

# Chemical Bonding and Molecular Structure

## Topic 1 Ionic and Covalent Bonding, Lewis Structure and Polar Character of Covalent Bond

### Revision Notes

► **Chemical Bond:** The attractive force which holds together the various constituent particles (atoms, ions of molecules, etc.) in different chemical species is known as chemical bond.

**Types of Bonding**

**Ionic or Electrovalent Bond**

Ionic bonding is a type of chemical bond that involves the electrostatic attraction between opposite charged ions together. Electrovalent compounds are formed by transfer of electron from a metal to a non-metal.

Na  $(1s^2, 2s^2 2p^6, 3s^1)$  +  $\cdot\text{Cl}\cdot$   $(3s^2 3p^5)$  →  $\text{Na}^+$   $(1s^2, 2s^2 2p^6)$   $\text{Cl}^-$   $(3s^2 3p^6)$   
or  $\text{Na}^+\text{Cl}^-$

- Ionic compounds have high melting points and high boiling points.
- Ionic compounds have higher enthalpies of fusion and vaporisation than molecular compounds.
- Ionic compounds are hard and brittle.
- Ionic compounds conduct electricity when they are dissolved in water or in molten state.
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- Ionic compounds conduct electricity when they are dissolved in water or in molten state.
- Ionic solids are good insulators.
- The ionic bond is non-directional. This is because each ion is surrounded by oppositely charged ions uniformly distributed all around the ion.

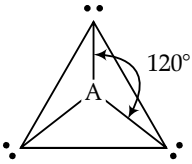
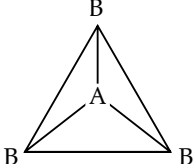
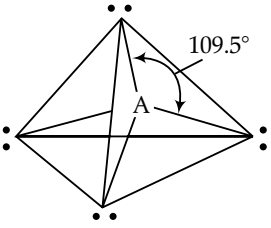
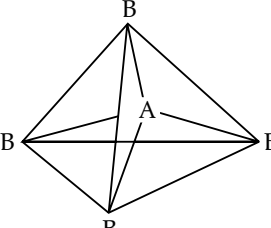
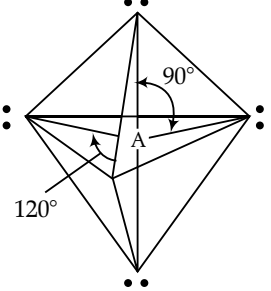
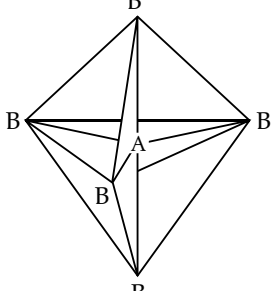
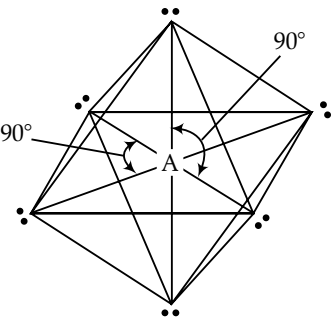
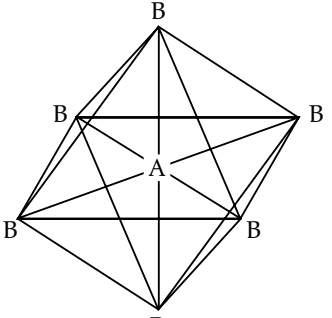
**Covalent Bond**

$\cdot\text{Cl}\cdot$  +  $\cdot\text{Cl}\cdot$  →  $\text{Cl}:\text{Cl}$  →  $\text{Cl}-\text{Cl}$   
Chlorine atoms      Chlorine molecule

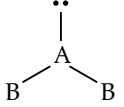
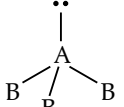
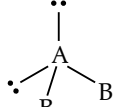
Or  $8e^-$      $8e^-$

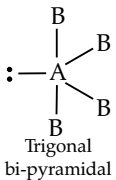
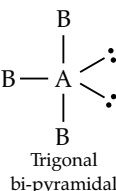
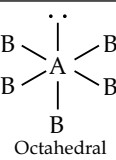
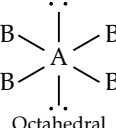
- **Low melting and boiling points:** Covalent compound consists of molecules that are held by weak forces. These can be easily overcome by heat.
- **Non-conductive nature:** Covalent compounds do not conduct electricity, i.e., electricity does not pass through the covalent compounds. This is because the covalent compounds do not contain ions of free electrons.
- **Solubility:** Covalent compounds are non-polar and do not dissolve in polar solvents like water. The covalent compounds however, dissolve in non-polar solvents, like benzene, toluene, etc.
- **Slow rate of reaction:** The reaction of the covalent compounds is quite slow. This reaction is molecular, and the molecular reactions are slow.
- Depending upon the number of 2, 4, or 6 electrons shared between two atoms, a covalent bond is called single, double or triple covalent bond, respectively.



3	 <p>Trigonal planar</p>	 <p>Trigonal planar</p>	$\text{BF}_3$
4	 <p>Tetrahedral</p>	 <p>Tetrahedral</p>	$\text{CH}_4, \text{NH}_4^+$
5	 <p>Trigonal bipyramidal</p>	 <p>Trigonal bipyramidal</p>	$\text{PCl}_5$
6	 <p>Octahedral</p>	 <p>Octahedral</p>	$\text{SF}_6$

► Shape (geometry) of Some Simple Molecules/Ions with Central Ions having One or More Lone Pairs of Electrons (E)

Molecule type	No. of bonding pairs	No. of lone pairs	Arrangement of electron pairs	Shape	Example
$\text{AB}_2\text{E}$	2	1	 <p>Trigonal planar</p>	Bent	$\text{SO}_2, \text{O}_3$
$\text{AB}_3\text{E}$	3	1	 <p>Tetrahedral</p>	Trigonal pyramidal	$\text{NH}_3$
$\text{AB}_2\text{E}_2$	2	2	 <p>Tetrahedral</p>	Bent	$\text{H}_2\text{O}$

$AB_4E$	4	1	 <p>Trigonal bi-pyramidal</p>	See saw	$SF_4$
$AB_3E_2$	3	2	 <p>Trigonal bi-pyramidal</p>	Distorted T-shape	$ClF_3$
$AB_5E$	5	1	 <p>Octahedral</p>	Square Pyramidal	$BrF_5$
$AB_4E_2$	4	2	 <p>Octahedral</p>	Square Planar	$XeF_4$

**► Valence bond theory :**

According to V.B.T, a covalent bond is formed between the two atoms by the overlap of half-filled valence atomic

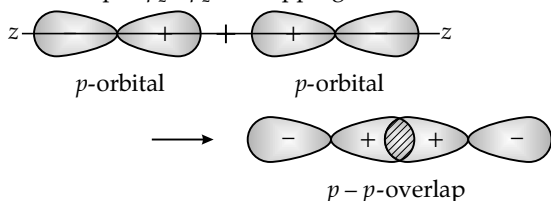
orbitals with similar energies of each atom containing one unpaired electron.

Greater the overlap, stronger is the bond.

**► Types of overlapping and nature of covalent Bond :**
**Types of Overlapping and Nature of Covalent Bond**
**Sigma ( $\sigma$ ) bond**
**Pi ( $\pi$ ) bond**

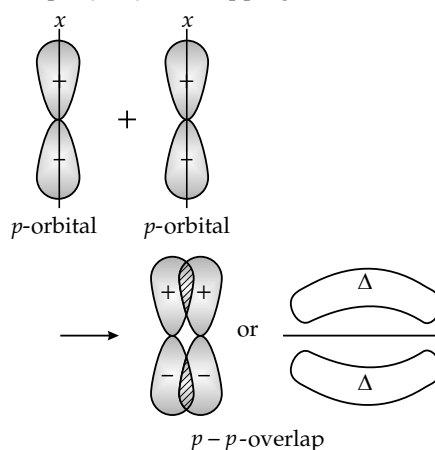
- This type of covalent bond is formed by the end to end overlap of bonding orbitals along the internuclear axis. The overlap is known as head on overlap or axial overlap.

- For example,  $p_z - p_z$  overlapping



- This type of covalent bond is formed by the sidewise overlap of the half-filled atomic orbitals of bonding atoms. Such an overlap is known as **sidewise** or **lateral overlap**. The atomic orbitals overlap in such a way that their axis remain parallel to each other and perpendicular to the internuclear axis.

- For example,  $p_x - p_x$  overlapping



**► Hybridisation:** The process of intermixing of the orbitals of slightly different energies so as to redistribute their energies resulting in the formation of new set of orbitals of equivalent energies and shape.

**► Characteristics of hybridisation :**

- The number of hybridised orbitals is equal to the number of the orbitals that get hybridised.

- The hybridised orbitals are always equivalent in energy and shape.

- The hybrid orbitals are more effective in forming stable bonds than the pure atomic orbitals.

- The hybrid orbitals are directed in space in some preferred directions to have stable arrangement. Therefore, the type of hybridisation indicates the **geometry of the molecule**.

### ►► Conditions for hybridisation

- Only the orbitals present in the valence shell of the atom are hybridised.
- The orbitals undergoing hybridisation should have only a small difference in energy. The orbitals which differ largely in energy cannot take part in hybridisation.
- Promotion is not essential condition prior to hybridisation.
- It is not essential that only half filled orbitals participate in hybridisation. In certain cases, even filled orbitals of valence shell participate in hybridisation.

Shape of Molecules/ions	Hybridisation type	Atomic orbitals	Example
Linear	$sp$	$s + p$	$\text{BeF}_2$
Triangular pyramidal	$sp^2$	$s + p(2)$	$\text{BCl}_3$
Tetrahedral	$sp^3$	$s + p_x + p_y + p_z$	$\text{CH}_4$
Square planar	$dsp^2$	$d + s + p(2)$	$[\text{Ni}(\text{CN})_4]^{2-}$ , $[\text{Pt}(\text{Cl})_4]^{2-}$
Trigonal bipyramidal	$sp^3d$	$s + p_x + p_y + p_z + d_z^2$	$\text{PF}_5$ , $\text{PCl}_5$
Square pyramidal	$sp^3d^2$	$s + p_x + p_y + p_z + d_{x^2-y^2}, d_{z^2}$	$\text{BrF}_5$
Octahedral	$sp^3d^2$ $d^2sp^3$	$s + p(3) + d(2) + d_{x^2-y^2}, d_{z^2}$ $d_{xy}, d_{x^2-y^2} + s + p(3)$	$\text{SF}_6$ , $[\text{CrF}_6]^{3-}$ $[\text{Co}(\text{NH}_3)_6]^{3+}$
Pentagonal bipyramidal	$sp^3d^3$	$s + p(3) + d_{xy}, d_{yz}, d_{xz}$	$\text{IF}_7$

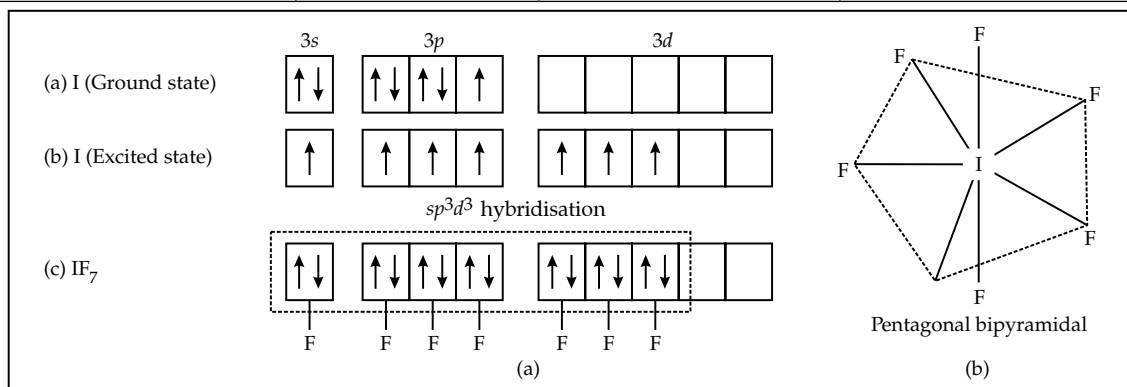


Fig. (a) Formation of  $\text{IF}_7$  molecule involving  $sp^3d^3$ -hybridisation, (b) Pentagonal bipyramidal geometry of  $\text{IF}_7$  molecule.

