boron

## 20. Column-I

- (A)  $\text{HCl}$  and  $\text{HCl}$   
(B)  $\text{HCl}$  and  $\text{C}_6\text{H}_6$   
(C)  $\text{Na}^+$  and  $\text{NH}_3$   
(D)  $\text{K}^+$  and  $\text{CCl}_4$

## 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

- Which of the following pairs has the strongest hydrogen bonding between themselves?  
[NSEC-2002]  
(A)  $\text{SiH}_4$  and  $\text{SiF}_4$  (B)  $\text{CH}_4$  and  $\text{CH}_3\text{OH}$   
(C)  $\text{CH}_3\text{COCH}_3$  and  $\text{CHCl}_3$  (D)  $\text{HCO}_2\text{H}$  and  $\text{CH}_3\text{CO}_2\text{H}$
- The number of hydrogen bonds formed by each  $\text{H}_2\text{O}$  molecule in an ice crystal is :  
[NSEC-2003]  
(A) 6 (B) 4 (C) 2 (D) 3
- The molecule with non-zero dipole moment is  
[NSEC-2004]  
(A)  $\text{BF}_3$  (B)  $\text{PCl}_3$  (C)  $\text{SiCl}_4$  (D)  $\text{ClF}_5$
- Bond orders of  $\text{NO}$  and  $\text{NO}^+$  are respectively  
[NSEC-2004]  
(A) 2.5 and 3 (B) 2 and 4 (C) 3.5 and 2.5 (D) 4 and 2
- The molecular orbital with highest energy in a nitrogen molecule is  
[NSEC-2004]  
(A)  $\sigma_{2p}$  (B)  $\pi_{2p}$  (C)  $\sigma^*_{2p}$  (D)  $\pi^*_{2p}$
- The substance that has the lowest boiling point is  
[NSEC-2004]  
(A)  $\text{HCl}$  (B)  $\text{H}_2\text{S}$  (C)  $\text{PH}_3$  (D)  $\text{SiH}_4$
- The compound in which H-bonding is not possible is:  
[NSEC-2005]  
(A)  $\text{CH}_3\text{OCH}_3$  (B)  $\text{H}_2\text{O}$  (C)  $\text{CH}_3\text{CH}_2\text{OH}$  (D)  $\text{CH}_3\text{COOH}$
- In solid  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ , copper is coordinated to  
[NSEC-2005]  
(A) One water molecule (B) three water molecules  
(C) Five water molecules (D) four water molecules.
- In thiosulphuric acid  $\text{H}_2\text{S}_2\text{O}_3$ , the oxidation states of sulphur atoms are  
[NSEC-2006]  
(A) +II, +II (B) 0, +IV (C) +I, +III (D) –II, +VI.
- 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)  $\text{CO}_3^{2-}$  (B)  $\text{O}_3$  (C)  $\text{SO}_2$  (D)  $\text{I}_3^-$
- 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) 2s and  $3p_y$  (B) 1s and  $3p_y$  (C) 1s and  $3p_z$  (D) 2s and  $3p_z$ .
- The structures of  $\text{AlCl}_3$  and  $\text{PCl}_3$  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  $\text{ClF}_3$  molecule are of the type [NSEC-2006]  
 (A)  $\text{sp}^3$  (B)  $\text{sp}^2$  (C)  $\text{sp}^2 \text{ d}$  (D)  $\text{sp}^3 \text{ d}$
14. The non-linear molecule is [NSEC-2006]  
 (A)  $\text{SO}_2$  (B)  $\text{CO}_2$  (C)  $\text{HCN}$  (D)  $\text{C}_2\text{H}_2$
15. Which of the following pairs is a Lewis acid & a Lewis base ? [NSEC-2006]  
 (A)  $\text{Cl}$  &  $\text{Ag}^+$  (B)  $\text{NH}_3$  &  $\text{BF}_3$  (C)  $\text{SO}_4^{2-}$  &  $\text{HSO}_4^-$  (D)  $\text{H}^+$  &  $\text{OH}^-$
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-2electron (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)  $\text{O}_2$  and  $\text{H}_2\text{O}$  (B)  $\text{BF}_3$  and  $\text{PCl}_3$  (C)  $\text{SO}_2$  and  $\text{SCl}_2$  (D)  $\text{CS}_2$  and  $\text{NO}_2$
20. The species containing the maximum number of lone pairs in the central atom is: [NSEC-2009]  
 (A)  $\text{ClO}_3^-$  (B)  $\text{XeF}_4$  (C)  $\text{SF}_4$  (D)  $\text{I}_3^-$
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 ( $\text{C}_2^{2-}$ ) 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  $\text{Al}_2\text{Cl}_6$  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 bipyramid  
 (C) Square pyramid (D) Trigonal planar
27. The compound that does not have a  $\pi$  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  $110^\circ$   
 (B) T-shaped with angle  $90^\circ$   
 (C) Bent T-shaped with angle close to  $89^\circ$   
 (D) Trigonal planar with bond angle close to  $120^\circ$
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

