

# CHEMICAL BONDING

## TOPIC-WISE STUDY MATERIAL

BY



Chemical bond:-

*This Material is Downloaded From ExamsRoad.com*

Chemical bond is the attractive force which holds various constituents together in a molecule.

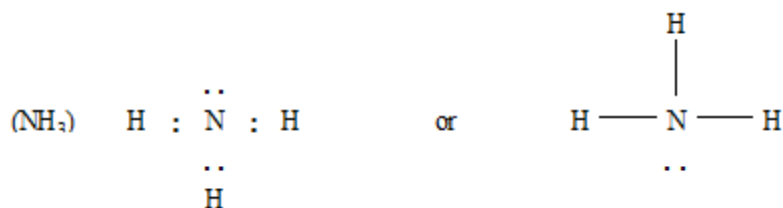
There are three types of chemical bonds: Ionic Bond, Covalent Bond, Co-ordinate Bond.

### Octet Rule:

Atoms form chemical bonds in order to complete their octet i.e. eight electrons in their valence shell.

### Lewis Structures:

- Pair of bonded electrons is by means of a 'dash' (-) usually called a 'bond'.
- Lone pairs or 'non-bonded' electrons are represented by 'dots'.
- Electrons present in the last shell of atoms are called valence electrons.



### Exceptions to the Octet Rule:

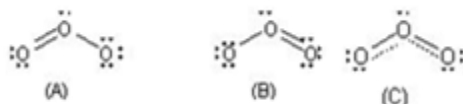
- Species with odd number of electrons: NO, NO<sub>2</sub>,
- Incomplete octet for the central atom: LiCl, BeH<sub>2</sub> and BCl<sub>3</sub>
- Expanded octet for the central atom: PF<sub>5</sub>, SF<sub>6</sub> and H<sub>2</sub>SO<sub>4</sub>

### Formal Charge:

- Formal charge is the difference between the number of valence electrons in an isolated atom and number of electrons assigned to that atoms in Lewis structure.
- Formal charge = [Total number of valence electrons in the free atom] - (Total number of lone pairs of electrons) - 1/2(Total number of shared electrons i.e. bonding electrons)]

### Resonance:

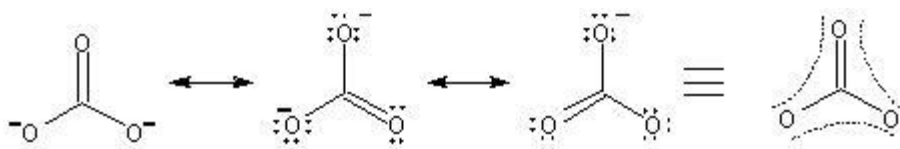
- For molecules and ions showing resonance it is not possible to draw a single Lewis structure.
- All the properties of such species can only be explained by two or more Lewis structures. Example: Resonance of O<sub>3</sub>



A and B are resonating or canonical structures and C is the resonance hybrid

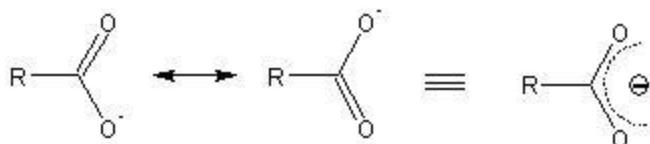
Some other examples

(i)  $\text{CO}_3^{2-}$  ion

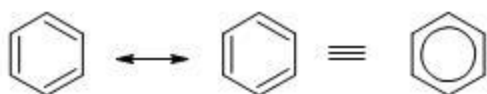


Example

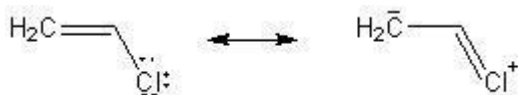
(ii) Carbon-oxygen bond lengths in carboxylate ion are equal due to resonance.



(iii) Benzene



(iv) Vinyl Chloride



## Ionic Bonding:

### Formation of Ionic Bond:

- Formation of ionic bond takes place between a metal and a non-metal by transfer of electron.
- Steps involved in formation of an ionic bond: :

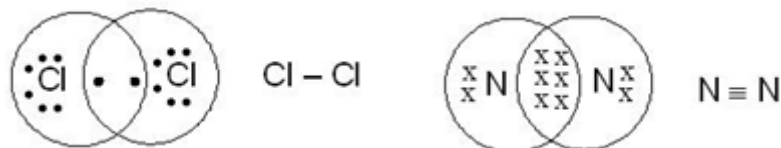
Steps	Equation	Energy involved
Formation of gaseous cations	$A(g) + \text{I.E.} \rightarrow A^+(g) + e$	Ionization Energy
Formation of gaseous anions	$X(g) + e \rightarrow X^-(g) + \text{E.A}$	Electron Affinity
Packing of ions of opposite charges to form ionic solids	$A^+(g) + X^-(g) \rightarrow AX(s) + \text{Energy}$	Lattice energy

### Conditions required of formation of ionic bonds:

- Low I.E of cation.
- High E.A of anion.
- High lattice energy.

## Covalent Bonding:

- Covalent bond is formed between two non-metals by sharing of electrons.
- Electron pairs which participate in bonding are called bond pairs.
- Electron pairs which do not participate in bonding are called lone pairs.
- There could be single, double or triple covalent bonds between two elements depending on the number of electrons being shared.



## VSEPR (Valence Shell Electron Pair Repulsion) Theory:

- The shape of the molecule is determined by repulsions between all of the electron pairs present in the valence shell.
- Order of the repulsion: Lone pair ↔ Lone pair > Lone pair ↔ Bond pair > Bond pair ↔ Bond pair.
- Repulsion among the bond pairs is directly proportional to the bond order and electronegativity difference between the central atom and the other atoms.

### Determination of shape of molecules using VSEPR theory:

- Calculate X using following method.

$$X = (\text{No. of valence electrons of central atom}) + (\text{No. of other atoms}) + (\text{Negative charge on the molecule}) - (\text{Positive charge on the molecule})$$

Use the following chart to find the shape.

X	Shape	Examples
2	Linear	HgCl <sub>2</sub> /BeCl <sub>2</sub>
3	Triangular planar	BF <sub>3</sub>
3	Angular	SnCl <sub>2</sub> , NO <sub>2</sub>
4	Tetrahedral	CH <sub>4</sub> , BF <sub>4</sub> <sup>-</sup>
4	Trigonal Pyramidal	NH <sub>3</sub> , PCl <sub>3</sub>
4	Angular	H <sub>2</sub> O
5	Trigonal bipyramidal	PCl <sub>5</sub> , PF <sub>5</sub>
5	Irregular tetrahedral	SF <sub>4</sub> , IF <sub>4</sub> <sup>+</sup>
5	T-shaped	ClF <sub>3</sub> , BrF <sub>3</sub>
5	Linear	XeF <sub>2</sub> , I <sub>3</sub> <sup>-</sup>
6	Octahedral	SF <sub>6</sub> , PF <sub>6</sub> <sup>-</sup>

6	Square Pyramidal	IF <sub>5</sub>
6	Square planar	XeF <sub>4</sub> , ICl <sub>4</sub>

#### Fajan's Rule:

It accounts for the covalent character in ionic compounds.

Covalency is favoured by

- Smaller cation .
- Larger anion and
- Large charge on either ion.

#### Dipole Moment:

- Dipole moment of any bond is the product of the net positive or negative charge and distance between the two charged ends, i.e., the bond length. i.e.  
Dipole moment (m) = electronic charge (e) × Distance (d) Dipole moment is measured in debye unit (D);
- Dipole moment of a molecule is vector addition of all the individual bond moments.

#### Percentage Ionic Character:

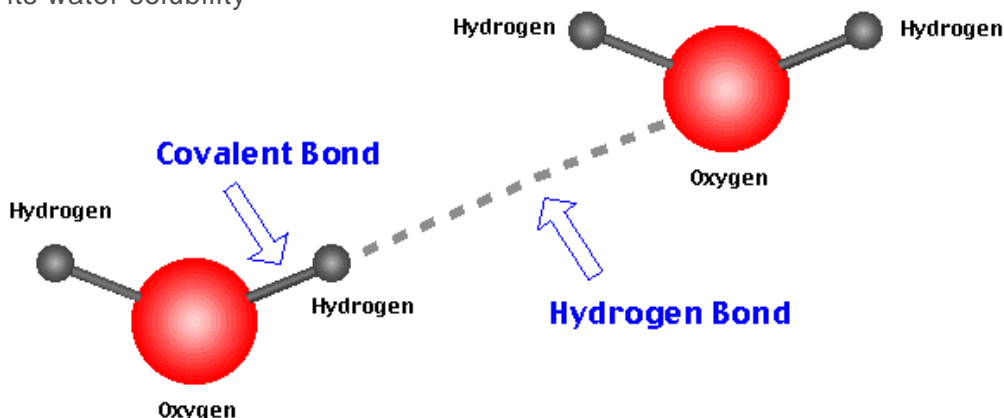
The percent ionic character =

$$\frac{\text{Observed dipole moment}}{\text{Expected dipole moment}} \times 100$$

#### Hydrogen Bonding:

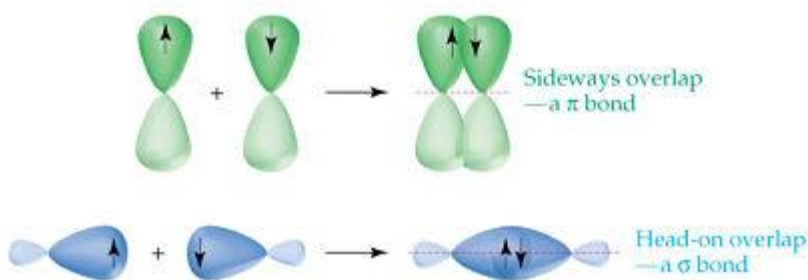
- Hydrogen bond is an electrostatic attractive force between covalently bonded hydrogen atom of one molecule or a part of a molecule and an electronegative atom (such as F, O, N) of another molecule (Inter-molecular hydrogen bonding) or another part of the same molecule (intramolecular hydrogen bonding).
- Intermolecular hydrogen bonding increases boiling point of the compound and also its water solubility

- Intramolecular hydrogen bonding decreases the boiling point of the compound and also its water solubility



### Valence bond theory (VBT):

- A covalent bond is formed by overlapping of valence shell atomic orbital of the two atoms having unpaired electron.
- There is maximum electron density between the bonding atoms.
- Greater the overlapping of atomic orbital higher is the strength of chemical bond.
- The bond formed by lateral overlap of two atomic orbitals having maximum overlapping on both sides of the line connecting the centres of the atoms is called a  $\pi$ -bond. A  $\pi$ -bond possess a plane of symmetry, often referred to as the nodal plane.