## Topic 3 Molecular Orbital Theory and Hydrogen Bond

### Revision Notes

- **Molecular orbital theory:** The basic idea of molecular orbital theory is that atomic orbital of individual atoms combine to form molecular orbitals.
- **Salient features of molecular orbital theory:**
  - Just like one atom, molecules have orbitals of definite energy levels.
  - Molecular orbitals are formed by the combination of atomic orbitals of proper symmetry and comparable energies.
  - The number of molecular orbitals formed is equal to the number of combining atomic orbitals. When two atomic orbitals combine they form two molecular orbitals.
  - These are called bonding molecular orbitals and antibonding molecular orbitals.
  - The bonding molecule has lower energy and hence greater stability whereas corresponding antibonding molecule has more energy and hence lesser stability.

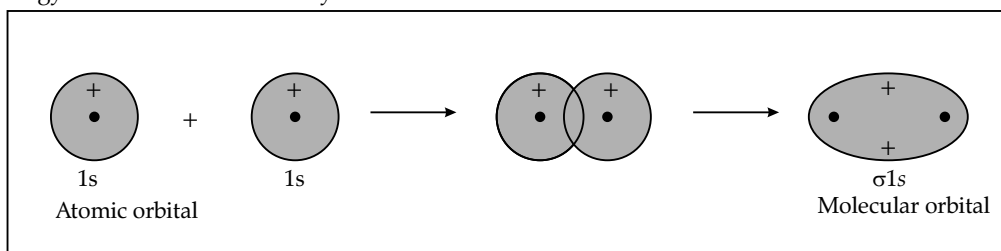


Fig. Formation of bonding molecular orbital

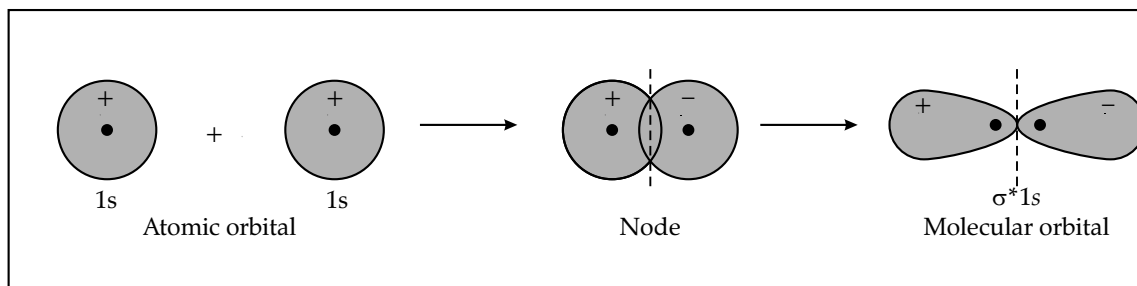


Fig. Formation of antibonding molecular orbital

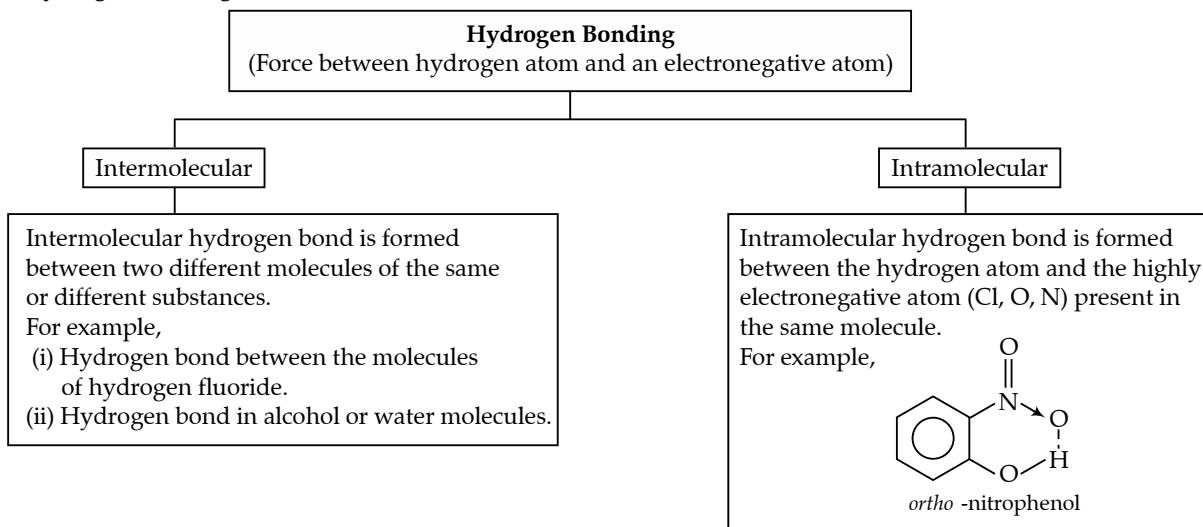
- ▶▶ The main condition for effective combination of atomic orbitals.
  - The combining atomic orbitals must have same or nearly the same energies.
  - The extent of overlapping between the atomic orbitals of two atoms should be large.
- ▶▶ For homonuclear diatomic molecules of second row elements such as  $\text{Li}_2$ ,  $\text{Be}_2$ ,  $\text{B}_2$ ,  $\text{C}_2$ ,  $\text{N}_2$ , the order of increasing energies for their molecules is  
Energy order 1 :

$$\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < (\pi 2p_x = \pi 2p_y) < \sigma 2p_z < (\pi^* 2p_x = \pi^* 2p_y) < \sigma^* 2p_z$$

For molecules  $\text{O}_2$  onwards, the increasing order of energies for molecular orbitals in which they are filled is as follows :  
Energy order 2 :

$$\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < \sigma 2p_z < (\pi 2p_x = \pi 2p_y) < (\pi^* 2p_x = \pi^* 2p_y) < \sigma^* 2p_z$$

▶▶ **Hydrogen Bonding :**



## Topic 1: Previous Year's Questions

1. Given below are two statements:

**Statement I:** pi bonds are weaker than  $\sigma$  bonds.

**Statement II:** pi bonds are formed by the overlapping of p – p orbitals along their axes.

In the light of above statements, choose the most appropriate answer from the options given below:

- (a) Both Statement I and Statement II are true.
- (b) Statement I is false but Statement II is true.
- (c) Both Statement I and Statement II are false.
- (d) Statement I is true but Statement II is false.

2. Given below are two statements:

**Statement I:**  $\text{NH}_3$  have high dipole moment than  $\text{PH}_3$

**Statement II:** Electronegativity of P is more than N.

In the light of above statements, choose the most appropriate answer from the options given below:

- (a) Both Statement I and Statement II are true.
- (b) Statement I is false but Statement II is true.
- (c) Both Statement I and Statement II are false.
- (d) Statement I is true but Statement II is false.

3. The number of  $\sigma$  bonds,  $\pi$  bonds and lone pair of electrons in pyridine, respectively are

- (a) 12, 3, 0
- (b) 11, 3, 1
- (c) 12, 2, 1
- (d) 11, 2, 0 [NEET 2023]

4. Amongst the following which one will have maximum 'lone pair-lone pair' electron repulsions ?

- (a)  $\text{ClF}_3$
- (b)  $\text{IF}_5$
- (c)  $\text{SF}_4$
- (d)  $\text{XeF}_2$  [NEET 2022]

5. Choose the correct statement :

- (a) Diamond and graphite have two dimensional network.

- (b) Diamond is covalent and graphite is ionic.  
 (c) Diamond is  $sp^3$  hybridised and graphite is  $sp^2$  hybridised.  
 (d) Both diamond and graphite are used as dry lubricants. [NEET 2022]
6. Which of the following molecules is non-polar in nature?  
 (a)  $\text{NO}_2$  (b)  $\text{POCl}_3$   
 (c)  $\text{CH}_2\text{O}$  (d)  $\text{SbCl}_5$  [NEET 2021]
7. Which of the following set of molecules will have zero dipole moment?  
 (a) Boron trifluoride, hydrogen fluoride, carbon dioxide, 1, 3-dichlorobenzene  
 (b) Nitrogen trifluoride, beryllium difluoride, water, 1, 3-dichlorobenzene  
 (c) Boron trifluoride, beryllium difluoride, carbon dioxide, 1, 4-dichlorobenzene  
 (d) Ammonia, beryllium difluoride, water, 1, 4-dichlorobenzene [NEET 2020 Phase I]
8. Identify a molecule which does not exist.  
 (a)  $\text{Li}_2$  (b)  $\text{C}_2$   
 (c)  $\text{O}_2$  (d)  $\text{He}_2$  [NEET 2020 Phase I]
9. Among the compounds shown below which one revealed a linear structure?  
 (a)  $\text{NO}_2$  (b)  $\text{HOCl}$   
 (c)  $\text{O}_3$  (d)  $\text{N}_2\text{O}$  [NEET 2020 Phase II]
10.  $\text{Be}^{2+}$  is isoelectronic with which of the following ions?  
 (a)  $\text{H}^+$  (b)  $\text{Li}^+$   
 (c)  $\text{Na}^+$  (d)  $\text{Mg}^{2+}$  [AIPMT 2014]
11. Which of the following molecules has the maximum dipole moment?  
 (a)  $\text{CO}_2$  (b)  $\text{CH}_4$   
 (c)  $\text{NH}_3$  (d)  $\text{NF}_3$  [AIPMT 2014]
12. Identify the correct order of solubility in aqueous medium.  
 (a)  $\text{CuS} > \text{ZnS} > \text{Na}_2\text{S}$  (b)  $\text{ZnS} > \text{Na}_2\text{S} > \text{CuS}$   
 (c)  $\text{Na}_2\text{S} > \text{CuS} > \text{ZnS}$  (d)  $\text{Na}_2\text{S} > \text{ZnS} > \text{CuS}$  [NEET 2013]
13. Which of the following is a polar molecule?  
 (a)  $\text{BF}_3$  (b)  $\text{SF}_4$   
 (c)  $\text{SiF}_4$  (d)  $\text{XeF}_4$  [NEET 2013]
14. Which of the following is least likely to behave as Lewis base?  
 (a)  $\text{NH}_3$  (b)  $\text{BF}_3$   
 (c)  $\text{OH}^-$  (d)  $\text{H}_2\text{O}$  [AIPMT 2011]
15. In the case of alkali metals, the covalent character decreases in the order:  
 (a)  $\text{MCl} > \text{MI} > \text{MBr} > \text{MF}$   
 (b)  $\text{MF} > \text{MCl} > \text{MBr} > \text{MI}$   
 (c)  $\text{MF} > \text{MCl} > \text{MI} > \text{MBr}$   
 (d)  $\text{MI} > \text{MBr} > \text{MCl} > \text{MF}$  [AIPMT 2009]
16. The correct order of C—O bond length among  $\text{CO}$ ,  $\text{CO}_3^{2-}$ ,  $\text{CO}_2$  is:  
 (a)  $\text{CO}_2 < \text{CO}_3^{2-} < \text{CO}$  (b)  $\text{CO} < \text{CO}_3^{2-} < \text{CO}_2$   
 (c)  $\text{CO}_3^{2-} < \text{CO}_2 < \text{CO}$  (d)  $\text{CO} < \text{CO}_2 < \text{CO}_3^{2-}$  [AIPMT 2007]
17. The electronegativity difference between N and F greater than that between N and H yet the dipole moment of  $\text{NH}_3$  (1.5 D) is larger than that of  $\text{NF}_3$  (0.2 D). This is because:  
 (a) In  $\text{NH}_3$  as well as  $\text{NF}_3$ , the atomic dipole and bond dipole are in the same direction.  
 (b) In  $\text{NH}_3$ , the atomic dipole and bond dipole are in the same direction whereas in  $\text{NF}_3$  these are in opposite directions  
 (c) In  $\text{NH}_3$  as well as  $\text{NF}_3$ , the atomic dipole and bond dipole are in opposite directions.  
 (d) In  $\text{NH}_3$  the atomic dipole and bond dipole are in the opposite directions whereas in  $\text{NF}_3$  these are in the same directions [AIPMT 2005]
18. The correct sequence of increasing covalent character is represented by:  
 (a)  $\text{LiCl} < \text{NaCl} < \text{BeCl}_2$  (b)  $\text{BeCl}_2 < \text{NaCl} < \text{LiCl}$   
 (c)  $\text{NaCl} < \text{LiCl} < \text{BeCl}_2$  (d)  $\text{BeCl}_2 < \text{LiCl} < \text{NaCl}$  [AIPMT 2005]
19. Which of the following would have a permanent dipole moment?  
 (a)  $\text{BF}_3$  (b)  $\text{SiF}_4$   
 (c)  $\text{SF}_4$  (d)  $\text{XeF}_4$  [AIPMT 2005]
20. Which of the following is isoelectronic?  
 (a)  $\text{CO}_2, \text{NO}_2$  (b)  $\text{NO}_2^-, \text{CO}_2$   
 (c)  $\text{CN}^-, \text{CO}$  (d)  $\text{SO}_2, \text{CO}_2$  [AIPMT 2002]
21. In  $\text{PO}_4^{3-}$  ion, the formal charge on each oxygen atom and P—O bond order respectively are:  
 (a)  $-0.75, 0.6$  (b)  $-0.75, 1.0$   
 (c)  $-0.75, 1.25$  (d)  $-3, 1.25$  [AIPMT 1998]
22. Which one is not paramagnetic among the following? [Atomic number of Be = 4, Ne = 10, As = 33, Cl = 17]  
 (a)  $\text{Cl}^-$  (b)  $\text{Be}^+$   
 (c)  $\text{Ne}^{2+}$  (d)  $\text{As}^+$  [AIPMT 1998]
23. For two ionic solids  $\text{CaO}$  and  $\text{KI}$ , identify the wrong statement among the following:  
 (a) Lattice energy of  $\text{CaO}$  is much larger than that of  $\text{KI}$   
 (b)  $\text{KI}$  is soluble in benzene  
 (c)  $\text{KI}$  has lower melting point  
 (d)  $\text{CaO}$  has higher melting point [AIPMT 1997]