- Which one of the following molecules is expected to exhibit diamagnetic behaviour ?  
[AIEEE-2013]  
(A)  $C_2$  (B)  $N_2$  (C)  $O_2$  (D)  $S_2$
- 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)  $H_2^-, He_2^{2+}$
- 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)  $Li_2^- < Li_2 < Li_2^+$
- Which one of the following properties is not shown by NO ?  
[JEE-M-2014]  
(A) It combines with oxygen to form nitrogen dioxide  
(B) It's bond order is 2.5  
(C) It is diamagnetic in gaseous state  
(D) It is a neutral oxide
- 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)  $Ba(OH)_2 < Ca(OH)_2 < Sr(OH)_2 < Mg(OH)_2$
- 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)  $MgCl_2$
- 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)  $BeSO_4$
- 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
- Which one has the highest boiling point ?  
[JEE-M-2015]  
(A) Kr (B) Xe (C) He (D) Ne
- Which intermolecular force is most responsible in allowing xenon gas to liquefy?  
[JEE (MAIN) ONLINE 2016]

## (Inorganic Chemistry)

- (A) Ionic  
(B) Instantaneous dipole- induced dipole  
(C) Dipole - dipole  
(D) Ion - dipole
11. The bond angle  $H - X - H$  is the greatest in the compound : **[JEE (MAIN) ONLINE 2016]**  
(A)  $NH_3$  (B)  $H_2O$  (C)  $PH_3$  (D)  $CH_4$
12. Which of the following species is not paramagnetic? **[JEE (MAIN) ONLINE 2017]**  
(A) NO (B) CO (C)  $O_2$  (D)  $B_2$
13. Which of the following is paramagnetic ? **[JEE-MAIN-2017 (On-line)]**  
(A) CO (B)  $O_2^{2-}$  (C)  $NO^+$  (D)  $B_2$
14.  $sp^3d^2$  hybridization is not displayed by : **[JEE-MAIN-2017 (On-line)]**  
(A)  $[CrF_6]^{3-}$  (B)  $BrF_5$  (C)  $PF_5$  (D)  $SF_6$
15. The number of  $S = O$  and  $S - OH$  bonds present in peroxodisulphuric acid and pyrosulphuric acid respectively are : **[JEE-MAIN-2017 (On-line)]**  
(A) (2 and 4) and (2 and 4) (B) (4 and 2) and (2 and 4)  
(C) (2 and 2) and (2 and 2) (D) (4 and 2) and (4 and 2)
16. The correct sequence of decreasing number of  $\pi$ -bonds in the structures of  $H_2SO_3$ ,  $H_2SO_4$  and  $H_2S_2O_7$  is **[JEE-MAIN-2017 (On-line)]**  
(A)  $H_2S_2O_7 > H_2SO_4 > H_2SO_3$  (B)  $H_2SO_3 > H_2SO_4 > H_2S_2O_7$   
(C)  $H_2S_2O_7 > H_2SO_3 > H_2SO_4$  (D)  $H_2SO_4 > H_2S_2O_7 > H_2SO_3$
17. The increasing order of the boiling point for the following compounds is :- **[JEE-MAIN-2017 (On-line)]**  
(I)  $C_2H_5OH$  (II)  $C_2H_5Cl$  (III)  $C_2H_5CH_3$  (IV)  $C_2H_5OCH_3$   
(A) (III) < (II) < (I) < (IV) (B) (II) < (III) < (IV) < (I)  
(C) (IV) < (III) < (I) < (II) (D) (III) < (IV) < (II) < (I)
18. The number of  $P - OH$  bonds and the oxidation state of phosphorus atom in pyrophosphoric acid ( $H_4P_2O_7$ ) respectively are :- **[JEE-MAIN-2017 (On-line)]**  
(A) five and four (B) five and five (C) four and five (D) four and four
19. The group having triangular planar structures is :- **[JEE-MAIN-2017 (On-line)]**  
(A)  $CO_3^{2-}$ ,  $NO_3^-$ ,  $SO_3$  (B)  $NCl_3$ ,  $BCl_3$ ,  $SO_3$   
(C)  $NH_3$ ,  $SO_3$ ,  $CO_3^{2-}$  (D)  $BF_3$ ,  $NF_3$ ,  $CO_3^{2-}$
20. In the molecular orbital diagram for the molecular ion,  $N_2^+$ , the number of electrons in the  $\sigma_{2p}$  molecular orbitals is : **[JEE Main online - 2018]**  
(A) 0 (B) 1 (C) 2 (D) 3