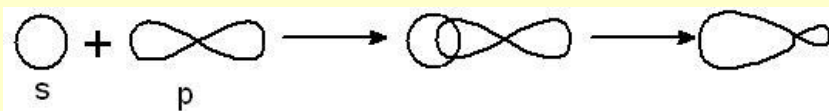


- $\sigma$ -Bond** : When covalent bond is formed by overlapping of atomic orbitals along the same axis it is called s - bond. Such type of bond is symmetrical about the line joining the two nuclei e.g.

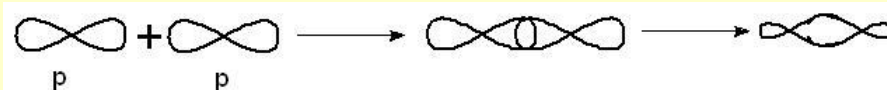
(a) s-s overlapping



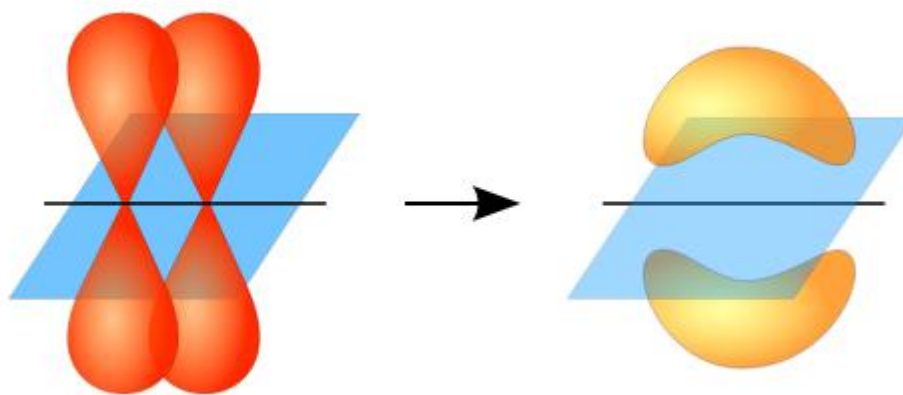
(b) s-p overlapping



(c) p-p overlapping



- **$\pi$  - Bond:** This type of bond is formed by the sidewise or lateral overlapping of two half filled atomic orbitals.



- [The strength of a bond depends upon the extent of overlapping of half-filled atomic orbitals. The extent of overlapping is between two atoms is always greater when there is end to end overlapping of orbitals than, when there is sidewise overlapping of orbitals. Hence s-bond is always stronger than p-bond.
- 
- The average distance between the nuclei of the two bonded atoms in a molecule is called bond length and the energy required to break one mole of bonds of particular type in gaseous state is called Bond energy or Bond strength. The same amount of energy is released in formation of one mol of particular bond.

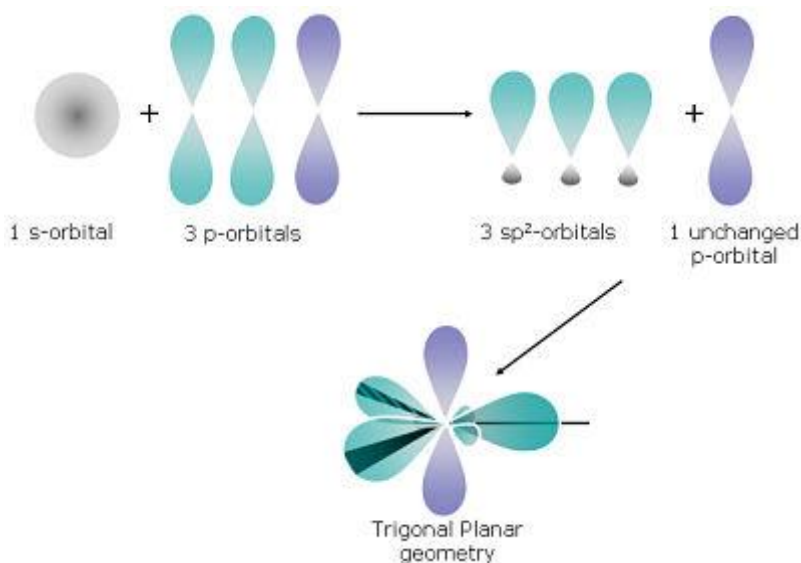
### Hybridization:

- The mixing of dissimilar orbital of similar energies to form new set of hybrid orbital.

- Number of hybrid orbital formed is equal to the no. of orbital taking part in hybridization.
- Depending upon the different combination of s and p orbitals, these types of hybridization are known.

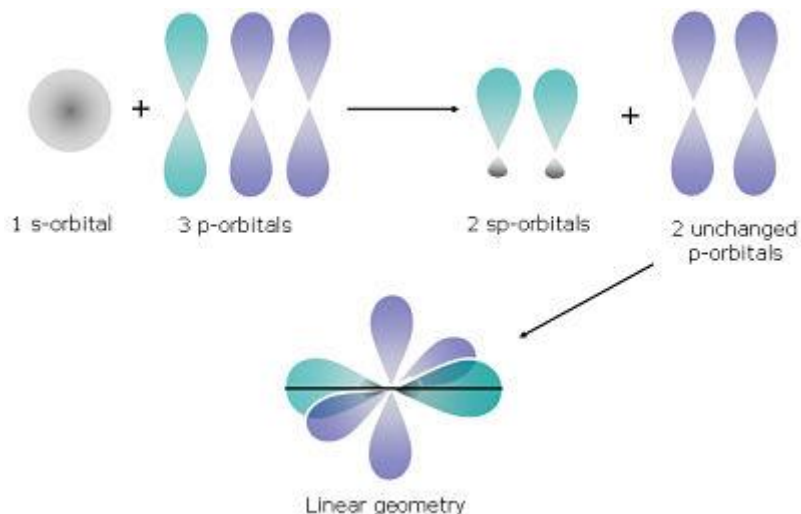
**sp<sup>3</sup> hybridization:** In this case, one s and three p orbitals hybridise to form four sp<sup>3</sup> hybrid orbitals. These four sp<sup>3</sup> hybrid orbitals are oriented in a tetrahedral arrangement.

**sp<sup>2</sup> hybridization:** In this case one s and two p orbitals mix together to form three sp<sup>2</sup> hybrid orbitals and are oriented in a trigonal planar geometry.



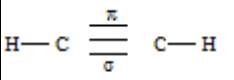
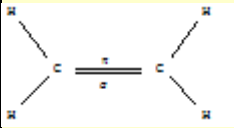
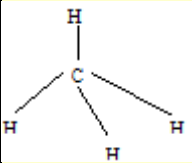
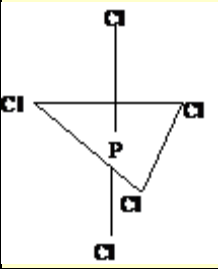
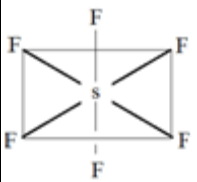
The remaining p orbital if required form side ways overlapping with the other unhybridized p orbital of other C atom and leads to formation of p<sub>2</sub>C = CH<sub>2</sub> bond as in H

**sp hybridization:** In this case, one s and one p orbital mix together to form two sp hybrid orbitals and are oriented in a linear shape.





The remaining two unhybridised p orbitals overlap with another unhybridised p orbital leading to the formation of triple bond as in  $\text{HC}\equiv\text{CH}$ .

Hybridization	Total Number of orbitals taking part	Shape	Examples
$\text{sp}$	2 (one s and one p)	Linear	
$\text{sp}^2$	3 (one s and two p)	Trigonal planar	
$\text{sp}^3$	4 (one s and three p)	Tetrahedral	
$\text{sp}^3\text{d}$	5 (one s, three p and one d)	Trigonal bipyramidal	
$\text{sp}^3\text{d}^2$	6 (one s, three p and two d)	Octahedral	

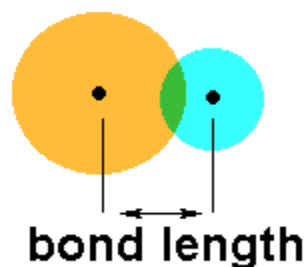
### Bond Characteristics:

#### Bond Length:

- The distance between the nuclei of two atoms bonded together is called bond length.
- It is expressed in angstrom ( $\text{\AA}$ ) units or picometer (pm).
- Bond length in ionic compound =  $r_c^+ + r_a^-$
- Bond length in covalent compound (AB) =  $r_A + r_B$

#### Important features of bond length

1. The bond length of the homonuclear diatomic molecules are twice the covalent radii.



- The lengths of double bonds are less than the lengths of single bonds between the same two atoms, and triple bonds are even shorter than double bonds. Single bond > Double bond > Triple bond (decreasing bond length)
- Bond length decreases with increase in s-character since s-orbital is smaller than a p-orbital.  
 $sp^3 C - H = 1.112\text{\AA}$ ;                       $sp^2 C - H = 1.103\text{\AA}$ ;                       $sp C - H = 1.08\text{\AA}$ ;  
 (25% s-character as in alkanes) (33.3% s-character as in alkenes) (50% s-character as in alkynes)
- Bond length of polar bond is smaller than the theoretical non-polar bond length.

### Bond Angel:

Bond angel is the angle between two adjacent bonds at an atom in a molecule made up of three or more atoms.

Bond angles mainly depend on the following three factors:

- Hybridization:** Bond angle depends on the state of hybridization of the central atom

Hybridization	Bond angle	Example
$sp^3$	$109^{\circ}28'$	$CH_4$
$sp^2$	$120^{\circ}$	$BCl_3$
$sp$	$180^{\circ}$	$BeCl_2$

Generally s-character increase in the hybrid bond, the bond angle increases.