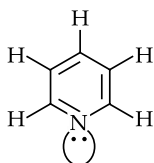
## Answer Key

1.	(d)	2.	(d)	3.	(b)	4.	(d)	5.	(c)	6.	(d)
7.	(c)	8.	(d)	9.	(d)	10.	(b)	11.	(c)	12.	(d)
13.	(b)	14.	(b)	15.	(d)	16.	(d)	17.	(b)	18.	(c)
19.	(c)	20.	(c)	21.	(c)	22.	(a)	23.	(b)		

## Answers with Explanation

1. (d) pi bonds are formed by the overlapping of p – p orbitals perpendicular to their axis, i.e., sidewise overlap.
2. (d) All the given molecules have same structure. The electronegativity of the central atom of given compounds is in the order  
 $\text{As} < \text{Sb} < \text{P} < \text{N}$   
 Thus, the highest bond dipole is for N—H bond which results in highest dipole moment of  $\text{NH}_3$ .

3. (b)



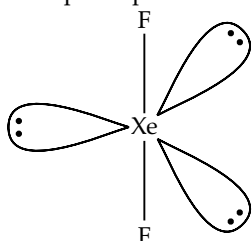
No. of  $\pi$  bond = 3  
 No. of lone pair = 1  
 No. of  $\sigma$  bond = 11

 4. (d) In  $\text{ClF}_3$ , there are 2 lone pairs

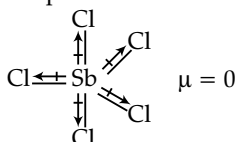
 In  $\text{IF}_5$ , there is 1 lone pair.

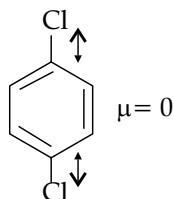
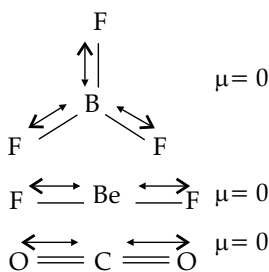
 In  $\text{SF}_4$ , there is 1 lone pair, and

 In  $\text{XeF}_2$ , there are 3 lone pairs.

 So, lone pair – lone pair repulsion is maximum in  $\text{XeF}_2$ .

 5. (c) In diamond, carbon atoms have tetrahedral arrangement, so hybridisation is  $sp^3$ .

 The shape of graphite is trigonal planar and the hybridisation possessed by it is  $sp^2$ .

 6. (d) The molecule which has net dipole moment equal to zero ( $\mu = 0$ ) is considered as non-polar molecule. In  $\text{SbCl}_5$ , net vector summation of bond moments will be zero, so it is a non-polar molecule.

 $sp^3d$ , trigonal bipyramidal

 7. (c) Due to their symmetrical structure,  $\text{BF}_3$ ,  $\text{BeF}_2$ ,  $\text{CO}_2$  and 1, 4-dichloro benzene molecules have a zero dipole moment.

 8. (d) For  $\text{He}_2$  molecule

Total number of electron = 4

 Electronic configuration is  $\sigma 1s^2, \sigma^* 1s^2$ 

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

$$= \frac{[2 - 2]}{2} = 0$$

 Since, bond order is zero, so  $\text{He}_2$  molecule does not exist.

 9. (d)  $\text{N}_2\text{O}$  is linear.

 10. (b) Electronic configuration of  $\text{Be}^{2+} = 1s^2$  i.e., 2 electrons

 Electronic configuration of  $\text{H}^+ = 1s^0$ 

i.e., zero electron

 Electronic configuration of  $\text{Li}^+ = 1s^2$ , i.e., 2 electrons

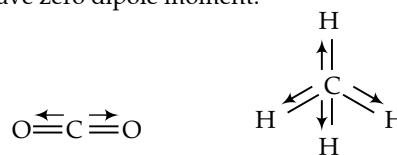
 Electronic configuration of  $\text{Na}^+ = 1s^2 2s^2 2p^6$ 

i.e., 10 electrons

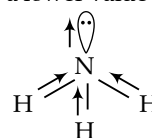
 Electronic configuration of  $\text{Mg}^{2+} = 1s^2 2s^2 2p^6$ 

i.e., 10 electrons

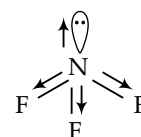
 Thus,  $\text{Be}^{2+}$  and  $\text{Li}^+$  iso electronic as both contains same number of electrons.

 11. (c) In case of  $\text{CO}_2$  and  $\text{CH}_4$  though the C—O and C—H bonds are polar but due to their symmetrical structure they have zero dipole moment.


Net dipole moment = 0    Net dipole moment = 0

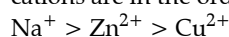
 Among  $\text{NH}_3$  and  $\text{NF}_3$ , the dipole moment of  $\text{NH}_3$  is higher due to direction of dipole of N—H bond is in the similar direction of lone pair but for  $\text{NF}_3$  the dipole moment of N—F bond is in opposite direction of lone pair which results a lower value of net dipole moment.


Net dipole moment is of higher value due to sum of dipoles in same direction

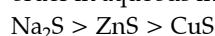


Net dipole moment is lower due to resultant of 3 N-F bonds is opposite due to the dipole of lone pair

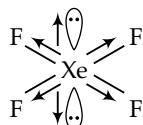
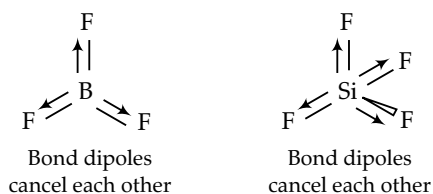
12. (d) Water is a polar compound so the salt which is more polar or having more ionic character will be more soluble in it. According to Fajans' rule, ionic character of compound increases with the increase in the size of cation. Now, among the given compounds, the size of cations are in the order as follows:



Thus, the order of ionic character and the solubility order in aqueous medium is as follows :

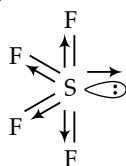

 13. (b) The molecules which have symmetrical structure are non-polar even they contain polar bonds due to cancellation of bond dipoles. Among the given molecules  $\text{BF}_3$ ,  $\text{SiF}_4$  and  $\text{XeF}_4$  are symmetric molecules.





Bond dipoles and dipoles of lone pairs of electrons cancel each other

But in  $\text{SF}_4$  there are four Si—F bonds and one lone pair due to which its structure is unsymmetrical. Hence, it is a polar molecule.



Net dipole moment  $\neq 0$

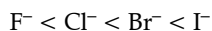
14. (b) The species which have a lone pair of electrons to donate or a negative charge on it can act as a Lewis base. Here, N atom in  $\text{NH}_3$  and O atom in  $\text{H}_2\text{O}$  have lone pair of electrons available for donation. In  $\text{OH}^-$  the negative charge on it results in to behave it as a Lewis base. But  $\text{BF}_3$  is an electron deficient species thus, it is least likely to behave as Lewis base.

15. (d) According to Fajans' rule,

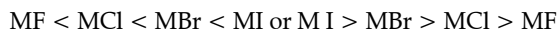
Covalent character  $\propto$  size of anion

$$\propto \frac{1}{\text{size of cation}}$$

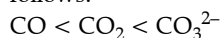
Now the order of size of anions in the given options is as follows



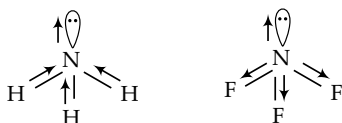
Thus, the covalent character of the given compounds varies as



16. (d) Bond length between two atoms decreases from single bond to multiple bonds between them. In  $\text{CO}$ , there is triple bond between C and O, in  $\text{CO}_2$  there is double bond between C and O. Thus, bond length of  $\text{CO}_2$  is greater than  $\text{CO}$ . In  $\text{CO}_3^{2-}$ , there are two single bonds between C and O and third oxygen atom forms double bond with carbon. These three oxygen atoms are identical due to resonance thus, each C—O bond length is smaller than a single bond but greater than the double bond. Thus, the correct order of bond length is as follows:



17. (b)



In  $\text{NH}_3$ , all the three bond dipoles are add to the atomic dipole as they are in same direction thus, giving high

value of dipole moment. However, in  $\text{NF}_3$ , the three N—F bond dipole are in opposite direction of atomic dipole thus, the net dipole moment for the molecule is less than the  $\text{NH}_3$ .

18. (c) Among the given compounds the anion is same, i.e., chloride ion however the difference is in the cations.

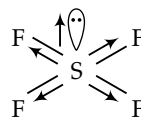
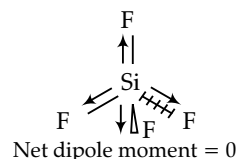
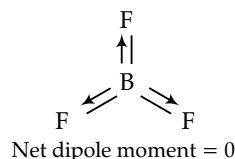
Now, according to Fajans' rule,

$$\text{Covalent character} \propto \frac{1}{\text{size of cation}}$$

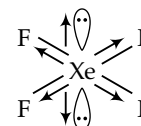
The size of cations varies as  $\text{Be}^{2+} < \text{Li}^+ < \text{Na}^+$ . Hence, covalent character of compounds is in the order as follows :



19. (c) Structures of the given compounds are as follows:



Due to lone pair there is permanent dipole moment



Net dipole moment = 0

20. (c) Number of electrons in  $\text{CO}_2 = 6 + 2(8) = 22$   
 Number of electrons in  $\text{NO}_2 = 7 + 2(8) = 23$   
 Number of electrons in  $\text{NO}_2^- = 7 + 2(8) + 1 = 24$   
 Number of electrons in  $\text{CN}^- = 6 + 7 + 1 = 14$   
 Number of electrons in  $\text{CO} = 6 + 8 = 14$   
 Number of electrons in  $\text{SO}_2 = 16 + 2(8) = 32$   
 Thus, species which are isoelectronic are  $\text{CN}^-$  and  $\text{CO}$ .

21. (c) Formula charge on each oxygen atom is as follows :

Total charge on  $\text{PO}_4^{3-}$  ion is  $-3$ .

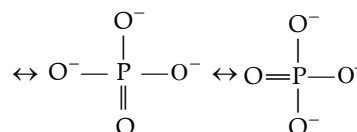
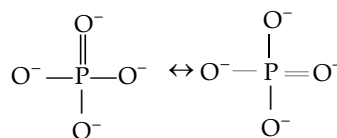
Number of oxygen atoms is 4.

