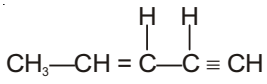
Chapter 4

Chemical Bonding and Molecular Structure

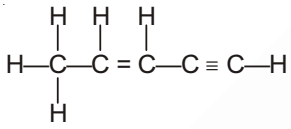
Solutions (Set-1)

Very Short Answer Type Questions :

1. What is total number of sigma and pi bonds in the following structure?



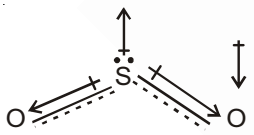
Sol.



It contains 10 sigma (σ) bonds and 3 pi (π) bonds.

2. Sketch the bond moments and resultant dipole moment in SO_2.

Sol.



3. Define ionic bond.

Sol. An ionic bond is a link formed as a result of the electrostatic attraction between the positive and negative ions.

4. Define a covalent bond.

Sol. A covalent bond is a chemical bond which is formed by the sharing of a pair of electrons between atoms.

5. Give reason, sucrose is a covalent compound but it is quite soluble in water.

Sol. The molecule of sucrose contains many –OH groups and hence are capable of forming H–bond with water.

6. Why hydrogen bonding does not exist in HCl though chlorine is quite electronegative?

Sol. This is due to large size of Cl–atom.

7. Why o-nitrophenol has lower boiling point than p-nitrophenol?

Sol. *p*-nitrophenol has higher boiling point due to intermolecular H-bonding.

8. Which *d*-orbital is involved in dsp^2 hybridisation?

Sol. $d_{x^2-y^2}$. This is because its four lobes lie along the x-axis and y-axis. The two *p*-orbitals can combine along these axes.

9. Define electrovalency.

Sol. The electrovalency is defined as the number of electron lost or gained by an atom. It is equal to the number of unit charge on the ion.

10. Write the electronic configuration and Lewis symbol for N^{3-}.

Sol. The electronic configuration of the N^{3-} ion is $1s^2\ 2s^2\ 2p^6$ and its Lewis symbol is $\left[:\ddot{N}:\right]^{3-}$.

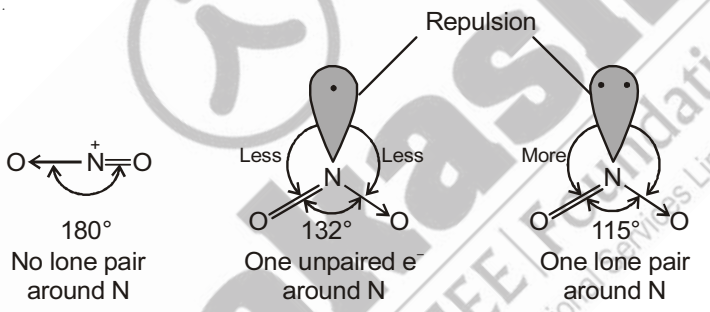
Short Answer Type Questions :

11. How do bond length of C–H bond differ in C_2H_6, C_2H_4 and C_2H_2?

Sol. Hybrid states of C atom in C_2H_6, C_2H_4 and C_2H_2 are respectively sp^3, sp^2 and sp. C–H bonds in C_2H_6, C_2H_4 and C_2H_2 are respectively $sp^3 - s\sigma$, $sp^2 - s\sigma$ and $sp - s\sigma$ bond. Since size of hybrid orbitals varies as $sp^3 > sp^2 > sp$. Therefore, $(sp^3 - s)\ \sigma > (sp^2 - s)\ \sigma > (sp - s)\ \sigma$ bond.

12. Arrange the following in order of decreasing bond angle around N atom, NO_2, NO_2^+, NO_2^-.

Sol. NO_2^+ is linear as there is no lone pair on N atom. NO_2 and NO_2^-, both have bent shape. In NO_2, there is one odd electron on N atom but in NO_2^- there is one lone pair of electron on N atom.



Bond angle around N decreases

13. How is VB theory different from Lewis concept in regard to the formation of covalent bond?

Sol. (i) Lewis concept considers the formation of covalent bond by mutual sharing of electrons. VB theory considers the formation of covalent bond by overlap of half filled atomic orbitals.

(ii) Lewis concept does not provide explanation for different shapes of molecules but VB theory does explain molecular shapes.

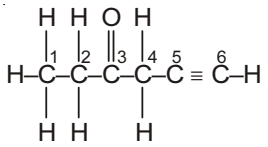
(iii) Lewis concept does not explain the bond strength but VB theory is able to explain it.