- Lone pair repulsion:** Bond angle is affected by the presence of lone pair of electrons at the central atom. A lone pair of electrons at the central atom always tries to repel the shared pair (bonded pair) of electrons. Due to this, the bonds are displaced slightly inside resulting in a decrease of bond angle.
- Electronegativity:** If the electronegativity of the central atom decreases, bond angle decreases.

### Bond Energy or Bond Strength:

- The amount of energy required to break a bond in molecule is called bond energy.
- Bond energy of sigma bond is more than that of a  $\pi$ -bond.
- Bond energy increases with decrease in bond length

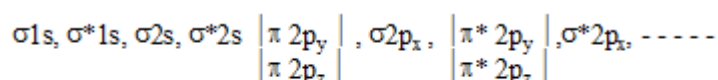
$C \equiv C > C = C > C - C$  (decreasing bond length)

$s < p < sp < sp^2 < sp^3$

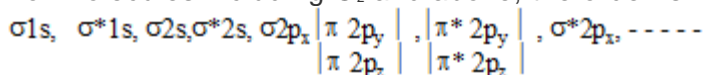
- The bond energy decreases with increase in number of lone pairs on the bonded atom.

## Molecular Orbital Theory:

- Molecular orbital are formed by linear combination of atomic orbital (LCAO)
- Atomic orbital of all the atoms are assumed to interfere with each other in the form of waves.
- Bonding molecular orbital are formed by constructive interference of atomic orbital.
- Anti-bonding orbital are formed by destructive interference of atomic orbital.
- Anti-bonding MO is of higher energy than Bonding MO.
- In simple homonuclear diatomic molecules the order of MO's based on increasing energy is



- For molecules including O<sub>2</sub> and above, the order is



- **Bond Order:** Bond-order = 1/2 (no. of bonding electrons - No. of anti-bonding electrons).

### Application of Mot to Homonuclear Diatomic Molecules

Species	Total number of electrons	Electronic configuration	Bond order	Magnetic Behaviour
H <sub>2</sub> <sup>+</sup>	1	s 1s <sup>1</sup>	(1-0)/2 = 1/2	Paramagnetic
H <sub>2</sub>	2	s 1s <sup>2</sup>	(2-0)/2 = 1	Diamagnetic
He <sub>2</sub> <sup>+</sup>	3	s1s <sup>2</sup> , s <sup>*</sup> 1s <sup>1</sup>	(2-1)/2 = 1/2	Paramagnetic
He <sub>2</sub>	4	s1s <sup>2</sup> , s <sup>*</sup> 1s <sup>2</sup>	(2-2)/2 = 0	Molecule does not exist
O <sub>2</sub>	16	s1s <sup>2</sup> , s <sup>*</sup> 1s <sup>2</sup> , s2s <sup>2</sup> , s <sup>*</sup> 2s <sup>2</sup> , s2p <sub>x</sub> <sup>2</sup> , p2p <sub>y</sub> <sup>2</sup> , p2p <sub>z</sub> <sup>2</sup> , p <sup>*</sup> 2p <sub>y</sub> <sup>1</sup> , p2p <sub>z</sub> <sup>1</sup>	(10-6)/2 = 2	Paramagnetic

### Application of MOT to Heteronuclear Diatomic Molecules

Molecules/Ions	Total No. of electrons	Magnetic behaviour
CO	14	Diamagnetic
NO	15	Paramagnetic
NO <sup>+</sup>	14	Diamagnetic
NO <sup>-</sup>	16	Diamagnetic
CN	13	Paramagnetic
CN <sup>-</sup>	14	Diamagnetic

**Question 1:**

Which one is electron deficient compound?

- (a)  $\text{NH}_3$
- (b)  $\text{ICl}$
- (c)  $\text{BCl}_3$
- (d)  $\text{PCl}_3$

**Question 2:**

$\text{I}_4\text{O}_9$  is a/an

- (a) ionic compound
- (b) covalent compound
- (c) coordinate compound
- (d) double salt

**Question 3:**

The lattice energy order for lithium halide is

- (a)  $\text{LiF} > \text{LiCl} > \text{LiBr} > \text{LiI}$
- (b)  $\text{LiCl} > \text{LiF} > \text{LiBr} > \text{LiI}$
- (c)  $\text{LiBr} > \text{LiCl} > \text{LiF} > \text{LiI}$
- (d)  $\text{LiI} > \text{LiBr} > \text{LiCl} > \text{LiF}$

**Question 4:**

The solubility of anhydrous  $\text{AlCl}_3$  and hydrous  $\text{AlCl}_3$  in diethylether are  $S_1$  and  $S_2$  respectively. Then

- (a)  $S_1 = S_2$
- (b)  $S_1 > S_2$
- (c)  $S_1 < S_2$
- (d) None of these

**Question 5:**

The correct statement for the molecule,  $\text{CsI}_3$  is

- (a) It is a covalent molecule
- (b) It contains  $\text{Cs}^+$  and  $\text{I}_3^-$  ions
- (c) It contains  $\text{Cs}^+$  and  $\text{I}^-$  ions
- (d) It contains  $\text{Cs}^+$ ,  $\text{I}^-$  and lattice  $\text{I}_2$  molecule

**Question 6:**

Among the following the maximum covalent character is shown by the compound

- (a)  $\text{FeCl}_2$
- (b)  $\text{SnCl}_2$
- (c)  $\text{AlCl}_3$
- (d)  $\text{MgCl}_2$

**Question 7:**

Which contains both polar and non-polar covalent bonds?

- (a)  $\text{NH}_4\text{Cl}$
- (b)  $\text{H}_2\text{O}_2$
- (c)  $\text{HCN}$
- (d)  $\text{CH}_4$

**Question 8:**

A metal  $M$  forms chlorides in its +2 and +4 oxidation states. Which of the following statements about these chlorides is correct?

- (a)  $M\text{Cl}_2$  is more volatile than  $M\text{Cl}_4$
- (b)  $M\text{Cl}_2$  is more soluble in anhydrous ethanol than  $M\text{Cl}_4$
- (c)  $M\text{Cl}_2$  is more ionic than  $M\text{Cl}_4$
- (d)  $M\text{Cl}_2$  is more easily hydrolysed than  $M\text{Cl}_4$

**Question 9:**

Dipole moments of  $\text{HCl} = 1.03 \text{ \AA}$ ,  $\text{HI} = 0.38 \text{ \AA}$ . Bond length of  $\text{HCl} = 1.3 \text{ \AA}$  and  $\text{HI} = 1.6 \text{ \AA}$ . The ratio of fraction of an electric charge  $e^-$ , existing on each atom in  $\text{HCl}$  and  $\text{HI}$  is

- (a) 1.2 : 1
- (b) 2.7 : 1
- (c) 1 : 3.3
- (d) 3.3 : 1

**Question 10:**

Which of the following has a bond order 1.75?

- (a)  $\text{ClO}_3^-$
- (b)  $\text{ClO}_4^-$
- (c)  $\text{NO}_3^-$
- (d)  $\text{CO}_3^{2-}$

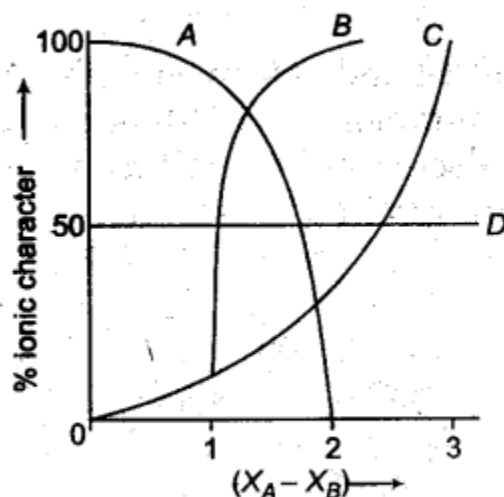
**Question 11:**

Which of the following is not correct regarding the structure of  $\text{POCl}_3$ ?

- (a) Lewis structure violates octet rule
- (b) It has irregular tetrahedral geometry
- (c)  $\text{P}=\text{O}$  bond and  $\text{P}-\text{Cl}$  bond repulsion is greater than  $\text{P}-\text{Cl}$  and  $\text{P}-\text{Cl}$  bond repulsion
- (d)  $\text{Cl}-\text{P}=\text{O}$  bond angle is lesser than  $\text{Cl}-\text{P}-\text{Cl}$  bond angle

**Question 12:**

For AB bond, if per cent ionic character is plotted against electronegativity difference ( $X_A - X_B$ ), the shape of the curve would look like as



The correct curve is

- (a) A      (b) B      (c) C      (d) D

**Question 13:**

The correct order in which the O—O bond length increases in the following is

- (a)  $H_2O_2 < O_2 < O_3$       (b)  $O_3 < H_2O_2 < O_2$   
 (c)  $O_2 < O_3 < H_2O_2$       (d)  $O_2 < H_2O_2 < O_3$

**Question 14:**

The correct order of C—O bond length among CO,  $CO_3^{2-}$ ,  $CO_2$  is

- (a)  $O_2 < CO_3^{2-} < CO$       (b)  $CO < CO_3^{2-} < CO_2$   
 (c)  $CO_3^{2-} < CO_2 < CO$       (d)  $CO < CO_2 < CO_3^{2-}$

**Question 15:**

The bond order of NO is 2.5 while that in  $\text{NO}^+$  is 3. Which of the following statements is true for these two species?

- (a) Bond length in  $\text{NO}^+$  is equal to that in NO
- (b) Bond length in NO is greater than in  $\text{NO}^+$
- (c) Bond length in  $\text{NO}^+$  is greater than in NO
- (d) Bond length is unpredictable

**Question 16:**

Which combination is best explained by the coordinate covalent bond?