## (Inorganic Chemistry)

21. Which of following is a Lewis acid? [JEE Main online - 2018]  
 (A)  $\text{PH}_3$  (B)  $\text{B}(\text{CH}_3)_3$  (C)  $\text{NaH}$  (D)  $\text{NF}_3$
22. (I) (II) [JEE Main online - 2018]  
 $\text{H} - \text{N} - \text{N} - \text{N}$   
 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)  $< 2 > 2$  (B)  $> 2 < 2$  (C)  $> 2 > 2$  (D)  $< 2 < 2$
23. The decreasing order of bond angles in  $\text{BF}_3$ ,  $\text{NH}_3$ ,  $\text{PF}_3$  and  $\text{I}_3^-$  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 :  $\text{N}_2\text{O}_3$ ,  $\text{N}_2\text{O}_4$  and  $\text{N}_2\text{O}_5$ ; the molecule(s) having N – N bond is/are: [JEE Main online - 2018]  
 (A) Only  $\text{N}_2\text{O}_5$  (B)  $\text{N}_2\text{O}_3$  and  $\text{N}_2\text{O}_5$   
 (C)  $\text{N}_2\text{O}_5$  and  $\text{N}_2\text{O}_4$  (D)  $\text{N}_2\text{O}_3$  and  $\text{N}_2\text{O}_4$
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  $\text{XCl}_3$  is electron deficient and easily reacts with  $\text{NH}_3$  to form  $\text{Cl}_3\text{X} \leftarrow \text{NH}_3$  adduct; however,  $\text{XCl}_3$  does not dimerize. X is: [JEE Main online - 2018]  
 (A) B (B) Al (C) Ga (D) In
28. Which of the following best describes the diagram below of a molecular orbital? [JEE Main online - 2018]  
 (A) A non-bonding orbital (B) An antibonding  $\sigma$  orbital  
 (C) A bonding  $\pi$  orbital (D) An antibonding  $\pi$  orbital
29. In  $\text{KO}_2$ , the nature of oxygen species and the oxidation state of oxygen atom are, respectively:



[JEE Main online - 2018]

- (A) Oxide and -2 (B) superoxide and  $-1/2$   
 (C) Peroxide and  $-1/2$  (D) Superoxide and -1

30. The number of P – O bonds in  $P_4O_6$  is:

[JEE Main online - 2018]

- (A) 6 (B) 9 (C) 12 (D) 18

31. In  $XeO_3 F_2$ , the number of  $\sigma$ -bond(s),  $\pi$ -bond(s) and lone pair(s) on Xe atom respectively are

[JEE Main online - 2018]

- (A) 5, 2, 0 (B) 4, 2, 2 (C) 5, 3, 0 (D) 4, 4, 0

32. Identify the pair in which the geometry of the species is T-shapes and square pyramidal, respectively :

[JEE Main online - 2018]

- (A)  $ClF_3$  and  $IO_4^-$  (B)  $ICl_2^-$  and  $ICl_5$   
 (C)  $XeOF_2$  and  $XeOF_4$  (D)  $IO_3^-$  and  $IO_2 F_2^-$

33. The incorrect geometry is represented by:

[JEE Main online - 2018]

- (A)  $BF_3$  - trigonal planar (B)  $H_2O$  - bent  
 (C)  $NF_3$  - trigonal planar (D)  $AsF_5$  - trigonal bipyramidal

34. Correct statements among a to d regarding silicones are :

[JEE Main online - 2019]

- (a) They are polymers with hydrophobic character  
 (b) They are biocompatible.  
 (c) In general, they have high thermal stability and low dielectric strength.  
 (d) Usually, they are resistant to oxidation and used as grease.