14. Consider the structure $\overset{1}{C}H_3\overset{2}{C}H_2\overset{3}{C}O\overset{4}{C}H_2\overset{5}{C}\equiv\overset{6}{C}H$ and answer the following:

(i) Which atoms in the structure have same hybrid state?

(ii) Arrange the atoms C_2, C_3, C_5 in decreasing order of s-character of bonding orbitals.

Sol. The given structure is



The hybrid states of various carbon atoms is

C_1 (sp^3) ; C_2 (sp^3) ; C_3 (sp^2) ; C_4 (sp^3) ; C_5 (sp) ; C_6 (sp)

(i) C_1, C_2, C_4 atoms have sp^3 hybrid state; C_5, C_6 atoms have sp hybrid state.

(ii) Decreasing order of *s*-character is $C_5 > C_3 > C_2$.

15. Arrange the following species in order of decreasing bond angles around the central atom in each set

(i) CH_4, NH_3, H_2O, BCl_3, C_2H_2

(ii) NH_3, NH_2^-, NH_4^+

(iii) H_2O, H_2Se, H_2Te, H_2S, $ZnCl_2$, CO_2.

Sol. (i) C_2H_2 (180°) > BCl_3 (120°) > CH_4 (109°.28′) > NH_3 (107°) > H_2O (104.5°).

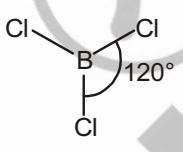
(ii) NH_4^+ (109°.28′) > NH_3 (107°) > NH_2^- (≈ 105°).

(iii) CO_2 (180°) > H_2O (104.5°) > H_2S (92°) > H_2Se (90.5°) > H_2Te (≈ 90°).

16. BF_3 is planar but anhydrous BF_4^- is tetrahedral. Explain.

Sol. In BF_3 molecule, B atom assumes sp^2 hybrid state. The three sp^2 hybrid orbitals are used to form sigma bonds with 3 fluorine atoms to give trigonal planar structure.

In anhydrous BF_4^-, boron atom is sp^3 hybridised, so it is tetrahedral.



Trigonal planar structure of BCl_3

Dimer of $AlCl_3$

17. (i) How bond energy varies from N_2^- to N_2^+ and why?

(ii) On the basis of molecular orbital theory what is similar between

(a) F_2, O_2^{--}

(b) CO, N_2, NO^+

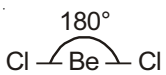
Sol. (i) Bond energy of N_2^+ ≈ bond energy of N_2^-. This is because they have the same bond order (N_2^- is slightly less stable and hence has less bond energy than N_2^+ due to presence of greater number of electrons in the antibonding molecular orbitals).

(ii) (a) Same bond order and bond length.

(b) Same bond order and bond length.

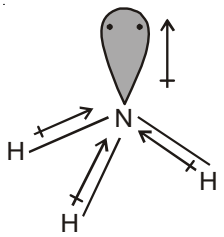
18. What is the hybrid state and shape of $BeCl_2$?

Sol. In the vapour state at high temperature, $BeCl_2$ exists as linear molecule, Cl–Be–Cl. The hybridization of the central atom is *sp*.

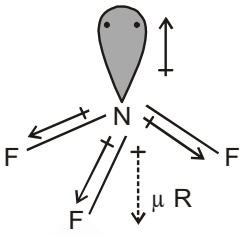


19. Out of NH_3 and NF_3 which has more polarity. Give reasons using diagram of bond moments.

Sol. NH_3 is more reactive than NF_3 because NH_3 is more polar as compared to NF_3. The higher dipole moment of NH_3 is because of the fact that in NH_3 the three N–H bond moments reinforce the lone pair moment while in NF_3, the three N–F bond moments oppose the lone pair moment.



$\mu = 4.9 \times 10^{-30}$ Cm



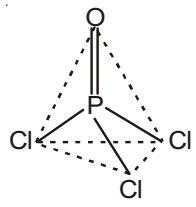
$\mu = 0.8 \times 10^{-30}$ Cm

20. Draw the structure of :

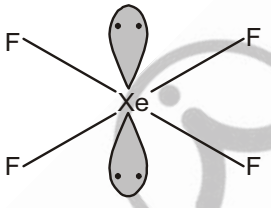
(i) $POCl_3$

(ii) XeF_4

Sol.