- (a)  $\text{H}^+ + \text{H}_2\text{O}$
- (b)  $\text{Cl} + \text{Cl}$
- (c)  $\text{Mg} + \frac{1}{2} \text{O}_2$
- (d)  $\text{H}_2 + \text{I}_2$

**Question 17:**

The common feature among the species  $\text{CN}^-$ , CO and  $\text{NO}^+$  are

- (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

**Question 18:**

The correct decreasing order of dipole moment in  $\text{CH}_3\text{Cl}$ ,  $\text{CH}_3\text{Br}$  and  $\text{CH}_3\text{F}$  is

- (a)  $\text{CH}_3\text{F} > \text{CH}_3\text{Cl} > \text{CH}_3\text{Br}$
- (b)  $\text{CH}_3\text{F} > \text{CH}_3\text{Br} > \text{CH}_3\text{Cl}$
- (c)  $\text{CH}_3\text{Cl} > \text{CH}_3\text{F} > \text{CH}_3\text{Br}$
- (d)  $\text{CH}_3\text{Cl} > \text{CH}_3\text{Br} > \text{CH}_3\text{F}$

**Question 19:**

The correct decreasing order of dipole moment in  $\text{CH}_3\text{Cl}$ ,  $\text{CH}_3\text{Br}$  and  $\text{CH}_3\text{F}$  is


- (a)  $\text{CH}_3\text{F} > \text{CH}_3\text{Cl} > \text{CH}_3\text{Br}$
- (b)  $\text{CH}_3\text{F} > \text{CH}_3\text{Br} > \text{CH}_3\text{Cl}$
- (c)  $\text{CH}_3\text{Cl} > \text{CH}_3\text{F} > \text{CH}_3\text{Br}$
- (d)  $\text{CH}_3\text{Cl} > \text{CH}_3\text{Br} > \text{CH}_3\text{F}$

**Question 20:**

Which one of the following conversions involve change in both hybridisation and shape?

- (a)  $\text{CH}_4 \longrightarrow \text{C}_2\text{H}_6$
- (b)  $\text{NH}_3 \longrightarrow \text{NH}_4^+$
- (c)  $\text{BF}_3 \longrightarrow \text{BF}_4^-$
- (d)  $\text{H}_2\text{O} \longrightarrow \text{H}_3\text{O}^+$

**Question 21:**

In piperidine,  N—H, N-atom has hybridisation

- (a)  $sp$
- (b)  $sp^2$
- (c)  $sp^3$
- (d)  $dsp^2$

**Question 22:**

A  $sp^3$ -hybrid orbital contains

- (a)  $\frac{1}{4}$  s-character
- (b)  $\frac{1}{2}$  s-character
- (c)  $\frac{3}{4}$  s-character
- (d) None of these

**Question 23:**

Structure of  $\text{ICl}_2^-$  is

- (a) trigonal
- (b) octahedral
- (c) square planar
- (d) distorted trigonal pyramidal



**Question 24:**

Planar structure is shown by

- (a)  $\text{CO}_3^{2-}$  (b)  $\text{BCl}_3$   
 (c)  $\text{N}(\text{SiH}_3)_3$  (d) All of these

**Question 25:**

Among the following, the species having square planar geometry for central atom are

- I.  $\text{XeF}_4$  II.  $\text{SF}_4$   
 III.  $[\text{NiCl}_4]^{2-}$  IV.  $[\text{PtCl}_4]^{2-}$   
 (a) I and IV (b) I and II  
 (c) II and III (d) III and IV

**Question 26:**

$\text{H}_2\text{O}$  is dipolar whereas,  $\text{BeF}_2$  is not. It is because

- (a) the electronegativity of F is greater than that of O  
 (b)  $\text{H}_2\text{O}$  involves hydrogen bonding whereas,  $\text{BeF}_2$  is a discrete molecule  
 (c)  $\text{H}_2\text{O}$  is linear and  $\text{BeF}_2$  is angular  
 (d)  $\text{H}_2\text{O}$  is angular and  $\text{BeF}_2$  is linear

**Question 27:**

Which of the following order of energies of molecules orbitals of  $\text{N}_2$  is correct? **[NCERT Exemplar]**

- (a)  $(\pi 2p_y) < (\sigma 2p_z) < (\pi 2p_x) \approx (\pi 2p_y)$   
 (b)  $(\pi 2p_y) > (\sigma 2p_z) > (\pi 2p_x) \approx (\pi 2p_y)$   
 (c)  $(\pi 2p_y) < (\sigma 2p_z) > (\pi 2p_x) \approx (\pi 2p_y)$   
 (d)  $(\pi 2p_y) > (\sigma 2p_z) < (\pi 2p_x) \approx (\pi 2p_y)$

**Question 28:**

In the formation of  $\text{N}_2^+$  from  $\text{N}_2$ , the electron is lost from

- (a)  $\sigma$ -orbital (b)  $\pi$ -orbital  
 (c)  $\sigma^*$ -orbital (d)  $\pi^*$ -orbital



**Direction (Q. Nos. 33-39)** Each of these questions contains two statements : Assertion and Reason. Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.

- (a) Assertion is true, Reason is true; Reason is the correct explanation for Assertion
- (b) Assertion is true, Reason is true; Reason is not a correct explanation for Assertion
- (c) Assertion is true, Reason is false
- (d) Both Assertion and Reason are false

**Question 33:**

**Assertion** The O—O bond length in  $\text{H}_2\text{O}_2$  is shorter than that of  $\text{O}_2\text{F}_2$ .

**Reason**  $\text{H}_2\text{O}_2$  is an ionic compound.

**Question 34:**

**Assertion**  $\text{SeCl}_4$  does not have a tetrahedral structure.

**Reason** Se in  $\text{SeCl}_4$  has two lone pairs.

**Question 35:**

**Assertion** All F—S—F angle in  $\text{SF}_4$  is greater than  $90^\circ$  but less than  $180^\circ$ .

**Reason** The lone pair-bond pair repulsion is weaker than bond pair-bond pair repulsion.

**Question 36:**

**Assertion**  $\text{BF}_3$  molecules is planar but  $\text{NF}_3$  is pyramidal.

**Reason** N-atom is smaller than B.

**Question 37:**

**Assertion** H—S—H bond angle in  $\text{H}_2\text{S}$  is closer to  $90^\circ$  but H—O—H bond angle in  $\text{H}_2\text{O}$  is  $104.5^\circ$ .

**Reason**  $lp - lp$  repulsion is stronger in  $\text{H}_2\text{S}$  than in  $\text{H}_2\text{O}$ .

**Question 38:**

**Assertion**  $B_2$  molecule is diamagnetic.

**Reason** The highest occupied molecular orbital is of  $\sigma$ -type.

**Question 39:**

**Assertion** Among the two H—O bonds in  $H_2O$  molecule, the energy required to break the first O—H bond and the other O—H bond is the same.

**Reason** This is because the electronic environment around oxygen is the same even after breakage of one O—H bond. **[NCERT Exemplar]**

**Question 40:**

Which of the following species contains equal number of  $\sigma$  and  $\pi$  bond? **[CBSE-AIPMT 2015]**

- (a)  $HCO_3^-$       (b)  $XeO_4$       (c)  $(CN)_2$       (d)  $CH_2(CN)_2$

**Question 41:**

Which of the following options represent the correct bond order? **[CBSE-AIPMT 2015]**

- (a)  $O_2^- > O_2 > O_2^+$       (b)  $O_2^- < O_2 < O_2^+$   
(c)  $O_2^- > O_2 < O_2^+$       (d)  $O_2^- < O_2 > O_2^+$

**Question 42:**

Maximum bond angle at nitrogen is present in which of the following? **[CBSE-AIPMT 2015]**

- (a)  $NO_2$       (b)  $NO_2^-$       (c)  $NO_2^+$       (d)  $NO_3^-$

**Question 43:**

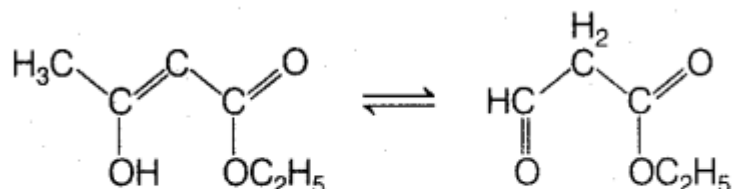
The correct bond order in the following species is.

**[CBSE-AIPMT 2015]**

- (a)  $O_2^{2+} < O_2^+ < O_2^-$       (b)  $O_2^{2+} < O_2^- < O_2^+$   
(c)  $O_2^{2+} < O_2^- < O_2^{2+}$       (d)  $O_2^- < O_2^+ < O_2^{2+}$

**Question 44:**

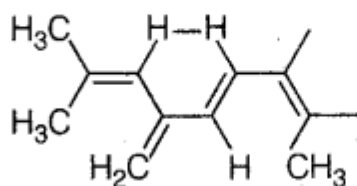
The enolic form of ethyl acetoacetate as below has



- (a) 18 sigma bonds and 2 Pi bonds
- (b) 16 sigma bonds and 1 Pi bond
- (c) 9 sigma bonds and 2Pi bonds
- (d) 9 sigma bonds and 1 Pi bond

**Question 45:**

The total number of  $\pi$  bond electrons in the following structure is



- (a) 4
- (b) 8
- (c) 12
- (d) 16

**Question 46:**

Which of the following molecules has the maximum dipole moment? **[CBSE-AIPMT 2014]**

- (a)  $\text{CO}_2$
- (b)  $\text{CH}_4$
- (c)  $\text{NH}_3$
- (d)  $\text{NF}_3$

**Question 47:**

Which one of the following species has plane triangular shape? **[CBSE-AIPMT 2014]**

- (a)  $\text{N}_3$
- (b)  $\text{NO}_3^-$
- (c)  $\text{NO}_2^-$
- (d)  $\text{CO}_2$

**Question 48:**

Which of the following is electron-deficient?

[NEET 2013]

- (a)  $(\text{SiH}_3)_2$       (b)  $(\text{BH}_3)_2$       (c)  $\text{PH}_3$       (d)  $(\text{CH}_3)_2$

**Question 49:**

Which one of the following molecules contains no  $\pi$ -bond?

[NEET 2013]

- (a)  $\text{H}_2\text{O}$       (b)  $\text{SO}_2$       (c)  $\text{NO}_2$       (d)  $\text{CO}_2$

**Question 50:**

Which of the following is a polar molecule?

[NEET 2013]

- (a)  $\text{SF}_4$       (b)  $\text{SiF}_4$       (c)  $\text{XeF}_4$       (d)  $\text{BF}_3$

**Question 51:**

Which of the following is paramagnetic? [NEET

- (a)  $\text{O}_2^-$       (b)  $\text{CN}^-$       (c)  $\text{NO}^+$       (d)  $\text{CO}$

**Question 52:**

$\text{XeF}_2$  is isostructural with

[NEET 2013]

- (a)  $\text{ICl}_2^-$       (b)  $\text{SbCl}_3$       (c)  $\text{BaCl}_2$       (d)  $\text{TeF}_2$

**Question 53:**

Which of the following species contains three bond pairs and one lone pair around the central atom?