- (A) (a), (b) and (c) only (B) (a), and (b) only  
 (C) (a), (b), (c) and (d) (D) (a), (b) and (d) only

35. According to molecular orbital theory, which of the following is true with respect to  $Li_2^+$  and  $Li_2^-$ ?

[JEE Main online - 2019]

- (A) Both are unstable (B)  $Li_2^+$  is unstable and  $Li_2^-$  is stable  
 (C)  $Li_2^+$  is stable and  $Li_2^-$  is unstable (D) Both are stable

36. The one that is extensively used as a piezoelectric material is : [JEE Main online - 2019]

- (A) Quartz (B) Amorphous silica  
 (C) Mica (D) Tridymite

## (Inorganic Chemistry)

37. Aluminium is usually found in +3 oxidation state. In contrast, thallium exists in +1 and +3 oxidation states. This is due to : **[JEE Main online - 2019]**  
 (A) lanthanoid contraction (B) lattice effect  
 (C) diagonal relationship (D) inert pair effect
38. In which of the following processes, the bond order has increased and paramagnetic character has changed to diamagnetic? **[JEE Main online - 2019]**  
 (A)  $O_2 \rightarrow O_2^{2-}$  (B)  $O_2 \rightarrow O_2^+$  (C)  $NO \rightarrow NO^+$  (D)  $N_2 \rightarrow N_2^+$
39. The type of hybridisation and number of lone pair(s) on electrons of Xe in  $XeOF_4$  respectively, are : **[JEE Main online - 2019]**  
 (A)  $sp^3d$  and 2 (B)  $sp^3d^2$  and 2  
 (C)  $sp^3d$  and 1 (D)  $sp^3d^2$  and 1
40. Two pi and half sigma bonds are present in : **[JEE Main online - 2019]**  
 (A)  $N_2^+$  (B)  $N_2$  (C)  $O_2^+$  (D)  $O_2$
41. The number of 2-centre-2-electron and 3-centre-2-electron bonds in  $B_2H_6$ , respectively, are: **[JEE Main online - 2019]**  
 (A) 2 and 2 (B) 4 and 2 (C) 2 and 4 (D) 2 and 1
42. The chloride that cannot get hydrolysed is : **[JEE Main online - 2019]**  
 (A)  $SiCl_4$  (B)  $CCl_4$  (C)  $PbCl_4$  (D)  $SnCl_4$
43. The relative stability of +1 oxidation state of group 13 elements follows the order :- **[JEE Main online - 2019]**  
 (A)  $Ga < Al < In < Tl$  (B)  $Al < Ga < In < Tl$   
 (C)  $Al < Ga < Tl < In$  (D)  $Tl < In < Ga < Al$
44. The hydride that is NOT electron deficient is :- **[JEE Main online - 2019]**  
 (A)  $SiH_4$  (B)  $AlH_3$  (C)  $B_2H_6$  (D)  $GaH_3$
45. The relative strength of interionic/ intermolecular forces in decreasing order is: **[JEE Main online - 2020]**  
 (A) dipole-dipole > ion-dipole > ion-ion  
 (B) ion-dipole > dipole-dipole > ion-ion  
 (C) ion-dipole > ion-ion > dipole-dipole  
 (D) ion-ion > ion-dipole > dipole-dipole
46. The dipole moments of  $CCl_4$ ,  $CHCl_3$  and  $CH_4$  are in the order: **[JEE Main online - 2020]**  
 (A)  $CH_4 = CCl_4 < CHCl_3$  (B)  $CCl_4 < CH_4 < CHCl_3$   
 (C)  $CHCl_3 < CH_4 = CCl_4$  (D)  $CH_4 < CCl_4 < CHCl_3$



## (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 :

C – Cl, C – Br, C – F, C – I

[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)

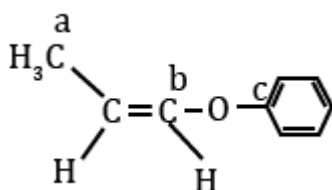
54. Which of the following are isostructural pairs? [JEE Main 2021]  
 (A)  $\text{SO}_4^{2-}$  and  $\text{CrO}_4^{2-}$  (B)  $\text{SiCl}_4$  and  $\text{TiCl}_4$   
 (C)  $\text{NH}_3$  and  $\text{NO}_3^-$  (D)  $\text{BCl}_3$  and  $\text{BrCl}_3$   
 (A) A and C only (B) A and B only  
 (C) B and C only (D) C and D only
55. The correct shape and I-I-I bond angles respectively in  $\text{I}_3^-$  ion are : [JEE Main 2021]  
 (A) Trigonal planar;  $120^\circ$   
 (B) Distorted trigonal planar;  $135^\circ$  and  $90^\circ$   
 (C) Linear;  $180^\circ$   
 (D) T-shaped;  $180^\circ$  and  $90^\circ$
56. According to molecular orbital theory, the species among the following that does not exist is: [JEE Main 2021]  
 (A)  $\text{He}_2^-$  (B)  $\text{He}_2^+$  (C)  $\text{O}_2^{2-}$  (D)  $\text{Be}_2$
57. Which among the following species has unequal bond lengths?  
 (A)  $\text{XeF}_4$  (B)  $\text{SiF}_4$  (C)  $\text{BF}_4^-$  (D)  $\text{SF}_4$
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) $\text{Ne}_2$ | (i) 1                |
| (b) $\text{N}_2$  | (ii) 2               |
| (c) $\text{F}_2$  | (iii) 0              |
| (d) $\text{O}_2$  | (iv) 3               |
- Choose the correct answer from the options given below: [JEE Main 2021]