So, average formula charge on each atom

$$= \frac{-3}{4} = -0.75$$

Bond order of P—O

$$= \frac{\text{Number of bonds between P and O}}{\text{Number of resonating structures}}$$



Thus, there are 4 resonating structures of  $\text{PO}_4^{3-}$  ion and the number of P—O bonds is

$$2 + 1 + 1 + 1 = 5$$

Thus, bond order of P—O =  $\frac{5}{4} = 1.25$

22. (a) Electronic configuration of  $\text{Cl}^- = 1s^2 2s^2 2p^6 3s^2 3p_x^2 3p_y^2 3p_z^2$   
 Here, all electrons are paired, so it is diamagnetic.  
 Electronic configuration of  $\text{Be}^+ = 1s^2 2s^1$   
 Here, one electron is unpaired, so it is paramagnetic.  
 Electronic configuration of  $\text{Ne}^{2+} = 1s^2 2s^2 2p_x^2 2p_y^1 2p_z^1$   
 Here, there are two unpaired electrons thus, it is paramagnetic.  
 Electronic configuration of  $\text{As}^+ = 1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p_x^1 4p_y^1$   
 Here, there are two unpaired electrons thus, it is paramagnetic.
23. (b) According to Fajans' rule,  
 covalent character  $\propto$  size of anion  $\propto \frac{1}{\text{size of cation}}$   
 Now, size of cation,  $\text{K}^+ > \text{Ca}^{2+}$   
 Size of anion,  $\text{O}^{2-} < \text{I}^-$   
 Thus, CaO is more covalent than KI.  
 Lattice energy of KI is lower than that of CaO. Also, KI has lower melting point than CaO.  
 Also, KI being ionic in nature is soluble in a polar solvent but benzene is a non-polar solvent thus, KI being polar is insoluble in a non-polar solvent like benzene.

## Topic 2: Previous Year's Questions

1. **Assertion (A):** Atoms can combine either by transfer of valence of electrons from one atom to another or by sharing of valence electrons.  
**Reason (R):** Sharing and transfer of valence electrons is done by atoms to have an octet in their valence shell.  
**In the light of the above statements, choose the most appropriate answer from the options given below:**  
 (a) Assertion is correct, reason is correct; reason is the correct explanation for assertion.  
 (b) Assertion is correct, reason is correct; reason is not the correct explanation for assertion.  
 (c) Assertion is correct, reason is incorrect.  
 (d) Assertion is incorrect, reason is correct.
2. **Given below are two statements:**  
**Statement I:** Lone pair – lone pair repulsive interactions are greater than lone pair – bond pair and bond pair – bond pair interactions.  
**Statement II:** The space occupied by lone pair electrons is more as compared to bond pair electrons.  
**In the light of above statements, choose the most appropriate answer from the options given below:**  
 (a) Both Statement I and Statement II are true.  
 (b) Statement I is false but Statement II is true.  
 (c) Both Statement I and Statement II are false.  
 (d) Statement I is true but Statement II is false.
3. **Amongst the following, the total number of species NOT having eight electrons around central atom in its outer most shell, is**  
 $\text{NH}_3, \text{AlCl}_3, \text{BeCl}_2, \text{CCl}_4, \text{PCl}_5$  :  
 (a) 2 (b) 4  
 (c) 1 (d) 3 [NEET 2023]

4. Match List-I with List-II :

List-I (Molecules)	List-II (Shape)
(a) $\text{NH}_3$	(i) Square pyramidal
(b) $\text{ClF}_3$	(ii) Trigonal bipyramidal
(c) $\text{PCl}_5$	(iii) Trigonal pyramidal
(d) $\text{BrF}_5$	(iv) T-shape

Choose the correct answer from the options given below :

- (a) (a) - (ii), (b) - (iii), (c) - (iv), (d) - (i)  
 (b) (a) - (iii), (b) - (iv), (c) - (ii), (d) - (i)  
 (c) (a) - (iv), (b) - (iii), (c) - (i), (d) - (ii)  
 (d) (a) - (iii), (b) - (iv), (c) - (i), (d) - (ii) [NEET 2022]
5.  $\text{BF}_3$  is planar and electron deficient compound. Hybridisation and number of electrons around the central atom, respectively are  
 (a)  $sp^2$  and 8 (b)  $sp^3$  and 4  
 (c)  $sp^3$  and 6 (d)  $sp^2$  and 6 [NEET 2021]

6. Match List-I with List-II.

List-I	List-II
(a) $\text{PCl}_5$	(i) Square pyramidal
(b) $\text{SF}_6$	(ii) Trigonal planar
(c) $\text{BrF}_5$	(iii) Octahedral
(d) $\text{BF}_3$	(iv) Trigonal bipyramidal

Choose the correct answer from the options given below.

- (a) (a)-(iv), (b)-(iii), (c)-(ii), (d)-(i)  
 (b) (a)-(iv), (b)-(iii), (c)-(i), (d)-(ii)  
 (c) (a)-(ii), (b)-(iii), (c)-(iv), (d)-(i)  
 (d) (a)-(iii), (b)-(i), (c)-(iv), (d)-(ii) [NEET 2021]
7. Identify the wrongly matched pair.

Molecule	Shape or geometry of molecule
(a) $\text{PCl}_5$	Trigonal planar
(b) $\text{SF}_6$	Octahedral
(c) $\text{BeCl}_2$	Linear
(d) $\text{NH}_3$	Trigonal pyramidal

[NEET 2020 Phase II]

8. Match the coordination number and type of hybridisation with distribution of hybrid orbitals in space based on valence bond theory.

Coordination number and type of hybridisation	Distribution of hybrid orbitals in space
(A) 4, $sp^3$	(i) trigonal bipyramidal
(B) 4, $dsp^2$	(ii) octahedral
(C) 5, $sp^3d$	(iii) tetrahedral
(D) 6, $d^2sp^3$	(iv) square planar

Select the correct option:

- (a) (A)-(ii) (B)-(iii) (C)-(iv) (D)-(i)  
 (b) (A)-(iii) (B)-(iv) (C)-(i) (D)-(ii)  
 (c) (A)-(iv) (B)-(i) (C)-(ii) (D)-(iii)  
 (d) (A)-(iii) (B)-(i) (C)-(iv) (D)-(ii) [NEET 2020 Phase II]
9. The hybridisations of atomic orbitals of nitrogen in  $\text{NO}_2^+$ ,  $\text{NO}_3^-$  and  $\text{NH}_4^+$  respectively are :  
 (a)  $sp$ ,  $sp^3$  and  $sp^2$  (b)  $sp^2$ ,  $sp^3$  and  $sp$   
 (c)  $sp$ ,  $sp^2$  and  $sp^3$  (d)  $sp^2$ ,  $sp$  and  $sp^3$   
 [NEET 2016, Phase II]

10. Which of the following pairs of ions is isoelectronic and isostructural?  
 (a)  $\text{CO}_3^{2-}$ ,  $\text{NO}_3^-$  (b)  $\text{ClO}_3^-$ ,  $\text{CO}_3^{2-}$   
 (c)  $\text{SO}_3^{2-}$ ,  $\text{NO}_3^-$  (d)  $\text{ClO}_3^-$ ,  $\text{SO}_3^{2-}$   
 [NEET 2016, Phase II]
11. Which of the following pairs of *d*-orbitals will have electron density along the axes?  
 (a)  $d_{z^2}$ ,  $d_{xz}$  (b)  $d_{xz}$ ,  $d_{yz}$   
 (c)  $d_{z^2}$ ,  $d_{x^2-y^2}$  (d)  $d_{xy}$ ,  $d_{x^2-y^2}$   
 [NEET 2016, Phase II]
12. Consider the molecules  $\text{CH}_4$ ,  $\text{NH}_3$  and  $\text{H}_2\text{O}$  which of the given statements is false?  
 (a) The H—O—H bond angle in  $\text{H}_2\text{O}$  is smaller than the H—N—H bond angle in  $\text{NH}_3$ .  
 (b) The H—C—H bond angle in  $\text{CH}_4$  is larger than the H—N—H bond angle in  $\text{NH}_3$ .  
 (c) The H—C—H bond angle in  $\text{CH}_4$ , the H—N—H bond angle in  $\text{NH}_3$  and the H—O—H bond angle in  $\text{H}_2\text{O}$  are all greater than  $90^\circ$ .  
 (d) The H—O—H bond angle in  $\text{H}_2\text{O}$  is larger than the H—C—H bond angle in  $\text{CH}_4$ .  
 [NEET 2016, Phase I]
13. Maximum bond angle at nitrogen is present in which of the following?  
 (a)  $\text{NO}_2^+$  (b)  $\text{NO}_3^-$   
 (c)  $\text{NO}_2$  (d)  $\text{NO}_2^-$   
 [AIPMT 2015]
14. Which of the following does not have tetrahedral structure?  
 (a)  $\text{BH}_4^-$  (b)  $\text{BH}_3$   
 (c)  $\text{NH}_4^+$  (d)  $\text{H}_2\text{O}$
15. Which one of the following species has plane triangular shape  
 (a)  $\text{N}_3$  (b)  $\text{NO}_3^-$   
 (c)  $\text{NO}_2^-$  (d)  $\text{CO}_2$  [AIPMT 2014]
16. Which one of the following molecules contain no  $\pi$ -bond?  
 (a)  $\text{CO}_2$  (b)  $\text{H}_2\text{O}$   
 (c)  $\text{SO}_2$  (d)  $\text{NO}_2$  [NEET 2013]
17. Considering the state of hybridisation of carbon atoms, find out the molecule among the following which is linear?  
 (a)  $\text{CH}_3 - \text{C} \equiv \text{C} - \text{CH}_3$   
 (b)  $\text{CH}_2 = \text{CH} - \text{CH}_2 - \text{C} \equiv \text{CH}$   
 (c)  $\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3$   
 (d)  $\text{CH}_3 - \text{CH} = \text{CH} - \text{CH}_3$  [AIPMT 2011]
18. Which of the two ions from the list given below, have the geometry that is explained by the same hybridisation of orbitals.  
 $\text{NO}_2^-$ ,  $\text{NO}_3^-$ ,  $\text{NH}_2^-$ ,  $\text{NH}_4^+$ ,  $\text{SCN}^-$ ?  
 (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  $\text{NO}_3^-$   
 [AIPMT 2011]
19. In which of the following pairs of molecules/ions, the central atoms have  $sp^2$  hybridisation?  
 (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  $\text{NH}_2^-$   
 [AIPMT 2010]
20. The correct order of increasing bond angles in the following species is :  
 (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)  $\text{ClO}_2^- < \text{Cl}_2\text{O} < \text{ClO}_2$  [AIPMT 2010]
21. In which one of the following species the central atom has the type of hybridisation which is not the same as they present in the other three?  
 (a)  $\text{SF}_4$  (b)  $\text{I}_3^-$   
 (c)  $\text{SbCl}_5^{2-}$  (d)  $\text{PCl}_5$  [AIPMT 2010]
22. In which of the following molecules/ions  $\text{BF}_3$ ,  $\text{NO}_2^-$ ,  $\text{NH}_2^-$  and  $\text{H}_2\text{O}$ , the central atom is  $sp^2$  hybridised?  
 (a)  $\text{NO}_2^-$  and  $\text{NH}_2^-$  (b)  $\text{NH}_2^-$  and  $\text{H}_2\text{O}$   
 (c)  $\text{NO}_2^-$  and  $\text{H}_2\text{O}$  (d)  $\text{BF}_3$  and  $\text{NO}_2^-$   
 [AIPMT 2009]
23. The correct order of increasing bond angles in the following triatomic species is :  
 (a)  $\text{NO}_2^- < \text{NO}_2^+ < \text{NO}_2$   
 (b)  $\text{NO}_2^- < \text{NO}_2 < \text{NO}_2^+$   
 (c)  $\text{NO}_2^+ < \text{NO}_2 < \text{NO}_2^-$   
 (d)  $\text{NO}_2^+ < \text{NO}_2^- < \text{NO}_2$  [AIPMT 2008]
24. The angular shape of ozone molecule ( $\text{O}_3$ ) consists of:  
 (a) 1 sigma and 2 pi-bonds  
 (b) 2 sigma and 2 pi-bonds  
 (c) 1 sigma and 1 pi-bond  
 (d) 2 sigma and 1 pi-bond [AIPMT 2008]
25. In which of the following pairs, the two species are isostructural?  
 (a)  $\text{SF}_4$  and  $\text{XeF}_4$  (b)  $\text{SO}_3^{2-}$  and  $\text{NO}_3^-$   
 (c)  $\text{BF}_3$  and  $\text{NF}_3$  (d)  $\text{BrO}_3^-$  and  $\text{XeO}_3$   
 [AIPMT 2007]
26. Which of the following is not isostructural with  $\text{SiCl}_4$ ?  
 (a)  $\text{SCl}_4^{3-}$  (b)  $\text{SO}_4^{2-}$   
 (c)  $\text{PO}_4^{3-}$  (d)  $\text{NH}_4^+$  [AIPMT 2006]
27. Which of the following species has a linear shape?  
 (a)  $\text{NO}_2^-$  (b)  $\text{SO}_2$   
 (c)  $\text{NO}_2^+$  (d)  $\text{O}_3$  [AIPMT 2006]
28. In which of the following molecules all the bonds are not equal?  
 (a)  $\text{ClF}_3$  (b)  $\text{BF}_3$   
 (c)  $\text{AlF}_3$  (d)  $\text{NF}_3$  [AIPMT 2006]
29. Which of the following is not a correct statement?  
 (a) The electron deficient molecules can act as Lewis acids.  
 (b) The canonical structures have no real existence.  
 (c) Every  $\text{AB}_5$  molecule does in fact have square pyramid structure.  
 (d) Multiple bonds are always shorter than corresponding single bond. [AIPMT 2006]
30. Which of the following molecules has trigonal planar geometry?  
 (a)  $\text{IF}_3$  (b)  $\text{PCl}_3$   
 (c)  $\text{NH}_3$  (d)  $\text{BF}_3$  [AIPMT 2005]
31. In  $\text{BrF}_3$  molecule, the lone pairs occupy equatorial positions to minimise:  
 (a) Lone pair – bond pair repulsion  
 (b) Bond pair – bond pair repulsion  
 (c) Lone pair – lone pair repulsion and lone pair – bond pair repulsion  
 (d) lone pair – lone pair repulsion [AIPMT 2004]
32.  $\text{H}_2\text{O}$  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. [AIPMT 2004]