- (a)  $\text{H}_2\text{O}$   
(b)  $\text{BF}_3$   
(c)  $\text{NH}_2$   
(d)  $\text{PCl}_3$

**Question 54:**

Which one of the following pairs is isostructural (i.e. having the same shape and hybridisation)?

[CBSE-AIPMT 2012]

- (a)  $\text{BCl}_3$  and  $\text{BrCl}_3$                       (b)  $\text{NH}_3$  and  $\text{NO}_3^-$   
(c)  $\text{NF}_3$  and  $\text{BF}_3$                       (d)  $\text{BF}_4^-$  and  $\text{NH}_4^+$

**Question 55:**

The pair of species with the same bond order is

[CBSE-AIPMT 2012]

- (a)  $\text{O}_2^{2-}$ ,  $\text{B}_2$     (b)  $\text{O}_2^+$ ,  $\text{NO}^+$     (c)  $\text{NO}$ ,  $\text{CO}$     (d)  $\text{N}_2$ ,  $\text{O}_2$

**Question 56:**

Bond order of 1.5 is shown by [CBSE-AIPMT

- (a)  $\text{O}_2^+$               (b)  $\text{O}_2^-$               (c)  $\text{O}_2^{2-}$               (d)  $\text{O}_2$

**Question 57:**

What is the nature of the bond between B and O in  $(\text{C}_2\text{H}_5)_2\text{OBH}_3$ ? [AFMC 2012]

- (a) Covalent                      (b) Coordinate covalent  
(c) Ionic bond                      (d) Banana shaped bond

**Question 58:**

In  $\text{TeCl}_4$ , the central atom tellurium involves

- (a)  $sp^3$ -hybridisation [A  
(b)  $sp^3d$ -hybridisation  
(c)  $sp^3d^2$ -hybridisation  
(d)  $dsp^2$ -hybridisation

**Question 59:**

Which of the following has the minimum bond length?

[CBSE-AIPMT 2011]

- (a)  $\text{O}_2^-$               (b)  $\text{O}_2^{2-}$               (c)  $\text{O}_2$               (d)  $\text{O}_2^+$

**Question 60:**

The correct order of increasing bond length of C — H, C — O, C — C and C = C is **[CBSE-AIPMT 2011]**

- (a) C — C < C = C < C — O < C — H  
 (b) C — O < C — H < C — C < C = C  
 (c) C — H < C — O < C — C < C = C  
 (d) C — H < C = C < C — O < C — C

**Question 61:**

Which of the two ions from the list given below, have the geometry that is explained by the same hybridisation of orbitals,  $\text{NO}_2^-$ ,  $\text{NO}_3^-$ ,  $\text{NH}_2^-$ ,  $\text{NH}_4^+$ ,  $\text{SCN}^-$ ?

**[CBSE-AIPMT 2011]**

- (a)  $\text{NH}_4^+$  and  $\text{NO}_3^-$  (b)  $\text{SCN}^-$  and  $\text{NH}_2^-$   
 (c)  $\text{NO}_2^-$  and  $\text{NH}_2^-$  (d)  $\text{NO}_2^-$  and  $\text{NO}_3^-$

**Question 62:**

The correct order of increasing bond angles in the following species is **[CBSE-AIPMT 2010]**

- (a)  $\text{Cl}_2\text{O} < \text{ClO}_2 < \text{ClO}_2^-$  (b)  $\text{ClO}_2 < \text{Cl}_2\text{O} < \text{ClO}_2^-$   
 (c)  $\text{Cl}_2\text{O} < \text{ClO}_2^- < \text{ClO}_2$  (d)  $\text{ClO}_2^- < \text{Cl}_2\text{O} < \text{ClO}_2$

**Question 63:**

In which of the following pairs of molecules/ions, the central atoms have  $sp^2$ -hybridisation?

**[CBSE-AIPMT 2010]**

- (a)  $\text{NO}_2^-$  and  $\text{NH}_3$  (b)  $\text{BF}_3$  and  $\text{NO}_2^-$   
 (c)  $\text{NH}_2^-$  and  $\text{H}_2\text{O}$  (d)  $\text{BF}_3$  and  $\text{NH}_2^-$

**Question 64:**

Which one of the following species does not exist under normal conditions? **[CBSE-AIPMT 2010]**

- (a)  $\text{Be}_2^+$  (b)  $\text{Be}_2$  (c)  $\text{B}_2$  (d)  $\text{Li}_2$



**Question 65:**

In which one of the following species, the central atom has the type of hybridisation which is not the same as that present in the other three? **[CBSE-AIPMT 2010]**

- (a)  $\text{SF}_4$       (b)  $\text{I}_3^-$       (c)  $\text{SbCl}_5^{2-}$       (d)  $\text{PCl}_5$

**Question 66:**

Which of the following molecules has trigonal planar geometry?

- (a)  $\text{BF}_3$   
(b)  $\text{NH}_3$   
(c)  $\text{PH}_3$   
(d)  $\text{IF}_3$

**Question 67:**

Maximum number of H-bonds in one molecule of water is

- (a) 1  
(b) 2  
(c) 3  
(d) 4

**Question 68:**

The compound containing coordinate bond is

- (a)  $\text{SO}_3$   
(b)  $\text{SO}_2$   
(c)  $\text{H}_2\text{SO}_4$   
(d) All of these

**Question 69:**

The shape of  $\text{IF}_7$  molecule is

- (a) octahedral  
(b) trigonal bipyramidal  
(c) tetrahedral  
(d) pentagonal bipyramidal

**Question 70:**

In a homonuclear molecule, which of the following sets of orbitals is degenerate? **[AFMC 2010]**

- (a)  $\sigma 1s$  and  $\sigma 2s$       (b)  $\pi 2p_x$  and  $\pi 2p_y$   
(c)  $\pi 2p_x$  and  $\sigma 2p_z$       (d)  $\sigma 2p_x$  and  $\sigma^* 2p_z$

**Answers:**

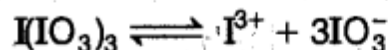
- |         |         |         |         |         |         |         |         |         |         |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1. (c)  | 2. (a)  | 3. (a)  | 4. (b)  | 5. (b)  | 6. (c)  | 7. (b)  | 8. (c)  | 9. (d)  | 10.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



### Hints and Solutions

1.  $\text{BCl}_3$  has six electrons in outer shell of boron atom. Hence, it is electron deficient compound.

2.  $\text{I}_4\text{O}_9$  is actually  $\text{I}(\text{IO}_3)_3$ . It is an ionic compound.



3. Smaller the size of anion, lesser is its polarisation, more is ionic nature, more is lattice energy.

4. Hydrus  $\text{AlCl}_3$  remains in ionic form and is less soluble in organic solvents, while anhydrous  $\text{AlCl}_3$  is covalent and highly soluble in organic solvents.

5.  $\text{CsI}_3$  is an ionic compound. It consists of  $\text{Cs}^+$  (cation) and  $\text{I}_3^-$  (anion) ions.  $\text{I}_3^-$  ion is made up of  $\text{I}_2$  and  $\text{I}^-$  which is linear in shape.

6. According to Fajan's rule, the polarising power and covalent character depends on large charge on ions:

(i) smaller size of cation (ii) larger size of anion. Here all anions are same, i.e.  $\text{Cl}^-$  anion hence, the covalent character will be decided by polarising power of cation.



↑  
Maximum charge

Out of the above  $\text{Al}^{3+}$  has maximum charge and polarising power, hence maximum covalent character.

7. In  $\text{H}_2\text{O}_2$ ,  $\text{O}-\text{O}$  bond is non-polar, while  $\text{O}-\text{H}$  bond is polar.

8.  $\text{MCl}_2$ ; oxidation state of  $M = +2$

$\text{MCl}_4$ ; oxidation state of  $M = +4$

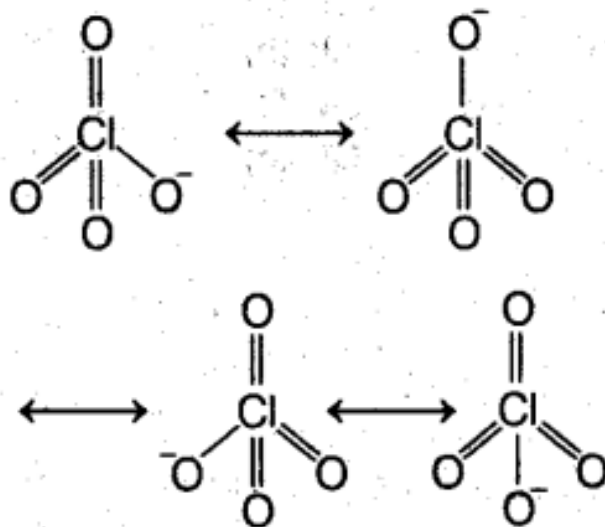
Since, higher the oxidation state, smaller the size and greater the polarising power, greater is the covalent character.

Therefore,  $MCl_4$  is more covalent and  $MCl_2$  is more ionic.

$$9. \mu = e \times d \Rightarrow e = \frac{\mu}{d}$$

$$\therefore \frac{e_{HCl}}{e_{HI}} = \frac{\mu_{HCl}}{d_{HCl}} \times \frac{d_{HI}}{\mu_{HI}} = \frac{1.03 \times 1.6}{1.3 \times 0.38} = 3.3:1$$

10.

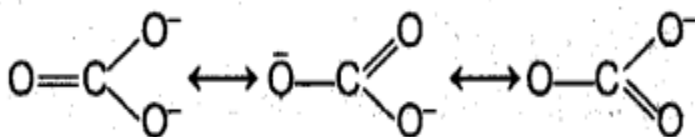


Bond order

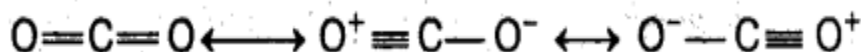
$$= 1 + \frac{\text{total number of double bond between Cl and O}}{\text{total number of bonds at delocalisation position}}$$

$$= 1 + \frac{3}{4} = \frac{7}{4} = 1.75$$

11. As electron density in  $P=O$  bond is more, it causes greater repulsion and reduces the  $Cl-P-Cl$  bond, consequently increases  $Cl-P=O$  bond.
12. % ionic character =  $16(X_A - X_B) + 3.5(X_A - X_B)^2$  From the above relation, it is clear that as soon as  $(X_A - X_B)$  increases, % ionic character will also increase. Therefore, curve C shows a correct path.
13. Bond length of  $O-O$  in  $O_2 = 1.21 \text{ \AA}$   
 Bond length of  $O-O$  in  $O_3 = 1.278 \text{ \AA}$   
 Bond length of  $O-O$  in  $H_2O_2 = 1.49 \text{ \AA}$   
 Therefore, correct order of  $O-O$  bond length is  
 $O_2 < O_3 < H_2O_2$
14. A multiple bond is always shorter than the corresponding single bond. The C-atom in  $CO_3^{2-}$  is  $sp^2$ -hybridised as shown.