## (Inorganic Chemistry)

- (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)  $SF_4, BF_4^-, ClF_3, AsF_3, PCl_5, BrF_5, XeF_4, SF_6$  [JEE Main 2021]

63. Identify the species having one  $\pi$ -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 some what 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. $\text{XeO}_3$	I. $\text{sp}^3 \text{d}$ ; linear
B. $\text{XeF}_2$	II. $\text{sp}^3$ ; pyramidal
C. $\text{XeOF}_4$	III. $\text{sp}^3 \text{d}^3$ ; distorted octahedral
D. $\text{XeF}_6$	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:  $\text{NO}$ ,  $\text{N}_2\text{O}$ ,  $\text{B}_2\text{O}_3$ ,  $\text{N}_2\text{O}_5$ ,  $\text{CO}$ ,  $\text{SO}_3$ ,  $\text{P}_4\text{O}_{10}$ 

- (A) 3 (B) 4 (C) 5 (D) 6 [JEE Main 2022]

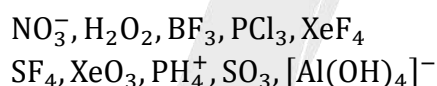
68. Arrange the following in increasing order of their covalent character. [JEE Main 2022]

- (A)  $\text{CaF}_2$  (B)  $\text{CaCl}_2$  (C)  $\text{CaBr}_2$  (D)  $\text{CaI}_2$

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



[JEE Main 2022]

70. Based upon VSEPR theory, match the shape (geometry) of the molecules in List-I with the molecules in List-II and select the most appropriate option [JEE Main 2022]

List-I (Shape) List-II (Molecules)

- (A) T-shaped (I)  $\text{XeF}_4$   
 (B) Trigonal planar (II)  $\text{SF}_4$   
 (C) Square planar (III)  $\text{ClF}_3$   
 (D) See-saw (IV)  $\text{BF}_3$

- (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  $\text{CH}_4$ ,  $\text{NH}_4^+$  and  $\text{BH}_4^-$ . Choose the correct option with respect to the there 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 :  $\text{N}_2$ ;  $\text{N}_2^+$ ;  $\text{O}_2$ ;  $\text{O}_2^+$ ? [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)	$\text{IF}_7$	I.	Three
(B)	$\text{ICl}_4^-$	II.	One
(C)	$\text{XeF}_6$	III.	Two
(D)	$\text{XeF}_2$	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. $\text{XeF}_4$	I. See - saw
B. $\text{SF}_4$	II. Square planar
C. $\text{NH}_4^+$	III. Bent T-shaped
D. $\text{BrF}$	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  $\text{BCl}_2^\ominus$ 

[JEE Main 2023]

## EXERCISE – JEE – ADVANCED

- 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
- Which of the following have identical bond order ? [IIT-1992]  
 (A)  $\text{CN}^-$  (B)  $\text{O}_2^-$  (C)  $\text{NO}^+$  (D)  $\text{CN}^+$
- Among the following the one that is polar and has the central atom with  $\text{sp}^2$  hybridisation is: [IIT-1997]  
 (A)  $\text{H}_2\text{CO}_3$  (B)  $\text{SiF}_4$  (C)  $\text{BF}_3$  (D)  $\text{HClO}_2$
- Which of the following is soluble in water ? [IIT-98]  
 (A)  $\text{CS}_2$  (B)  $\text{C}_2\text{H}_5\text{OH}$  (C)  $\text{CCl}_4$  (D)  $\text{CHCl}_3$
- The correct order of hybridization of the central atom in the following species  $\text{NH}_3$ ,  $[\text{PtCl}_4]^{2-}$ ,  $\text{PCl}_5$  and  $\text{BCl}_3$  is : [IIT-2001]  
 (A)  $\text{dsp}^2$ ,  $\text{sp}^3$  d,  $\text{sp}^2$  and  $\text{sp}^3$  (B)  $\text{sp}^3$ ,  $\text{dsp}^2$ ,  $\text{sp}^3$  d,  $\text{sp}^2$   
 (C)  $\text{dsp}^2$ ,  $\text{sp}^2$ ,  $\text{sp}^3$ ,  $\text{sp}^3$  d (D)  $\text{dsp}^2$ ,  $\text{sp}^3$ ,  $\text{sp}^2$ ,  $\text{sp}^3$  d
- The common features among the species  $\text{CN}^-$ ,  $\text{CO}$  and  $\text{NO}^+$  are : [IIT-2001]  
 (A) bond order three and isoelectronic  
 (B) bond order three and weak field ligands  
 (C) bond order two and  $\pi$ -acceptors  
 (D) isoelectronic and weak field ligands
- Which of the following molecular species has unpaired electron(s)? [JEE-2002]  
 (A)  $\text{N}_2$  (B)  $\text{F}_2$  (C)  $\text{O}_2^-$  (D)  $\text{O}_2^{2-}$
- According to molecular orbital theory which of the following statement about the magnetic character and bond order is correct regarding  $\text{O}_2^+$  [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  $> \text{O}_2$
- Among the following, the paramagnetic compound is [JEE-2007]  
 (A)  $\text{Na}_2\text{O}_2$  (B)  $\text{O}_3$  (C)  $\text{N}_2\text{O}$  (D)  $\text{KO}_2$
- The species having bond order different from that in  $\text{CO}$  is [JEE-2007]  
 (A)  $\text{NO}^-$  (B)  $\text{NO}^+$  (C)  $\text{CN}^-$  (D)  $\text{N}_2$