33. Among the following pairs which of the two species are not isostructural is :

- (a)  $\text{SiF}_4$  and  $\text{SF}_4$  (b)  $\text{IO}_3^-$  and  $\text{XeO}_3$   
 (c)  $\text{BH}_4^-$  and  $\text{NH}_4^+$  (d)  $\text{PF}_6^-$  and  $\text{SF}_6$

[AIPMT 2004]

34. In a regular octahedral molecule,  $\text{MX}_6$  the number of X—M—X bonds at  $180^\circ$  is :

- (a) 3 (b) 2  
 (c) 6 (d) 4

[AIPMT 2004]

35. Which of the following statement is not correct for sigma and pi-bonds formed between two carbon atoms?

- (a) Free rotation of atoms about a sigma bond is allowed but not in case of a pi-bond.  
 (b) Sigma bond determines the direction between carbon atoms but a pi-bond has no primary in this regard.  
 (c) Sigma bond is stronger than a pi-bond.  
 (d) Bond energies of sigma and pi-bonds are of the order of 264 kJ/mol and 347 kJ/mol respectively.

[AIPMT 2003]

36. In  $\text{NO}_3^-$  ion number of bond pair and lone pair of electrons on nitrogen atom are :

- (a) 2, 2 (b) 3, 1  
 (c) 1, 3 (d) 4, 0

[AIPMT 2002]

37. In which of the following bond angle is maximum ?

- (a)  $\text{NH}_3$  (b)  $\text{NH}_4^+$   
 (c)  $\text{PCl}_3$  (d)  $\text{SCl}_2$

[AIPMT 2001]

38. Which of the following two are isostructural?

- (a)  $\text{XeF}_2$  and  $\text{IF}_2^-$  (b)  $\text{NH}_3$  and  $\text{BF}_3$   
 (c)  $\text{CO}_3^{2-}$  and  $\text{SO}_3^{2-}$  (d)  $\text{PCl}_5$  and  $\text{ICl}_5$

[AIPMT 2001]

39. Main axis of a diatomic molecule is z, molecular orbital  $p_x$  and  $p_y$  overlaps to form, which of the following orbitals?

- (a)  $\pi$ -molecular orbital (b)  $\sigma$ -molecular orbital  
 (c)  $\delta$ -molecular orbital (d) No bond will form

[AIPMT 2001]

40. Which one of the following is planar?

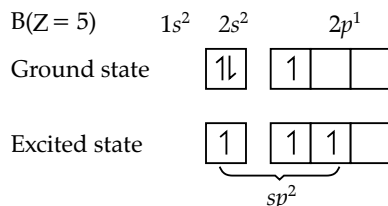
- (a)  $\text{XeF}_4$  (b)  $\text{XeO}_4$   
 (c)  $\text{XeO}_3\text{F}$  (d)  $\text{XeO}_3\text{F}_2$

[AIPMT 2000]

4. (b)

$\text{NH}_3$	$\text{ClF}_3$	$\text{PCl}_5$	$\text{BrF}_5$
bp = 3, lp = 1 Steric No. = 4 Hybridisation $-\text{sp}^3$	bp = 3, lp = 2 Steric No. = 5 Hybridisation $-\text{sp}^3\text{d}$	bp = 5, lp = 0 Steric No. = 5 Hybridisation $-\text{sp}^3\text{d}$	bp = 5, lp = 1 Steric No. = 6 Hybridisation $-\text{sp}^3\text{d}^2$
Trigonal pyramidal	T-shaped	Trigonal Bipyramidal	Square Pyramidal

5. (d)



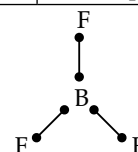
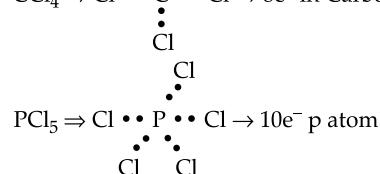
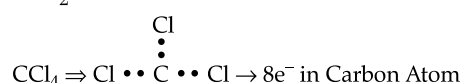
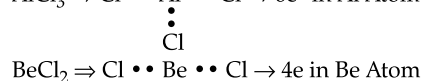
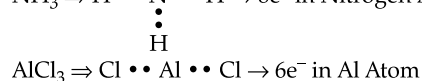
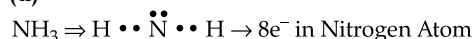
## Answer Key

1.	(a)	2.	(a)	3.	(d)	4.	(b)	5.	(d)	6.	(b)
7.	(a)	8.	(b)	9.	(c)	10.	(a,d)	11.	(c)	12.	(d)
13.	(a)	14.	(b)	15.	(b)	16.	(b)	17.	(a)	18.	(d)
19.	(b)	20.	(d)	21.	(c)	22.	(d)	23.	(b)	24.	(d)
25.	(d)	26.	(a)	27.	(c)	28.	(a)	29.	(c)	30.	(d)
31.	(d)	32.	(d)	33.	(a)	34.	(a)	35.	(d)	36.	(d)
37.	(b)	38.	(a)	39.	(d)	40.	(a)				

## Answers with Explanation

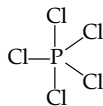
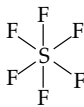
1. (a) Atoms combine either by transfer of valence electrons from one atom to another or by sharing of valence electrons to have an octet in their valence shell.
2. (a) While the lone pairs are localised on the central atom, each bonded pair is shared between two atoms. As a result, the lone pair electrons in a molecule occupy more space as compared to the bonding pairs of electrons. This results in greater repulsion between lone pairs of electrons as compared to the lone pair – bond pair and bond pair – bond pair repulsions.

3. (d)



Here, boron atom is  $\text{sp}^2$  hybridised and it contains 6 electrons around the central atom after the formation of bond with boron atom.

6. (b)

(a)  $\text{PCl}_5$  - (iv) Trigonal bipyramidal  
 $sp^3d$  hybridised(b)  $\text{SF}_6$  - (iii) Octahedral  
 $sp^3d^2$  hybridised(c)  $\text{BrF}_5$  - (i) Square pyramidal  
 $sp^3d^2$  hybridised(d)  $\text{BF}_3$  - (ii) Trigonal planar  
 $sp^2$  hybridised7. (a)  $\text{PCl}_5$  is trigonal bipyramidal.8. (b)  $sp^3$  is tetrahedral,  $dsp^2$  is square planar,  $sp^3d$  is trigonal bipyramidal,  $d^2sp^3$  is octahedral.

9. (c) Hybridisation of atomic orbitals of nitrogen in the given ions can be calculated by the formula as follows :

$$\text{Hybridisation} = \frac{1}{2}(\text{valence electrons} + \text{univalent atoms attached to central atom} - \text{charge on cation} + \text{charge on anion})$$
For  $\text{NO}_2^+$  =  $\frac{1}{2}(5 + 0 - 1 + 0) = 2$ Two hybrid orbitals means  $sp$ -hybridisationFor  $\text{NO}_3^-$  =  $\frac{1}{2}(5 + 0 - 0 + 1) = 3$ Three hybrid orbitals means  $sp^2$ -hybridisationFor  $\text{NH}_4^+$  =  $\frac{1}{2}(5 + 4 - 1 + 0) = 4$ 4 hybrid orbitals means  $sp^3$ -hybridisation10. (a, d)  $\text{CO}_3^{2-}$ , number of electrons  
=  $6 + 3(8) + 2 = 32$ 

According to VSEPR theory it is trigonal planar in shape.

 $\text{NO}_3^-$ , number of electrons =  $7 + 3(8) + 1 = 32$ 

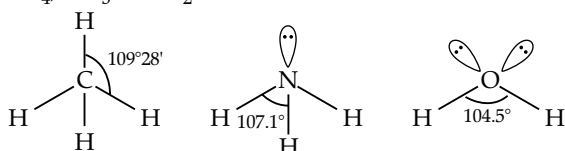
According to VSEPR theory it is trigonal planar in shape.

 $\text{ClO}_3^-$ , number of electrons  
=  $17 + 3(8) + 1 = 42$ 

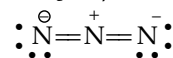
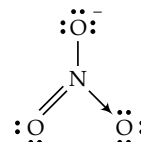
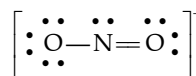
According to VSEPR theory, it is trigonal pyramidal in shape.

 $\text{SO}_3^{2-}$ , number of electrons  
=  $16 + 3(8) + 2 = 42$ 

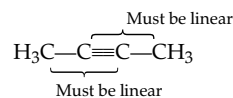
According to VSEPR theory, it is trigonal pyramidal in shape.

Thus,  $\text{CO}_3^{2-}$ ,  $\text{NO}_3^-$  and  $\text{ClO}_3^-$ ,  $\text{SO}_3^{2-}$  are isoelectronic11. (c)  $d_{xy}$ ,  $d_{yz}$  and  $d_{xz}$  orbital have electron density in between their corresponding axes while  $d_{x^2-y^2}$  and  $d_z^2$  have electron density along the corresponding axes, i.e.,  $d_{x^2-y^2}$  is along  $x$  and  $y$  axes while  $d_z^2$  along  $z$ -axis.12. (d) According to the VSEPR theory, the structures of  $\text{CH}_4$ ,  $\text{NH}_3$  and  $\text{H}_2\text{O}$  are as follows :

In  $\text{CH}_4$ , there is no lone pair of electrons thus it is perfectly tetrahedral in shape and has H—C—H bond angle of  $109^\circ 28'$  but in  $\text{NH}_3$  there is one lone pair which due to more repulsion with bond pairs of electrons pushes them more closer thus bond angle decreases to  $107^\circ$ . In  $\text{H}_2\text{O}$ , there are two lone pair of electrons which suppress the bond angle more to  $104.5^\circ$ .

13. (a)  $\text{NO}_2^+$  →  $sp$  hybridisation, i.e.,  $180^\circ$  bond angle. $\text{NO}_3^-$  →  $sp^2$  hybridisation, i.e.,  $120^\circ$  bond angle $\text{NO}_2^-$  →  $sp^2$  hybridisation with two bond pairs and one lone pair thus, bond angle is  $115^\circ$ . $\text{NO}_2$  →  $sp^2$  hybridisation with two bond pairs and one orbital contains one electron thus bond angle increases to  $134^\circ$ .Thus, maximum bond angle at nitrogen is of  $\text{NO}_2^+$ 14. (b)  $\text{BH}_4^-$ ,  $\text{NH}_4^+$  and  $\text{H}_2\text{O}$  all have four electron pairs thus, they have tetrahedral structure but  $\text{BH}_3$ , has three bond pairs of electrons with no lone pairs of electrons thus, it has trigonal planar shape.15. (b) Hybridisation of  $\text{N}_3$  is  $sp$  thus, it is linear in shape :Hybridisation of  $\text{NO}_3^-$  is  $sp^2$  thus, it is plane triangular in shapeHybridisation of  $\text{NO}_2^-$  is  $sp$ , thus it is linear in shapeHybridisation of  $\text{CO}_2$  is  $sp$ , thus it is linear in shape

$$= \frac{5}{4} = 1.25$$

16. (b) All the given oxides have oxygen atom with lone pair of electrons available to donate to the central atom which result in  $\pi$ -bond. But in  $\text{H}_2\text{O}$  the hydrogen atom attached to oxygen does not have vacant orbital to accept the lone pair of electrons from oxygen thus, it cannot form a  $\pi$ -bond while carbon, sulphur and nitrogen have vacant orbitals to form  $\pi$ -bond by accepting lone pair of electrons from oxygen atom.17. (a) The carbon atoms which have  $sp$  hybridisation form a linear molecule. Among the given compounds,  $\text{CH}_3\text{—C}\equiv\text{C—CH}_3$  has  $sp$  hybridised carbon atoms which are attached to  $sp^3$  hybridised carbon atoms. But the whole molecule is linear as shown below :18. (d)  $\text{NO}_2^-$  has  $sp^2$  hybridisation and trigonal planar geometry,  $\text{NO}_3^-$  has  $sp^2$  hybridisation and trigonal planar geometry,  $\text{NH}_2^-$  has  $sp^3$  hybridisation and tetrahedral geometry,  $\text{NH}_4^+$  has  $sp^3$  hybridisation and tetrahedral geometry and  $\text{SCN}^-$  has  $sp$  hybridisation and linear geometry.19. (b)  $\text{NO}_2^-$  is  $sp^2$  hybridised as it has two bond pairs and one lone pair of electrons.