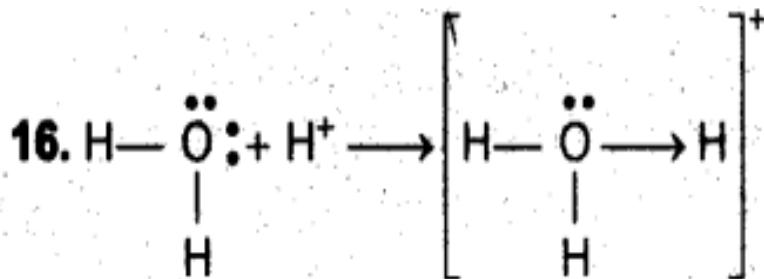
The C-atom in  $CO_2$  is  $sp$ -hybridised with bond distance of carbon-oxygen is 122 pm.



The C-atom in  $CO$  is  $sp$ -hybridised with  $C-O$  bond distance 110 pm :  $C \equiv O$

So, the correct order is  $CO < CO_2 < CO_3^{2-}$ .

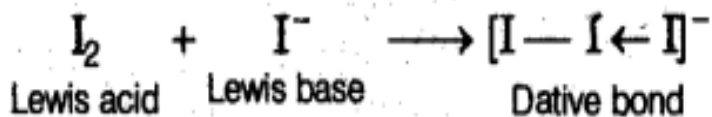
15. Higher the bond order, shorter will be the bond length.  
 So,  $NO$  has greater bond length than  $NO^+$ .



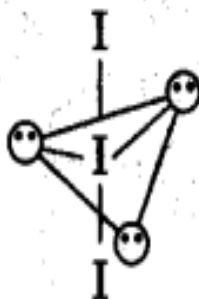
17. Each species contains 14 electrons and bond order 3.

18. C—F bond length is smaller than C—Cl bond length, hence  $\text{CH}_3\text{F}$  dipole moment is less than  $\text{CH}_3\text{Cl}$ .

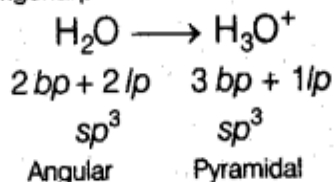
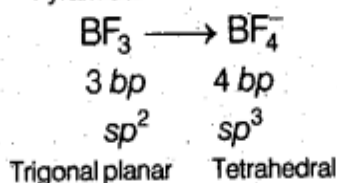
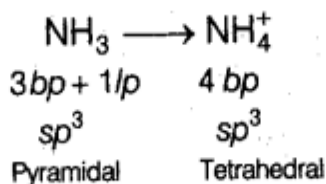
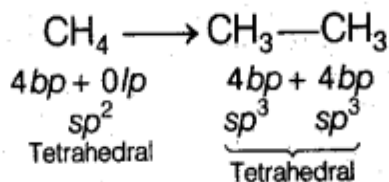
19.  $\text{I}_3^-$  ion is made up of an  $\text{I}_2$  molecule and  $\text{I}^-$  ion.



Central atom I is  $sp^3d$ -hybridised with 2 bond pairs and 3 lone pairs and should possess trigonal pyramidal structure. However, due to the presence of  $lp - lp$  and  $bp - lp$  repulsion, the three lone pairs occupy the equatorial position in order to minimise the repulsive forces. Thus, the ion is therefore linear in shape with a bond angle of exactly  $180^\circ$ .

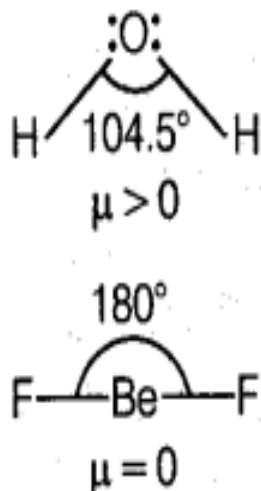


20.



21. In piperidine, N is  $\text{sp}^3$ -hybridised having three sigma bonds and one lone pair.
22. In  $\text{sp}^3$ -hybridisation, there is 25% s-character and 75% p-character.
23. In  $\text{ICl}_2^-$ , I is  $\text{sp}^3d$ -hybridised. Due to the presence of lone pair of electrons, it acquires distorted trigonal pyramidal shape.
24. C in  $\text{CO}_3^{2-}$  and B in  $\text{BCl}_3$  are  $\text{sp}^2$ -hybridised thus, acquire planar geometry. Although N in  $\text{N}(\text{SiH}_3)_3$  is  $\text{sp}^3$ -hybridised but the steric hindrance caused by three bulky groups makes it planar for higher stability.
25. (i) In  $\text{XeF}_4$ , Xe is  $\text{sp}^3d^2$ -hybridised and it is square planar.  
 (ii)  $\text{SF}_4$  is distorted trigonal bipyramidal in shape.  
 (iii)  $[\text{NiCl}_4]^{2-}$  is tetrahedral in shape ( $\text{sp}^3$ -hybridised).  
 (iv)  $[\text{PtCl}_4]^{2-}$  is square planar in structure.

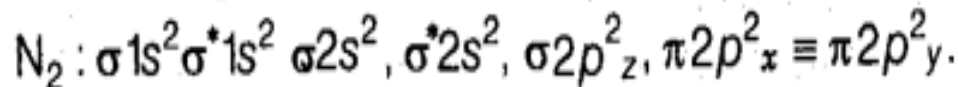
- 26.** The structure of  $\text{H}_2\text{O}$  is angular V-shaped and has  $sp^3$ -hybridisation and bond angle is  $105^\circ$ . Its dipole moment value is positive or more than zero.



But in  $\text{BeF}_2$ , structure is linear due to  $sp$ -hybridisation ( $\mu = 0$ ). Thus, due to  $\mu > 0$ ,  $\text{H}_2\text{O}$  is dipolar and due to  $\mu = 0$ ,  $\text{BeF}_2$  is non-polar.

- 27.** Electronic configuration of N is  $1s^2 2s^2 2p^3$ .

In  $\text{N}_2$  molecule, there are 14 electrons. Therefore, its electronic configuration is



Hence, option (a) is correct.

- 28.** In the formation of  $\text{N}_2^+$  from  $\text{N}_2$ , one electron is removed from  $\sigma$ -orbital.



**29.** Strength of hydrogen bond between H — F is the strongest and hence, it has the shortest H-bond.

**30.** Peroxide ion is  $O_2^{2-}$

$$O_2^{2-} (18) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_x^2, \pi 2p_y^2 \approx \pi 2p_z^2$$

$$\pi^* 2p_y^2 \approx \pi^* 2p_z^2$$

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

$O_2^{2-}$  is diamagnetic due to the absence of unpaired electrons and number of antibonding electron pairs in  $O_2^{2-}$  ion is four,  $\sigma^* 2 p_x$  is vacant.

**31.**  $NO_3^- = 32$

$CN^- = 14$

$PO_4^{3-} = 40$

$CO_3^{2-} = 32$

$N_2 = 14$

$SO_4^{2-} = 40$

$BO_3^{3-} = 32$

$C_2^{2-} = 14$

$ClO_4^- = 40$

Hence, all these ions are isoelectronic with each other.

Whereas,

$$CO_3^{2-} = 32$$

$$NO_3^- = 32$$

$$SO_3^{2-} = 34$$

are not isoelectronic with each other.

**32.** (A) Ethane,  $\overset{sp^3}{CH_3} - \overset{sp^3}{CH_3}$

$\Rightarrow$  2  $sp^3$ -hybrid carbons

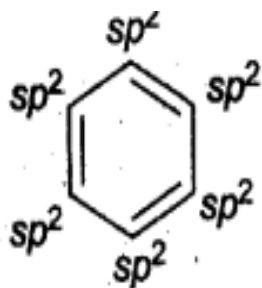
(B) Ethene,  $\overset{sp^2}{CH_2} = \overset{sp^2}{CH_2}$

$\Rightarrow$  2  $sp^2$ -hybrid carbons

(C) Acetylene,  $\overset{sp}{CH} \equiv \overset{sp}{CH}$

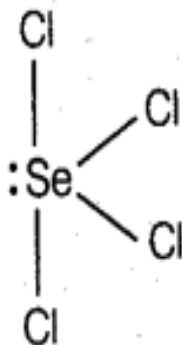
$\Rightarrow$  2  $sp$ -hybrid carbons

(D) Benzene,



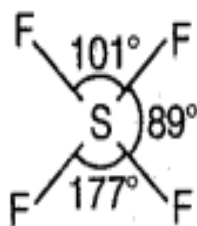
$\Rightarrow$  6  $sp^2$ -hybrid carbons

- 33.** The O — O bond length is shorter in  $O_2F_2$  than in  $H_2O_2$  due to higher electronegativity of F-atom.  $H_2O_2$  is a covalent compound.
- 34.**  $SeCl_4$  has see-saw geometry, i.e. distorted trigonal pyramidal geometry. In  $SeCl_4$ , Se is  $sp^3d$ -hybridised.

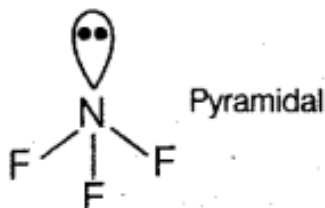


- 35.**  $SF_4$  has see-saw shape. It has non-planar structure. In this structure, bond angles are different between different S—F atoms.

According to VSEPR theory  $lp - lp > lp - bp > bp - bp$ .