## (Inorganic Chemistry)

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** :  $\text{Pb}^{+4}$  compounds are stronger oxidizing agents than  $\text{Sn}^{+4}$  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) $\text{B}_2$   | (P) Paramagnetic                   |
| (B) $\text{N}_2$   | (Q) undergoes oxidation            |
| (C) $\text{O}_2^-$ | (R) Undergoes reduction            |
| (D) $\text{O}_2$   | (S) Bond order $\geq 2$            |
|                    | (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)  $\text{NH}_3$  (B)  $\text{CH}_3\text{NH}_2$  (C)  $(\text{CH}_3)_2\text{NH}$  (D)  $(\text{CH}_3)_3\text{N}$
15. The species having pyramidal shape is [JEE-2010]  
 (A)  $\text{SO}_3$  (B)  $\text{BrF}_3$  (C)  $\text{SiO}_3^{2-}$  (D)  $\text{OsF}_2$
16. Assuming that Hund's rule is violated, the bond order and magnetic nature of the diatomic molecule  $\text{B}_2$  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]

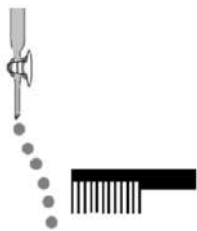
## (Inorganic Chemistry)

18. The total number of diprotic acids among the following is [JEE-2010]  
 $\text{H}_3\text{PO}_4$        $\text{H}_2\text{SO}_4$        $\text{H}_2\text{CO}_3$        $\text{H}_2\text{S}_2\text{O}_7$   
 $\text{H}_3\text{BO}_3$        $\text{H}_3\text{PO}_2$        $\text{H}_2\text{CrO}_4$        $\text{H}_2\text{SO}_3$
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)  $\text{Be}_2$       (B)  $\text{B}_2$       (C)  $\text{C}_2$       (D)  $\text{N}_2$
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 – d $\pi$ antibonding    |
| (Q)    | (2) d – d $\sigma$ bonding     |
| (R)    | (3) d – d $\sigma$ 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  $\text{B}_2\text{H}_6$  are completely reacted with methanol. The number of moles of boron containing product formed is - [JEE Adv. 2015]
23. When  $\text{O}_2$  is adsorbed on a metallic surface, electron transfer occurs from the metal to  $\text{O}_2$ . The TRUE, statement (s) regarding this adsorption is (are) [JEE Adv. 2015]  
 (A)  $\text{O}_2$  is physisorbed  
 (B) heat is released  
 (C) occupancy of  $\pi^*_{2p}$  of  $\text{O}_2$  is increased  
 (D) bond length of  $\text{O}_2$  is increased
24. According to Molecular Orbital Theory, [JEE Adv. 2016]  
 (A)  $\text{C}_2^{2-}$  is expected to be diamagnetic  
 (B)  $\text{O}_2^{2+}$  is expected to have a longer bond length than  $\text{O}_2$   
 (C)  $\text{N}_2^+$  and  $\text{N}_2^-$  have the same bond order  
 (D)  $\text{He}_2^+$  has the same energy as two isolated He atoms
25. The order of the oxidation state of the phosphorus atom in  $\text{H}_3\text{PO}_2$ ,  $\text{H}_3\text{PO}_4$ ,  $\text{H}_3\text{PO}_3$ , and  $\text{H}_4\text{P}_2\text{O}_6$  is [JEE Adv. 2017]  
 (A)  $\text{H}_3\text{PO}_4 > \text{H}_3\text{PO}_2 > \text{H}_3\text{PO}_3 > \text{H}_4\text{P}_2\text{O}_6$     (B)  $\text{H}_3\text{PO}_3 > \text{H}_3\text{PO}_2 > \text{H}_3\text{PO}_4 > \text{H}_4\text{P}_2\text{O}_6$   
 (C)  $\text{H}_3\text{PO}_4 > \text{H}_4\text{P}_2\text{O}_6 > \text{H}_3\text{PO}_3 > \text{H}_3\text{PO}_2$     (D)  $\text{H}_3\text{PO}_2 > \text{H}_3\text{PO}_3 > \text{H}_4\text{P}_2\text{O}_6 > \text{H}_3\text{PO}_4$