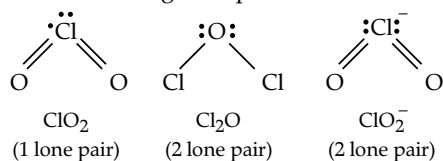
$\text{NH}_3$  is  $sp^3$  hybridised on it has three bond pairs and one lone pair of electrons.

$\text{BF}_3$  is  $sp^2$  hybridised as it has three bond pairs of electrons only.

$\text{NH}_2^-$  is  $sp^3$  hybridised as it has two bond pairs and lone pairs of electrons.  $\text{H}_2\text{O}$  is  $sp^3$  hybridised as it has two bond pairs and two lone pairs of electrons.

$\text{H}_2\text{O}$  is  $sp^3$  hybridised as it has two bond pairs and two lone pairs of electrons.

20. (d) Structure of the given species are as follows :



As  $\text{ClO}_2$  has only one lone pair of electrons thus due to lower lone pair – bond pair it has highest bond angle than  $\text{Cl}_2\text{O}$  and  $\text{ClO}_2^-$  which has two lone pairs of electrons.

Now, among  $\text{Cl}_2\text{O}$  and  $\text{ClO}_2^-$ , greater bond angle is for  $\text{Cl}_2\text{O}$  due to higher electronegativity of oxygen than chlorine. As electronegativity of central atom increases the bond pair of electrons are more closer to it and hence more repulsion between them to give a larger bond angle. Thus, the order of increasing bond angle is  $\text{ClO}_2^- < \text{Cl}_2\text{O} < \text{ClO}_2$

21. (c) Hybridisation can be evaluated from the formula  $H = \frac{1}{2} [\text{Valence electrons} + \text{Monovalent atoms} - \text{Positive charge} + \text{Negative charge}]$

For  $\text{SF}_4$ ,  $H = \frac{1}{2} [6 + 4 - 0 + 0] = 5$   
i.e.,  $sp^3d$  hybridisation

For  $\text{I}_3^-$ ,  $H = \frac{1}{2} [7 + 2 - 0 + 1] = 5$   
i.e.,  $sp^3d$  hybridisation

For  $\text{SbCl}_5^{2-}$ ,  $H = \frac{1}{2} [5 + 5 - 0 + 2] = 6$   
i.e.,  $sp^3d^2$  hybridisation

For  $\text{PCl}_5$ ,  $H = \frac{1}{2} [5 + 5 - 0 + 0] = 5$   
i.e.,  $sp^3d$  hybridisation

Thus,  $\text{SbCl}_5^{2-}$  has different hybridisation than other three species.

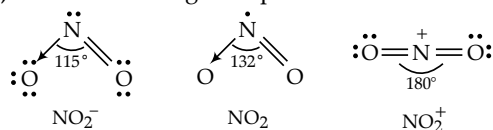
22. (d)  $\text{NO}_2^- \Rightarrow 2$  bond pairs + 1 lone pair  $\Rightarrow sp^2$  hybridisation

$\text{NH}_2^- \Rightarrow 2$  bond pairs + 2 lone pairs  
 $\Rightarrow sp^3$  hybridisation

$\text{H}_2\text{O} \Rightarrow 2$  bond pairs + 2 lone pairs  
 $\Rightarrow sp^3$  hybridisation

$\text{BF}_3 \Rightarrow 3$  bond pairs only  $\Rightarrow sp^2$  hybridisation

23. (b) Structure of the given species are as follows :

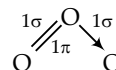


As  $\text{NO}_2^-$  has one lone pair of electrons on nitrogen atom thus, due to bond pair lone pair repulsion it decreases the bond angle O – N – O than in the  $\text{NO}_2$  molecule where there is no lone pair of electrons.  $\text{NO}_2^+$  is a linear molecule thus, it has highest O – N – O bond angle of 180°. Hence, order of increasing bond angle is



24. (d) Ozone has one double-bond and one single-bond.

The single-bond is the sigma-bond and in double-bond there is one sigma-bond and one pi-bond.



Thus, there are 2  $\sigma$ -bonds and 1 pi-bond in  $\text{O}_3$  molecule.

25. (d) Hybridisation of Br in  $\text{BrO}_3^-$

$$= \frac{1}{2}(7 + 0 - 0 + 1) = 4$$

Four hybrid orbital means  $sp^3$  hybridisation

Hybridisation of Xe in  $\text{XeO}_3$

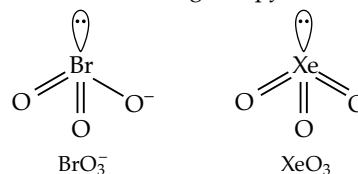
$$= \frac{1}{2}(8 + 0 - 0 + 0) = 4$$

Hybridisation of Xe in  $\text{XeO}_3$

$$= \frac{1}{2}(8 + 0 - 0 + 0) = 4$$

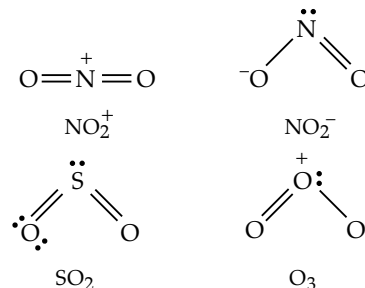
Four hybrid orbitals means  $sp^3$  hybridisation.

Thus, both  $\text{BrO}_3^-$  and  $\text{XeO}_3$  are  $sp^3$  hybridised with three bond pairs of electrons and one lone pair of electrons and results in trigonal pyramidal shape.

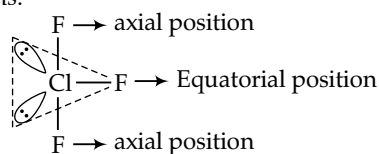


26. (a)  $\text{SCl}_4$  is not isostructural with  $\text{SiCl}_4$  as  $\text{SCl}_4$  has four bond pairs of electrons and one lone pair of electrons and due to this it has see-saw shape. While  $\text{SiCl}_4$ ,  $\text{SO}_4^{2-}$ ,  $\text{PO}_4^{3-}$  and  $\text{NH}_4^+$  all have tetrahedral geometry and are isostructural.

27. (c) Among the given species,  $\text{NO}_2^+$  has linear shape due to  $sp$  hybridisation of nitrogen atom. While  $\text{NO}_2^-$ ,  $\text{SO}_2$  and  $\text{O}_3$  have angular shape due to lone pair of electrons.



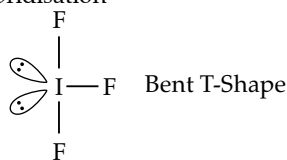
28. (a) The structure of  $\text{ClF}_3$  is trigonal bipyramid with three bond pairs of electrons and two lone pairs of electrons.



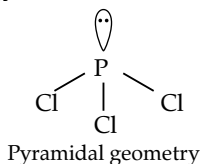
Thus, one Cl–F bond is equatorial bond and two Cl–F bonds are axial bonds and these two types of bonds are of different length. While  $\text{BF}_3$  and  $\text{AlF}_3$  have symmetrical trigonal planar structure and  $\text{NF}_3$  has pyramidal geometry with one lone pair and three similar N–F bonds.

29. (c)  $\text{AB}_5$  molecule has generally trigonal bipyramidal structure. Sometimes due to presence of lone pair of electrons the structure gets distorted.

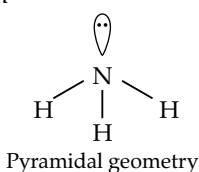
30. (d)  $\text{IF}_3$  has three bond pairs and two lone pairs, thus, it has  $sp^3d$  hybridisation



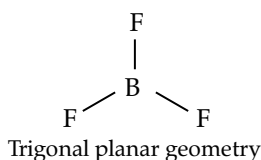
$\text{PCl}_3$  has three bond pairs and one lone pair thus, it has  $sp^3$  hybridisation



$\text{NH}_3$  has three bond pairs and one lone pair thus, it has  $sp^3$  hybridisation



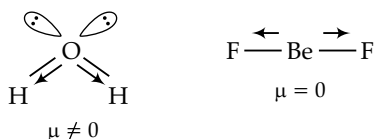
$\text{BF}_3$  has three bond pairs and no lone pair thus, it has  $sp^2$  hybridisation.



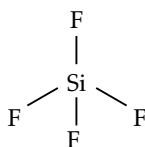
31. (d) Lone pair - Lone pair repulsion > lone pair - bond pair repulsion > bond pair - bond pair repulsion.

Thus, in  $\text{BrF}_3$  molecule where Br is  $sp^3d$  hybridised, i.e., trigonal bipyramidal geometry, the lone pairs of electrons are arranged on equatorial position as they are at maximum distance at these positions and hence they have minimum repulsion at these positions.

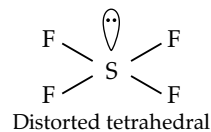
32. (d) In  $\text{H}_2\text{O}$  the central atom oxygen has two lone pairs of electrons and two bond pairs of electrons. Thus, the shape of  $\text{H}_2\text{O}$  is bent or V-shape. Thus, the two dipoles of H-O bonds have some resultant value as they are not exactly in the opposite direction to cancel out each other. While in  $\text{BeF}_2$ , there are two bond pairs on central atom Be, hence it is linear in shape. Thus, the two dipoles of bonds are exactly in opposite direction to each other and cancel each other to give net zero dipole moment.



33. (a) In  $\text{SiF}_4$  there are four bond pairs of electrons and no lone pair of electrons thus, it forms a tetrahedral molecule with  $sp^3$  hybridisation.

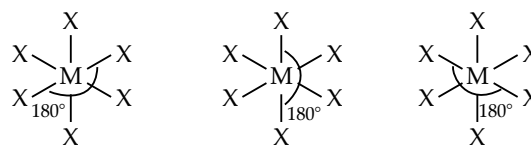


While in  $\text{SF}_4$ , sulphur atom has four bond pairs of electrons and one lone pair of electrons to give a  $sp^3d$  hybridised distorted tetrahedral molecule.



Thus,  $\text{SiF}_4$  and  $\text{SF}_4$  are not isostructural to each other.

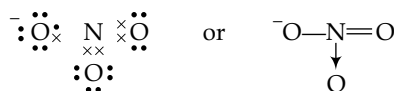
34. (a) The  $\text{MX}_6$  molecule with regular octahedral geometry is as follows :



Thus, there are 3 X—M—X bonds with bond angle  $180^\circ$ .

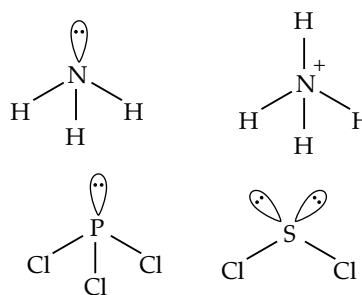
35. (d) Free rotation of atoms is possible with sigma bond and due to overlapping of orbital in pi-bond form above and below the plane of the atoms, the free rotation is not possible. Sigma bond determines the direction between carbon atoms and not a pi-bond. Sigma bond is stronger bond due to head to head axial overlap of orbital while pi-bond is weaker due to less efficient sideways overlapping. Bond energy of C—C sigma-bond is 347 kJ/mol and for C=C the bond energy is 619 kJ/mol.

36. (d) The structure of  $\text{NO}_3^-$  ion is as follows:



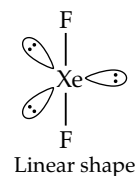
Hence, nitrogen atom has four bond pairs of electrons and zero lone pairs of electrons.