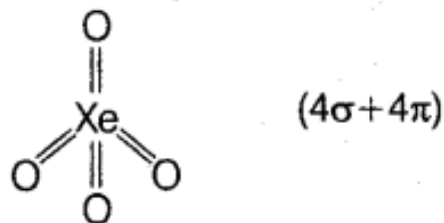
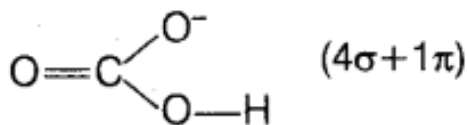
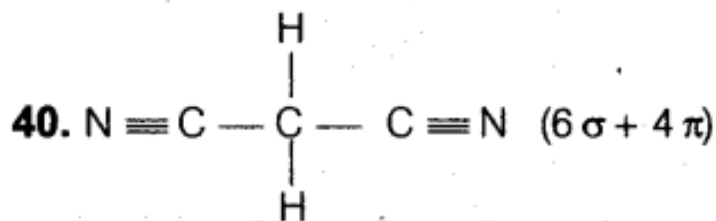
- 36.** In  $\text{BF}_3$ , boron is  $sp^2$ -hybridised, so it is trigonal planar. In  $\text{NF}_3$ , nitrogen is  $sp^3$ -hybridised. But due to the presence of one lone pair it becomes pyramidal from tetrahedral.



- 37.** Lone pair- bond pair repulsion, is stronger in  $\text{H}_2\text{S}$  as bond pair - bond pair repulsion becomes weak with increase in size of central atom.
- 38.** The total number of electrons in  $\text{B}_2 = 10$ ,

$\text{B}_2 = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^1 \approx \pi 2p_y^1$ . It has 2 unpaired electrons, therefore, it is paramagnetic and highest occupied molecular orbital is of  $\pi$ -type.

- 39.** The bond enthalpies of the two O—H bonds in  $\text{H—O—H}$  are not equal because electronic environment around O is not same after breakage of one O—H bond.





In  $\text{XeO}_4$  equal number of  $\sigma$  and  $\pi$  bonds i.e. four

$$41. \text{O}_2^- = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, (\pi 2p_x^2 \approx \pi 2p_y^2)$$

$$(\pi^* 2p_x^2 \approx \pi^* 2p_y^1)$$

$$\text{Bond order} = \frac{\text{number of } e^- \text{ in BMO} - \text{number of } e^- \text{ ABMO}}{2}$$

$$= \frac{10 - 7}{2} = 3/2 = 1.5$$

$$\text{O}_2^+ = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, (\pi 2p_x^2 \approx \pi 2p_y^2)$$

$$(\pi^* 2p_x^1 \approx \pi^* 2p_y^0)$$

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

$$\text{O}_2 = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, (\pi 2p_x^2 \approx \pi 2p_y^2)$$

$$(\pi^* 2p_x^1 \approx \pi^* 2p_y^1)$$

$$\text{Bond order} = \frac{10 - 6}{2} = \frac{4}{2} = 2$$

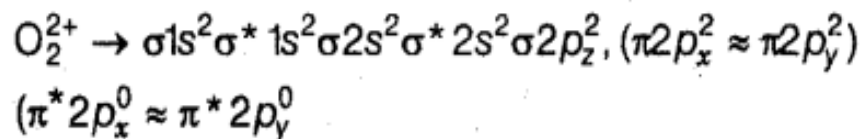
Correct bond order —  $\text{O}_2^- < \text{O}_2 < \text{O}_2^+$

42. Species	$\text{NO}_3^-$	$\text{NO}_2$	$\text{NO}_2^-$	$\text{NO}_2^+$
Hybridisation	$sp^2$	$sp^2$	$sp^2$	$sp$ (linear)
Bond angle	$120^\circ$	$< 120^\circ$	$< 120^\circ$	$180^\circ$

So,  $\text{NO}_2^+$  has maximum bond angle.

43.  $O_2^- \Rightarrow$  bond order  $= \frac{10-7}{2} \Rightarrow 3/2 = 1.5$

$O_2^+ \rightarrow$  bond order  $= \frac{10-5}{2} = 5/2 = 2.5$



Bond order  $= \frac{10-4}{2} = \frac{6}{2} = 3$

Correct bond order is  $O_2^{2+} > O_2^+ > O_2^-$

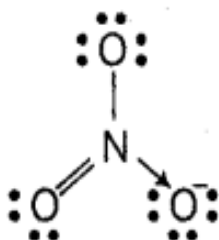
44. The enolic form of ethyl acetate has 18 single bond (16 sigma bond) and 2 double bond (2 sigma and 2 Pi bonds).

45. There are 4  $\pi$  bonds hence, total  $\pi$  electrons are 8.

46.  $NH_3$  has maximum dipole moment.

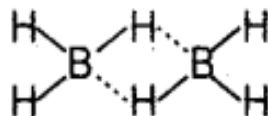
Dipole moment in  $NH_3 = 4.90 \times 10^{-30} \text{ cm}$

47.



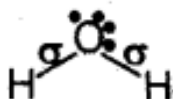
N is  $sp^2$ -hybridised and no lone pair of electron is present that's why  $NO_3^+$  has triangular planar shape.

48.  $(BH_3)_2$  or  $(B_2H_6)$



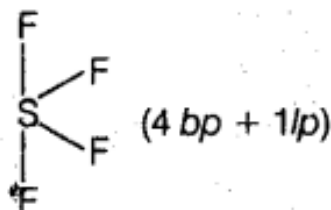
It contains two 3-centre-2-electron bonds.

49.

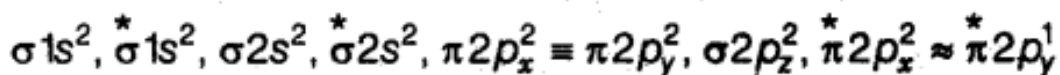


It contains only two  $\sigma$ -bonds.

50.  $\text{SF}_4$  has  $sp^3d$ -hybridisation and see-saw shape and is polar in nature.



51. According to MOT,  $\text{O}_2^-$  has one unpaired electron.



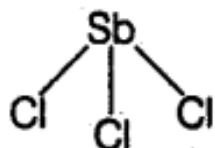
Hence, it is paramagnetic.

52.  $\text{F} - \text{Xe} - \text{F}$

$sp^3d$  and linear

$\text{Cl} - \text{I} - \text{Cl}$

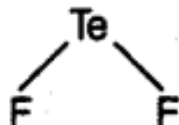
$sp^3d$  and linear



$sp^3$  V-shaped

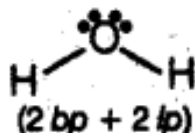
$\text{Cl} - \text{Ba} - \text{Cl}$

$sp$ -linear

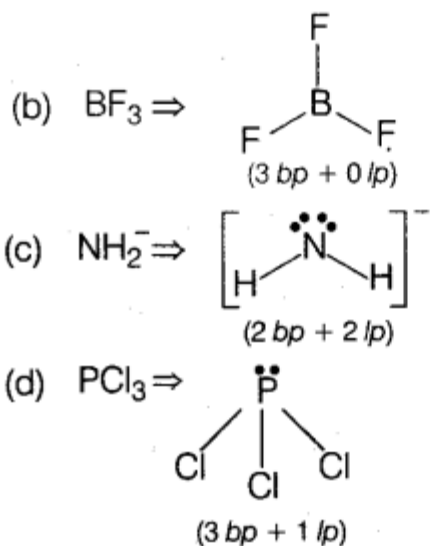


$sp^3$  V-shaped

53. (a)  $\text{H}_2\text{O} \Rightarrow$



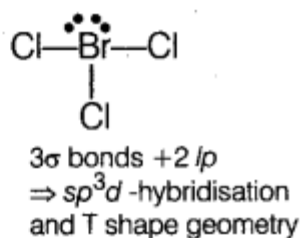
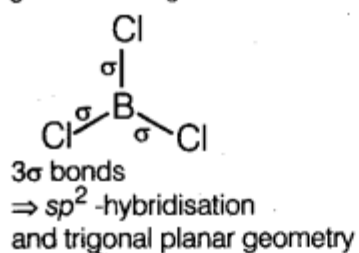
[bp = bond pairs and lp = lone pairs]



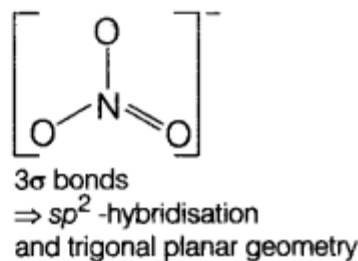
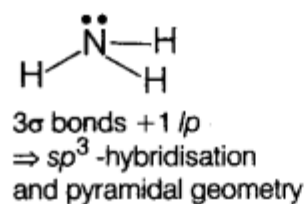
Thus, in  $\text{PCl}_3$ , the central atom P has three bond pairs and one lone pair.

**54.** If number of bond pairs and lone pairs are same for the given pairs, then they are isostructural.

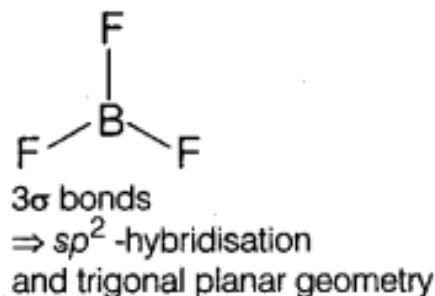
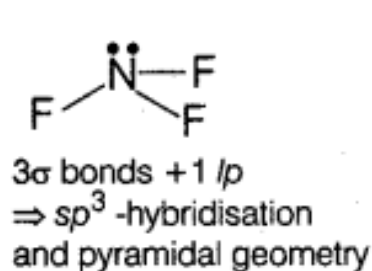
(a)  $\text{BCl}_3$  and  $\text{BrCl}_3$



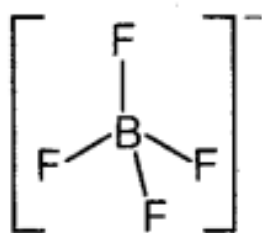
(b)  $\text{NH}_3$  and  $\text{NO}_3^-$



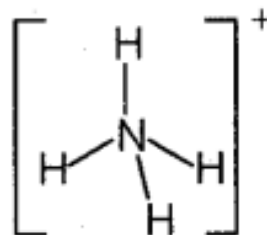
(c)  $\text{NF}_3$  and  $\text{BF}_3$



(d)  $BF_4^-$  and  $NH_4^+$



4 $\sigma$  bonds  
 $\Rightarrow sp^3$ -hybridisation  
 and tetrahedral geometry



4 $\sigma$  bonds  
 $\Rightarrow sp^3$ -hybridisation  
 and tetrahedral geometry

Thus,  $BF_4^-$  and  $NH_4^+$  are isostructural.