## (Inorganic Chemistry)

26. The correct statement(s) about the oxoacid,  $\text{HClO}_4$  and  $\text{HClO}$  is(are) [JEE Adv. 2017]  
 (A)  $\text{HClO}_4$  is more acidic than  $\text{HClO}$  because of the resonance stabilization of its anion  
 (B)  $\text{HClO}_4$  is formed in the reaction between  $\text{Cl}_2$  and  $\text{H}_2\text{O}$   
 (C) The central atom in both  $\text{HClO}_4$  and  $\text{HClO}$  is  $\text{sp}^3$  hybridized  
 (D) The conjugate base of  $\text{HClO}_4$  is weaker base than  $\text{H}_2\text{O}$
27. The colour of the  $\text{X}_2$  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  $\text{X}_2$  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)  $\text{AlCl}_3$  has the three-centre two-electron bonds in its dimeric structure  
 (C)  $\text{BH}_3$  has the three-centre two-electron bonds in its dimeric structure  
 (D) The Lewis acidity of  $\text{BCl}_3$  is greater than that of  $\text{AlCl}_3$
29. The option(s) with only amphoteric oxides is (are) [JEE Adv. 2017]  
 (A)  $\text{Cr}_2\text{O}_3$ ,  $\text{BeO}$ ,  $\text{SnO}$ ,  $\text{SnO}_2$  (B)  $\text{ZnO}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{PbO}$ ,  $\text{PbO}_2$   
 (C)  $\text{NO}$ ,  $\text{B}_2\text{O}_3$ ,  $\text{PbO}$ ,  $\text{SnO}_2$  (D)  $\text{Cr}_2\text{O}_3$ ,  $\text{CrO}$ ,  $\text{SnO}$ ,  $\text{PbO}$
30. Among  $\text{H}_2$ ,  $\text{He}_2^+$ ,  $\text{Li}_2$ ,  $\text{Be}_2$ ,  $\text{B}_2$ ,  $\text{C}_2$ ,  $\text{N}_2$ ,  $\text{O}_2^-$ , and  $\text{F}_2$  the number of diamagnetic species is (Atomic number  $\text{H} = 1$ ,  $\text{He} = 2$ ,  $\text{Li} = 3$ ,  $\text{Be} = 4$ ,  $\text{B} = 5$ ,  $\text{C} = 6$ ,  $\text{N} = 7$ ,  $\text{O} = 8$ ,  $\text{F} = 9$ ) [JEE Adv. 2017]
31. The sum of the number of lone pairs of electrons on each central atom in the following species is  $[\text{TeBr}_6]^{2-}$ ,  $[\text{BrF}_2]^+$ ,  $\text{SNF}_3$  and  $[\text{XeF}_3]^-$  [JEE Adv. 2017]  
 (Atomic number:  $\text{N} = 7$ ,  $\text{F} = 9$ ,  $\text{S} = 16$ ,  $\text{Br} = 35$ ,  $\text{Te} = 52$ ,  $\text{Xe} = 54$ )
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)  $\text{NO}_2$ ,  $\text{NH}_3$ ,  $\text{POCl}_3$ ,  $\text{CH}_3\text{Cl}$  (B)  $\text{BeCl}_2$ ,  $\text{CO}_2$ ,  $\text{BCl}_3$ ,  $\text{CHCl}_3$   
 (C)  $\text{SO}_2$ ,  $\text{C}_6\text{H}_5\text{Cl}$ ,  $\text{H}_2\text{Se}$ ,  $\text{BrF}_5$  (D)  $\text{BF}_3$ ,  $\text{O}_3$ ,  $\text{SF}_6$ ,  $\text{XeF}_6$
33. Among  $\text{B}_2\text{H}_6$ ,  $\text{B}_3\text{N}_3\text{H}_6$ ,  $\text{N}_2\text{O}$ ,  $\text{N}_2\text{O}_4$ ,  $\text{H}_2\text{S}_2\text{O}_3$  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 :  
 $\text{O}_2$ ,  $\text{HF}$ ,  $\text{H}_2\text{O}$ ,  $\text{NH}_3$ ,  $\text{H}_2\text{O}_2$ ,  $\text{CCl}_4$ ,  $\text{CHCl}_3$ ,  $\text{C}_6\text{H}_6$ ,  $\text{C}_6\text{H}_5\text{Cl}$ . [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)  $\sigma$  orbital has a total of two nodal planes.
- (B)  $\sigma^*$  orbital has one node in the  $xz$ -plane containing the molecular axis.
- (C)  $\pi$  orbital has one node in the plane which is perpendicular to the molecular axis and goes through the center of the molecule.
- (D)  $\pi^*$  orbital has one node in the  $xy$ -plane containing the molecular axis.