37. (b) Structures of the given molecules are as follows :

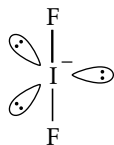


All the given molecules have same number of electron pairs thus, have similar geometry but in  $\text{NH}_3$ ,  $\text{PCl}_3$  and  $\text{SCl}_2$  due to presence of lone pairs of electrons on central atom there is more repulsion between lone pair of electrons and bond pair of electrons and hence the bond angle decreases in these cases. Therefore,  $\text{NH}_4^+$  has maximum bond angle.

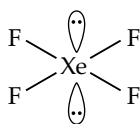
38. (a) In  $\text{XeF}_2$ , Xe is  $sp^3d$  hybridised and linear in shape due to three lone pairs on Xe atom.



In  $\text{IF}_2^-$  the I atom is also  $sp^3d$  hybridised in which there are two bond pairs of electrons and three lone pairs of electrons to form trigonal bipyramidal geometry in which lone pairs are in equatorial position. Thus, the shape of  $\text{IF}_2^-$  is linear as shown below.



39. (d) The molecular orbitals  $p_x$  and  $p_y$  are perpendicular to each other thus, they cannot overlap each other and hence, no bond will be formed.
40. (a)  $\text{XeF}_4$  has four bond pairs of electrons and two lone pairs of electrons *i.e.*, it involves  $sp^3d^2$  hybridisation of Xe atom. The two lone pairs of electrons are arranged so that they are far apart from each other so, these two lone pairs are positioned at axial positions at  $180^\circ$  angle. Thus, four Xe—F bonds are in a plane. Thus, the  $\text{XeF}_4$  molecule is a planar molecule.



### Topic 3: Previous Year's Questions

- Assertion A:** The bond order of helium is always zero.  
**Reason R:** The number of electrons in bonding molecular orbital and antibonding molecular orbital is equal.  
**In the light of the above statements, choose the most appropriate answer from the options given below:**

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.  
 (b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion.  
 (c) Assertion is correct, reason is incorrect.  
 (d) Assertion is incorrect, reason is correct.
- Assertion A:** Bond order of  $\text{O}_2^-$  is 1.5  
**Reason R:** The number of electrons in bonding molecular orbital and antibonding molecular orbital is equal.  
**In the light of the above statements, choose the most appropriate answer from the options given below:**

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.  
 (b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion.  
 (c) Assertion is correct, reason is incorrect.  
 (d) Assertion is incorrect, reason is correct.
- The correct order of energies of molecular orbitals of  $\text{N}_2$  molecule, is:**

(a)  $\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < \sigma 2p_z < (\pi 2p_x = \pi 2p_y) < (\pi^* 2p_x = \pi^* 2p_y) < \sigma^* 2p_z$   
 (b)  $\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < \sigma 2p_z < \sigma^* 2p_z < (\pi 2p_x = \pi 2p_y) < (\pi^* 2p_x = \pi^* 2p_y)$   
 (c)  $\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < (\pi 2p_x = \pi 2p_y) < (\pi^* 2p_x = \pi^* 2p_y) < \sigma 2p_z < \sigma^* 2p_z$   
 (d)  $\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < (\pi 2p_x = \pi 2p_y) < \sigma 2p_z < (\pi^* 2p_x = \pi^* 2p_y) < \sigma^* 2p_z$  [NEET 2023]
- The stability of  $\text{Cu}^{2+}$  is more than  $\text{Cu}^+$  salts in aqueous solution due to**

(a) enthalpy of atomisation.  
 (b) hydration energy.  
 (c) second ionisation enthalpy.  
 (d) first ionisation enthalpy. [NEET 2023]
- Which amongst the following is incorrect statement ?**

(a) The bond orders of  $\text{O}_2^+$ ,  $\text{O}_2$ ,  $\text{O}_2^-$  and  $\text{O}_2^{2-}$  are 2.5, 2, 1.5 and 1, respectively.  
 (b)  $\text{C}_2$  molecules have four electrons in its two degenerate  $\pi$  molecular orbitals.  
 (c)  $\text{H}_2^+$  ion has one electron.  
 (d)  $\text{O}_2^+$  ion is diamagnetic. [NEET 2022]
- Which one of the following diatomic molecular species has only  $\pi$  bonds according of Molecular Orbital Theory?**

(a)  $\text{N}_2$  (b)  $\text{C}_2$   
 (c)  $\text{Be}_2$  (d)  $\text{O}_3$  [NEET 2019]
- Which one of the following pairs of species have the same bond order?**

(a)  $\text{CO}$ ,  $\text{NO}$  (b)  $\text{O}_2$ ,  $\text{NO}^+$   
 (c)  $\text{CN}^-$ ,  $\text{CO}$  (d)  $\text{N}_2$ ,  $\text{O}_2^-$  [NEET 2017]
- Which one of the following compounds shows the presence of intramolecular hydrogen bond?**

(a)  $\text{H}_2\text{O}_2$   
 (b)  $\text{HCN}$   
 (c) Cellulose  
 (d) Concentrated acetic acid [NEET 2016, Phase 2]
- Decreasing order of stability of  $\text{O}_2$ ,  $\text{O}_2^-$ ,  $\text{O}_2^+$  and  $\text{O}_2^{2-}$  is :**

(a)  $\text{O}_2^{2-} > \text{O}_2^- > \text{O}_2 > \text{O}_2^+$   
 (b)  $\text{O}_2 > \text{O}_2^+ < \text{O}_2^{2-} > \text{O}_2^-$   
 (c)  $\text{O}_2^- > \text{O}_2^{2-} > \text{O}_2^+ > \text{O}_2$   
 (d)  $\text{O}_2^+ > \text{O}_2 > \text{O}_2^- > \text{O}_2^{2-}$  [AIPMT 2015]
- Which of the following is paramagnetic?**

(a)  $\text{CO}$  (b)  $\text{O}_2^-$   
 (c)  $\text{CN}^-$  (d)  $\text{NO}^+$  [NEET 2013]
- The pair of species with the same bond order is**

(a)  $\text{O}_2^{2-}$ ,  $\text{B}_2$  (b)  $\text{O}_2^+$ ,  $\text{NO}^+$   
 (c)  $\text{NO}$ ,  $\text{CO}$  (d)  $\text{N}_2$ ,  $\text{O}_2$  [NEET 2013]
- Which of the following has the minimum bond length?**

(a)  $\text{O}_2^-$  (b)  $\text{O}_2^-$   
 (c)  $\text{O}_2$  (d)  $\text{O}_2^+$  [AIPMT 2011]
- Which one of the following species does not exist under normal conditions?**

(a)  $\text{Be}_2^+$  (b)  $\text{Be}_2$   
 (c)  $\text{B}_2$  (d)  $\text{Li}_2$  [AIPMT 2010]
- What is the dominant intermolecular force on bond that must be overcome in converting liquid  $\text{CH}_3\text{OH}$  to gas?**

(a) Hydrogen bonding  
 (b) Dipole – Dipole interaction  
 (c) Covalent bonds  
 (d) London or dispersion forces [AIPMT 2009]
- According to Molecular Orbital Theory which of the following lists rank the nitrogen species in terms of increasing bond order?**

(a)  $\text{N}_2^- < \text{N}_2 < \text{N}_2^{2-}$  (b)  $\text{N}_2^{2-} < \text{N}_2^- < \text{N}_2$   
 (c)  $\text{N}_2 < \text{N}_2^{2-} < \text{N}_2^-$  (d)  $\text{N}_2^- < \text{N}_2^{2-} < \text{N}_2$  [AIPMT 2009]



16. Four diatomic species are listed below in different sequences. Which of these presents the correct order of their increasing bond order?  
 (a)  $O_2^- < NO < C_2^{2+} < He_2^+$   
 (b)  $NO < C_2^{2-} < O_2^- < He_2^+$   
 (c)  $C_2^{2-} < He_2^+ < NO < O_2^-$   
 (d)  $He_2^+ < O_2^- < NO < C_2^{2-}$  [AIPMT 2008]
17. The number of unpaired electrons in a paramagnetic diatomic molecule of an element with atomic number 16 is  
 (a) 2 (b) 3  
 (c) 4 (d) 1 [AIPMT 2006]
18. In  $X-H \cdots Y$ , X and Y both are electronegative elements, then :  
 (a) Electron density on X will increase and on H will decrease  
 (b) In both, electron density will increase  
 (c) In both, electron density will decrease  
 (d) On X, electron density will decrease and on H, electron density will increase. [AIPMT 2001]
19. Which one of the following is not paramagnetic?  
 (a) NO (b)  $N_2^+$   
 (c) CO (d)  $O_2^-$  [AIPMT 2000]
20. The relationship between the dissociation energy of  $N_2$  and  $N_2^+$  is :  
 (a) Dissociation energy of  $N_2^+ >$  dissociation energy of  $N_2$ .  
 (b) Dissociation energy of  $N_2 =$  dissociation energy of  $N_2^+$   
 (c) Dissociation energy of  $N_2 >$  dissociation energy of  $N_2^+$   
 (d) Dissociation energy of  $N_2$  can either be lower or higher than the dissociation energy of  $N_2^+$  [AIPMT 2000]
21. Which one of the following molecules will form a linear polymeric structure due to hydrogen bonding?  
 (a)  $NH_3$  (b)  $H_2O$   
 (c) HCl (d) HF [AIPMT 2000]
22. The number of anti-bonding electron pairs in  $O_2^{2-}$  molecular ion on the basis of molecular orbital theory is : (at. no. of O is 8)  
 (a) 5 (b) 2  
 (c) 4 (d) 6 [AIPMT 1998]
23. The high density of water compared to ice is due to :  
 (a) hydrogen bonding interactions  
 (b) dipole – dipole interactions  
 (c) dipole – induced dipole interactions  
 (d) induced dipole – induced dipole interactions [AIPMT 1997]
24.  $N_2$  and  $O_2$  are converted into mono anions  $N_2^-$  and  $O_2^-$  respectively. Which of the following statement is wrong?  
 (a) In  $N_2^-$ , the N—N bond weakens  
 (b) In  $O_2^-$ , O—O length increases  
 (c) In  $O_2^-$ , bond order decreases  
 (d)  $N_2^-$ , becomes diamagnetic [AIPMT 1997]
25. The ion that is isoelectronic with CO is :  
 (a)  $O_2^-$  (b)  $N_2^+$   
 (c)  $O_2^+$  (d)  $CN^-$  [AIPMT 1997]
26. The ground state electronic configuration of valence shell electrons in nitrogen molecule ( $N_2$ ) is written as  $KK, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2, \sigma 2p_z^2$   
 Bond order in nitrogen molecule is :  
 (a) 0 (b) 1  
 (c) 2 (d) 3 [AIPMT 1995]
27. The correct order of the O—O bond length in  $O_2$ ,  $H_2O_2$  and  $O_3$  is :  
 (a)  $O_2 > O_3 > H_2O_2$  (b)  $O_3 > H_2O_2 > O_2$   
 (c)  $O_2 > H_2O_2 > O_3$  (d)  $H_2O_2 > O_3 > O_2$  [AIPMT 1995]
28. Which of the following species is paramagnetic?  
 (a)  $O_2^{2-}$  (b) NO  
 (c) CO (d)  $CN^-$  [AIPMT 1995]

## Answer Key

1.	(a)	2.	(b)	3.	(d)	4.	(b)	5.	(d)	6.	(b)
7.	(c)	8.	(c)	9.	(d)	10.	(b)	11.	(a)	12.	(d)
13.	(b)	14.	(a)	15.	(b)	16.	(d)	17.	(a)	18.	(a)
19.	(c)	20.	(c)	21.	(d)	22.	(c)	23.	(a)	24.	(d)
25.	(d)	26.	(d)	27.	(d)	28.	(b)				

## Answers with Explanation

1. (a) B.O. (For Helium) =  $\frac{1}{2}(N_b - N_a) = \frac{1}{2}(2 - 2) = 0$
2. (b) Bond order of  $O_2^- = \frac{1}{2}[10 - 7] = \frac{3}{2} = 1.5$   
 Thus,  $O_2^-$  has the bond order of 1.5.
3. (d) For molecule up to  $N_2$  increasing order of energies in various molecular orbital is  
 $\sigma 1s, \sigma^* 1s, \sigma 2s, \sigma^* 2s, \pi 2p_x = \pi 2p_y, \sigma 2p_z, \pi^* 2p_x = \pi^* 2p_y, \sigma^* 2p_z$
4. (b) Stability of  $Cu^{2+}$  in more than  $Cu^+$  salts in aqueous solution. This is due to high hydration energy of  $Cu^{2+}$  ion than  $Cu^+$ .
5. (d) Molecular orbital electronic configuration of  $O_2$  is  $\sigma 1s^2 \sigma^* 1s^2, \sigma 2s^2 \sigma^* 2s^2, \sigma 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^1 = \pi^* 2p_y^1$   
 In  $O_2^+$ , the electronic configuration is:  
 $\sigma 1s^2 \sigma^* 1s^2, \sigma 2s^2 \sigma^* 2s^2, \sigma 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^1 = \pi^* 2p_y^1$   
 Since, there is one unpaired electron in  $O_2^+$ , so it is paramagnetic in nature.
6. (b) Molecular orbital configuration  $C_2$  is:  
 $\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2$
7. (c) For any species to have same bond order we can expect them to have same number of electrons. Calculating the number of electrons in various species :  
 $CO = (6 + 8) = 14$   
 $NO = (7 + 8) = 15$   
 $O_2 = (8 + 8) = 16$   
 $NO^+ = (7 + 8 - 1) = 14$   
 $CN^- = (6 + 7 + 1) = 14$   
 $O^- = (8 + 8 + 1) = 17$   
 $N_2 = (6 + 7 - 1) = 12$   
 $CN^-$  and  $CO$  have same number of electrons and have same bond order equal to 3.
8. (c) Cellulose is a polymer of glucose which are interlinked to each other. The chain of cellulose is stabilised by two hydrogen bond parallel to the

glycosidic linkage. Hydrogen bonding it is considered as intramolecular hydrogen bonding. While  $\text{H}_2\text{O}_2$ , HCN and  $\text{CH}_3\text{COOH}$  form intermolecular hydrogen bonding.