55.  $O_2^{2-} (8 + 8 + 2 = 18) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2$

$$\pi 2p_x^2 \approx \pi 2p_y^2, \pi^* 2p_x^2 \approx \pi^* 2p_y^2$$

$$\text{Bond order (BO)} = \frac{N_b - N_a}{2} = \frac{10 - 8}{2} = 1$$

$$B_2 (5 + 5 = 10) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^1 \approx \pi 2p_y^1$$

$$BO = \frac{6 - 4}{2} = 1$$



Thus,  $O_2^{2-}$  and  $B_2$  have the same bond order.

**Note** BO of  $O_2^+$  = 2.5,  $NO^+$  = 3,  $NO$  = 2.5,  $CO$  = 3,  
 $N_2$  = 3 and  $O_2$  = 2

**56.** (a) MO configuration of  $O_2^+(8 + 8 - 1 = 15)$

$$BO = \frac{N_b - N_a}{2} = \frac{10 - 5}{2} = 2.5$$

Similarly,

(b)  $O_2^-(8 + 8 + 1 = 17)$

$$\text{So, } BO = \frac{N_b - N_a}{2} = \frac{10 - 7}{2} = 1.5$$

(c)  $O_2^{2-}(8 + 8 + 2 = 18)$

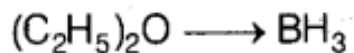
$$\text{So, } BO = \frac{N_b - N_a}{2} = \frac{10 - 8}{2} = 1$$

(d)  $O_2(8 + 8 = 16)$

$$BO = \frac{10 - 6}{2} = 2$$

Thus,  $O_2^-$  shows the bond order 1.5.

**57.** In  $(C_2H_5)_2OBH_3$  coordinate bond is formed in between B and O.



$(C_2H_5)_2O$  gives one lone pair of electron to  $BH_3$ . So, it is called electron pair donor and  $BH_3$  is called electron pair acceptor.

58. Number of hybrid orbital =  $\frac{1}{2}$  [number of  $e^-$  in valence shell of atom + number of monovalent atoms - charge on cation + charge on anion]

No. of hybrid orbital	2	3	4	5	6	7
Type of hybridisation	$sp$	$sp^2$	$sp^3$	$sp^3d$	$sp^3d^2$	$sp^3d^3$

Hybridisation in  $TeCl_4$

$$\text{Number of hybrid orbital} = \frac{1}{2} [6 + 4 + 0 + 0] = 5$$

Hence,  $TeCl_4$  shows  $sp^3d$ -hybridisation.

59. Bond order of  $O_2^+$  =  $\frac{10-5}{2} = 2.5$

$$\text{Bond order of } O_2^- = \frac{10-7}{2} = 1.5$$

$$\text{Bond order of } O_2^{2-} = \frac{10-8}{2} = 1$$

$$\text{Bond order of } O_2 = \frac{10-6}{2} = 2$$

$\therefore$  Maximum bond order = minimum bond length.

$\therefore$  Bond length is minimum for  $O_2^+$ .

60. C—H; bond length = 0.109 nm

C=C; bond length = 0.134 nm

C—O; bond length = 0.143 nm

C—C; bond length = 0.154 nm

$\therefore$  Correct order of bond length is



61.  $NO_2^- \longrightarrow sp^2$ -hybridisation

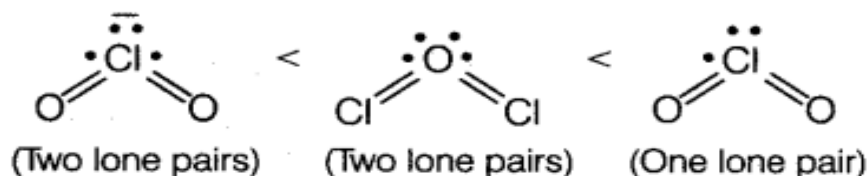
$NO_3^- \longrightarrow sp^2$ -hybridisation

$NH_2^+ \longrightarrow sp^3$ -hybridisation

$\text{NH}_4^- \longrightarrow sp^3$ -hybridisation  
 $\text{SCN}^+ \longrightarrow sp$ -hybridisation  
 $\therefore \text{NO}_2^-$  and  $\text{NO}_3^-$  both have the same hybridisation.

- 62.** As the number of lone pairs of electrons increases, bond angle decreases due to repulsion between  $lp - lp$ . Moreover, as the electronegativity of central atom decreases, bond angle decreases.

Hence, the order of bond angle is



(Cl is less electronegative as compared to O).

- 63.** For  $sp^2$ -hybridisation, there must be  $3\sigma$  bonds or  $2\sigma$  bonds along with a lone pair of electrons.

- (i)  $\text{NO}_2^- \Rightarrow 2\sigma + 1lp = 3$ , i.e.  $sp^2$ -hybridisation  
 (ii)  $\text{NH}_3 \Rightarrow 3\sigma + 1lp = 4$ , i.e.  $sp^3$ -hybridisation  
 (iii)  $\text{BF}_3 \Rightarrow 3\sigma + 0lp = 3$ , i.e.  $sp^2$ -hybridisation  
 (iv)  $\text{NH}_2^- \Rightarrow 2\sigma + 2lp = 4$ , i.e.  $sp^3$ -hybridisation  
 (v)  $\text{H}_2\text{O} \Rightarrow 2\sigma + 2lp = 4$ , i.e.  $sp^3$ -hybridisation

Thus, among the given pairs, only  $\text{BF}_3$  and  $\text{NO}_2^-$  have  $sp^2$ -hybridisation.

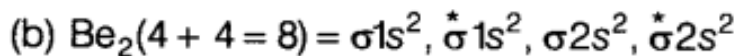
- 64.** Molecules with zero bond order, do not exist.

(a)  $\text{Be}_2^+ (4 + 4 - 1 = 7) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^1$

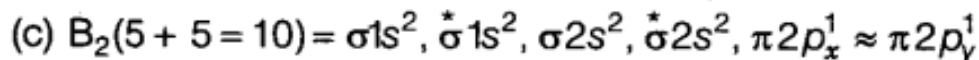
$$\text{BO} = \frac{4 - 3}{2} = 0.5$$

(b)  $\text{Be}_2 (4 + 4 = 8) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2$

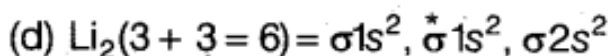
$$\text{BO} = \frac{4 - 4}{2} = 0$$



$$\text{BO} = \frac{4 - 4}{2} = 0$$



$$\text{BO} = \frac{6 - 4}{2} = 1$$



$$\text{BO} = \frac{4 - 2}{2} = 1$$

Thus,  $\text{Be}_2$  does not exist under normal conditions.

- 65.** Molecules having the same number of hybrid orbitals, have same hybridisation and number of hybrid orbitals.

$$H = \frac{1}{2}[V + Y - C + A]$$

where,  $V$  = number of valence electrons of central atom

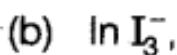
$Y$  = number of monovalent atoms

$C$  = charge on cation

$A$  = charge on anion



$$H = \frac{1}{2}[6 + 4 - 0 + 0] = 5$$



$$H = \frac{1}{2}[7 + 2 + 1] = 5$$

(c) In  $\text{SbCl}_5^{2-}$ ,

$$H = \frac{1}{2} [5 + 5 + 2] = 6$$

(d) In  $\text{PCl}_5$ ,

$$H = \frac{1}{2} [5 + 5 + 0 - 0] = 5$$

Since, only  $\text{SbCl}_5^{2-}$  has different number of hybrid orbitals (i.e. 6) from the other given species, its hybridisation is different from the others, i.e.  $sp^3d^2$ .

(The hybridisation of other species is  $sp^3d$ ).

66. (a)  $\text{BF}_3 \Rightarrow 3bp + 0lp$

$\Rightarrow sp^2$ -hybridisation and trigonal planar geometry.

(b)  $\text{NH}_3 \Rightarrow 3bp + 1lp$

$\Rightarrow sp^3$ -hybridisation and pyramidal geometry.

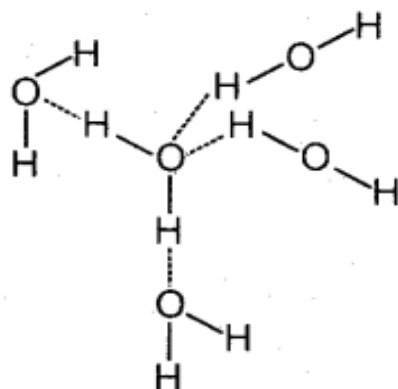
(c)  $\text{PH}_3 \Rightarrow 3bp + 1lp$

$\Rightarrow sp^3$ -hybridisation and pyramidal geometry.

(d)  $\text{IF}_3 \Rightarrow 3bp + 2lp$

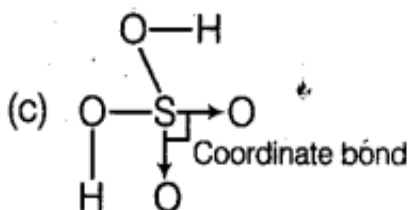
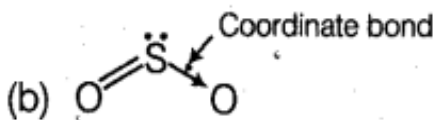
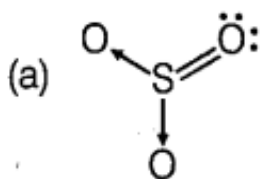
$\Rightarrow sp^3d$ -hybridisation and T-shape.

67. A water molecule can form a maximum of four H-bonds as:



(Dotted lines represent H-bonds)

68. The structures of the given compounds are as:



(Arrow represents coordinate bonds)

Thus, all the given compounds contain coordinate bond.

69. Number of hybrid orbitals,

$$H = \frac{1}{2} [V + Y + A - C]$$

$$\therefore H = \frac{1}{2} [7 + 7 + 0 - 0] = 7$$

Thus, the hybridisation of  $\text{IF}_7$  is  $sp^3d^3$  and its geometry is pentagonal bipyramidal.

70. Orbitals having nearly same energy are called degenerate orbitals. Among the given,  $\pi 2p_x$  and  $\pi 2p_y$  orbitals are of equivalent energy, thus, are called degenerate orbitals.