A

## 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;  $2O$  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  $H_4P_2O_6$  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  $H_3PO_4$  :

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

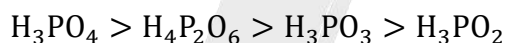
In  $H_3PO_3$  :

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

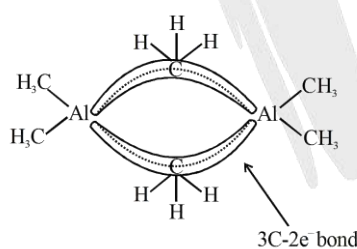
In  $H_4P_2O_6$  :

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

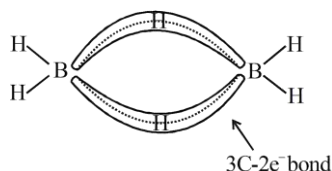
Thus, the order of oxidation state is :



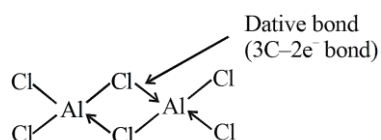
- 28 (A) Structure of  $Al_2(CH_3)_6$



- (B) Structure of  $B_2H_6$



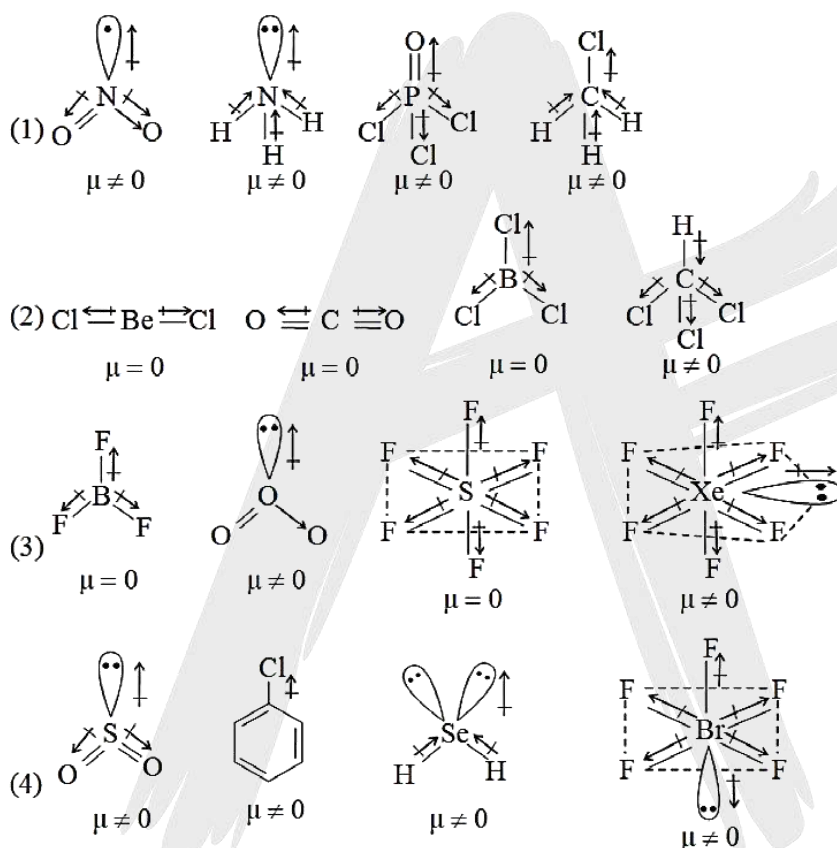
- (C) Structure of  $Al_2Cl_6$



(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)  
 $C_2$  :  $\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2$  (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)  
 $F_2$  :  $\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^2 = \pi^* 2p_y^2$  (Diamagnetic)

32.



33.