9. (d) Bond order of  $\text{O}_2 = \frac{1}{2}[8 - 4] = 2$

Bond order of  $\text{O}_2^- = \frac{1}{2}[8 - 5] = \frac{3}{2} = 1.5$

Bond order of  $\text{O}_2^{2-} = \frac{1}{2}[8 - 6] = 1$

Bond order of  $\text{O}_2^+ = \frac{1}{2}[8 - 3] = \frac{5}{2} = 2.5$

Stability is directly proportional to bond order thus, the correct order is  $\text{O}_2^+ > \text{O}_2 > \text{O}_2^- > \text{O}_2^{2-}$

10. (b) Electronic configuration of  $\text{CO}$ ,  $\text{CN}^-$  and  $\text{NO}^+$  (14 electrons)

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \pi 2p_x^2 = \pi 2p_y^2 < \sigma 2p_z^2$$

As no unpaired electrons. Thus, they are diamagnetic in nature.

Electronic configuration of  $\text{O}_2^-$  (17 electrons)

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \sigma 2p_z^2 < \pi 2p_x^2 = \pi 2p_y^2 < \pi^* 2p_x^1 = \pi^* 2p_y^1$$

It contains 1 unpaired electron thus, it is paramagnetic in nature.

11. (a) Electronic configuration of

$$\text{O}_2^{2-} = \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \sigma 2p_z^2 < \pi 2p_x^2 = \pi 2p_y^2 < \pi^* 2p_x^2 = \pi^* 2p_y^2$$

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

Electronic configuration of  $\text{B}_2$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \pi 2p_x^1 = \pi 2p_y^1$$

Bond order =  $\frac{1}{2}[6 - 4] = 1$

Thus, both  $\text{O}_2^{2-}$  and  $\text{B}_2$  have same bond order.

12. (d) Bond order of  $\text{O}_2^- = 1.5$ ,  $\text{O}_2 = 2$ ;  $\text{O}_2^+ = 2.5$

Now, bond length  $\propto \frac{1}{\text{bond order}}$

Thus, the species which has maximum bond order has minimum bond length therefore,  $\text{O}_2^+$  has minimum bond length.

13. (b) According to Molecular Orbital Theory, the electronic configuration of  $\text{Be}_2^+$  is as follows:

$$\text{Be}_2^+ \text{ (7 electrons)} = \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^1$$

Bond order =  $\frac{1}{2}[4 - 3] = \frac{1}{2}$ . Thus,  $\text{Be}_2^+$  can exist.

$$\text{For } \text{Be}_2 \text{ (8 electrons)} = \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2$$

Bond order =  $\frac{1}{2}[4 - 4] = 0$ . Thus,  $\text{Be}_2$  does not exist

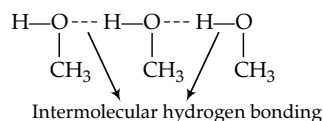
$$\text{For } \text{B}_2 \text{ (10 electrons)} = \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \pi 2p_x^1 = \pi 2p_y^1$$

Bond order =  $\frac{1}{2}[6 - 4] = 1$ . Thus,  $\text{B}_2$  can exist.

$$\text{For } \text{Li}_2 \text{ (6 electrons)} = \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2$$

Bond order =  $\frac{1}{2}[4 - 2] = 1$ . Thus,  $\text{Li}_2$  can exist.

14. (a)  $\text{CH}_3\text{OH}$  forms intermolecular hydrogen bonding shown as follows :



This hydrogen bonding must be overcome to convert liquid  $\text{CH}_3\text{OH}$  to a gas.

15. (b) Electronic configuration of  $\text{N}_2$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \pi 2p_x^2 = \pi 2p_y^2 < \sigma 2p_z^2$$

Bond order =  $\frac{1}{2}[10 - 4] = 3$

Electronic configuration of  $\text{N}_2^-$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \pi 2p_x^2 = \pi 2p_y^2 < \sigma 2p_z^2 < \pi^* 2p_x^1 = \pi^* 2p_y^1$$

Bond order =  $\frac{1}{2}[10 - 5] = 2.5$

Electronic configuration of  $\text{N}_2^{2-}$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \pi 2p_x^2 = \pi 2p_y^2 < \sigma 2p_z^2 < \pi^* 2p_x^2 = \pi^* 2p_y^2$$

Bond order =  $\frac{1}{2}[10 - 6] = 2$

Hence, the increasing bond order is

$$\text{N}_2^{2-} < \text{N}_2^- < \text{N}_2$$

16. (d) Electronic configuration of  $\text{O}_2^-$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \sigma 2p_z^2 < \pi 2p_x^2 = \pi 2p_y^2 < \pi^* 2p_x^1 = \pi^* 2p_y^1$$

Bond order =  $\frac{1}{2}[10 - 7] = 1.5$

Electronic configuration of  $\text{NO}$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \sigma 2p_z^2 < \pi 2p_x^2 = \pi 2p_y^2 < \pi^* 2p_x^1 < 2p_y^0$$

Bond order =  $\frac{1}{2}[10 - 5] = 2.5$

Electronic configuration of  $\text{C}_2^{2-}$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \pi 2p_x^2 = \pi 2p_y^2 < \sigma 2p_z^2$$

Bond order =  $\frac{1}{2}[10 - 4] = 3$

Electrons configuration of  $\text{He}_2^+ = \sigma 1s^2 < \sigma^* 1s^1$

Bond order =  $\frac{1}{2}[2 - 1] = 0.5$

17. (a) Diatomic molecule of element with atomic number 16 must have 32 electrons. Therefore, electronic configuration of diatomic molecule is as follows :

$$\begin{aligned} \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \pi 2p_x^2 = \pi 2p_y^2 < \sigma 2p_z^2 < \pi 3p_x^2 = \pi 3p_y^2 < \sigma 3p_z^2 < \pi^* 3p_x^1 = \pi^* 3p_y^1 \\ < \sigma^* 3s^2 < \sigma 3p_z^2 < \pi 3p_x^2 = \pi 3p_y^2 < \pi^* 3p_x^1 = \pi^* 3p_y^1 \end{aligned}$$

Thus, according to the above electronic configuration the diatomic molecule has 2 unpaired electrons.

18. (a) As X and Y both are electronegative elements thus both attracts the electron density from H thus, electron density on H decreases and on X it increases.

19. (c) Electronic configuration of NO

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \sigma 2p_z^2 < \pi 2p_x^2 \\ = \pi 2p_y^2 < \pi^* 2p_x^2 = \pi^* 2p_y^0$$

It contains one unpaired electron, hence, it is paramagnetic.

Electronic configuration of  $N_2^+$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \pi 2p_x^2 = \pi 2p_y^2 < \sigma 2p_z^1$$

It contains are unpaired electron, hence, it is paramagnetic.

Electronic configuration of CO

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \sigma 2p_z^2 < \pi 2p_x^2 = \pi 2p_y^2$$

It has no unpaired electron, hence, it is diamagnetic.

Electronic configuration of  $O_2^-$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \sigma 2p_z^2 < \pi 2p_x^2 \\ = \pi 2p_y^2 < \pi^* 2p_x^2 < \pi^* 2p_y^1$$

It contains one unpaired electron, hence, it is paramagnetic.

20. (c) For  $N_2$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \pi 2p_x^2 = \pi 2p_y^2 < \sigma 2p_z^2$$

$$\text{Bond order} = \frac{1}{2}[10 - 4] = 3$$

$$\text{For } N_2^+ = \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \pi 2p_x^2 \\ = \pi 2p_y^2 < \sigma 2p_z^1$$

$$\text{Bond order} = \frac{1}{2}[9 - 4] = 2.5$$

Now, dissociation energy is more for the species which have higher bond order. Thus,  $N_2$  has higher dissociation energy.

21. (d)  $NH_3$  and  $H_2O$  are non-linear molecules. Among HCl and HF, a linear polymeric structure is formed by HF molecules shown as follows :



↓

Hydrogen bonding

22. (c) According to Molecular Orbital Theory, electronic configuration of  $O_2^{2-}$  is as follows :

$$\sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \sigma 2p_z^2 < \pi 2p_x^2 \\ = \pi 2p_y^2 < \pi^* 2p_x^2 = \pi^* 2p_y^2$$

Thus, number of anti bonding electron pairs is 4.

23. (a) Water molecule due to presence of hydrogen atom attached to electronegative oxygen atom shows hydrogen bonding between their molecules. When it exists in liquid state then their molecules are close to each other but when it condenses to ice then the water

molecules are not too close and it has open structure having large spaces between the water molecules thus, the density of ice is less than that of liquid water.

24. (d) Electronic configuration of  $N_2$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \pi 2p_x^2 = \pi 2p_y^2 < \sigma 2p_z^2$$

Electronic configuration of  $O_2$

$$= \sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \sigma 2p_z^2 < \pi 2p_x^2 \\ = \pi 2p_y^2 < \pi^* 2p_x^1 < \pi^* 2p_y^1$$

When  $N_2^-$  is formed then one extra electron is added to anti bonding orbital thus, the bond weakens as one single unpaired electron is added to anti bonding orbitals. Thus, it is paramagnetic and not diamagnetic.

When  $O_2^-$  is formed then one extra electron is added to anti bonding orbital thus, bond order decreases and bond length increases.

25. (d)  $CO = 6 + 8 = 14$  electrons

$$O_2^- = 8 + 8 + 1 = 17 \text{ electrons;}$$

$$N_2^+ = 7 + 7 - 1 = 13 \text{ electrons}$$

$$O_2^+ = 8 + 8 - 1 = 15 \text{ electrons;}$$

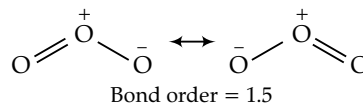
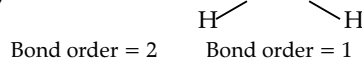
$$CN^- = 6 + 7 + 1 = 14 \text{ electrons}$$

26. (d) Bond order of

$$N_2 = \frac{1}{2}[N_b - N_a]$$

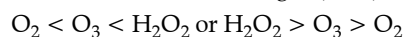
$$= \frac{1}{2}[8 - 2] = \frac{6}{2} = 3$$

27. (d)  $O=O$



$$\text{As bond length} \propto \frac{1}{\text{Bond order}}$$

Hence, order of bond length (0-0) is



28. (b) Electronic configuration of NO (7 + 8 = 15 electrons) is as follows :

$$\sigma 1s^2 < \sigma^* 1s^2 < \sigma 2s^2 < \sigma^* 2s^2 < \sigma 2p_z^2 < \pi 2p_x^2 \\ = \pi 2p_y^2 < \pi^* 2p_x^2 < \pi^* 2p_y^0$$

Thus, it contains one unpaired electron in  $\pi^* 2p_x$  orbital thus, it is paramagnetic in nature.