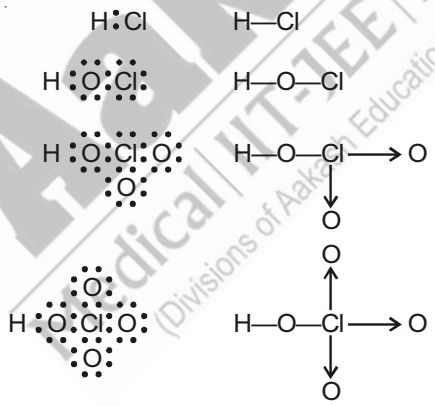
Tetrahedral



Square planar

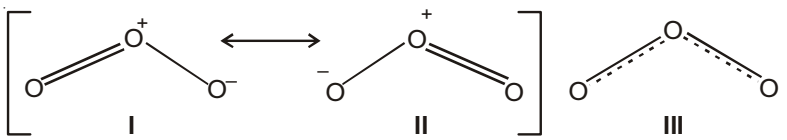
21. Represent the bonding in HCl (hydrochloric acid), HClO (hypochlorous acid); $HClO_3$ (Chloric acid) and $HClO_4$ (Perchloric acid) in terms of Lewis dot representation.

Sol.



22. Give two resonating structures of ozone which satisfy octet rule? Also give the probable hybrid structure.

Sol. The resonating structure of O_3 molecule which satisfy the octet rule are structure **I** and structure **II**. The probable hybrid structure is represented by **III**.



I **II** **III**

Resonating structure **Hybrid structure**

23. (i) Why melting point of MgO (2800°C) is much higher than that of BaO (1920°C)?

(ii) Why solubility of $MgCl_2$ much greater than that of MgF_2?

(iii) Why AlF_3 is a high melting solid whereas SiF_4 is a gas?

Sol. (i) Lattice enthalpy of MgO is higher than that of BaO due to relatively larger size of Ba^{2+} ion.

(ii) Size of Cl^- ions is larger than F^- ions consequently, Lattice enthalpy of $MgCl_2$ is smaller than that of MgF_2. Due to smaller value of $\Delta_L H°$ of $MgCl_2$, its solubility in water is relatively more.

(iii) AlF_3 is ionic compound while SiF_4 is a non polar covalent compound. Hence interparticle forces in AlF_3 are quite strong.

24. (i) Arrange the following in order of increasing bond strength F_2, N_2, O_2, Cl_2.

(ii) Give two resonating structures of N_2O which satisfy octet rule.

Sol. (i) $F_2 > Cl_2 < O_2 < N_2$.

O_2 has double bond while N_2 has triple bond. The bond strength of F_2 is smaller because the presence of three lone pairs around each F atom cause repulsive interactions. It is because of very small size of F atom.

(ii) The two resonating structure of N_2O are

25. Using VSEPR theory identify the type of hybridisation and draw the structure of OF_2.

Sol. The Lewis dot structure of OF_2 is

Since O is surrounded by 2 bond pair and 2 lone pair. Hence, arrangement of lone pair and bond pair should be tetrahedral. Therefore hybrid state of O should be sp^3.

26. (i) Why $BeCl_2$ is linear molecule while $SnCl_2$ is angular?

(ii) What type of ionic species constitute the compound $CsBr_3$?

Sol. (i) Be is surrounded by only two bond pairs while in $SnCl_2$, Sn is surrounded by two bond pairs as well as one lone pairs.

(ii) The ionic species constituting $CsBr_3$ and Cs^+ and tribromide ions (Br_3^-).

27. (i) KHF_2 is known but $KHCl_2$ is not known. Explain.

(ii) Which of the following has highest bond angle?

H_2O, CO_2, NH_3, CH_4

(iii) Among N_2O, SO_2, I_3^+ and I_3^-, which are linear species?

Sol. (i) In KHF_2, the ions present are K^+ and HF_2^-. The HF_2^- ion is formed by combination of H–F and F^- ions due to H-bonding. [F……H–F]$^-$. The corresponding $[HCl_2]^-$ ion is not possible because Cl^- ion cannot form effective H-bonding with HCl.

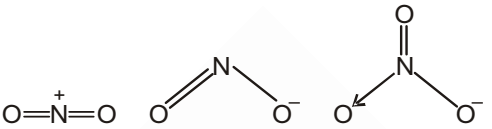
(ii) Highest bond angle is in CO_2 *i.e.*, 180°.

(iii) N_2O and I_3^- are linear species.

28. Arrange the following in order of (i) increasing N–O bond length (ii) Increasing bond angles. Also Give reasons: NO_2^+, NO_2^-, NO_3^-.

Sol. Type of hybridisation of central atom, *i.e.*, N atom in NO_2^+ is *sp* hybridised while in NO_2^- and NO_3^-, it is sp^2 hybridized.

Their structures are :



Bond angle	180°	>	132°	>	120°
Bond order	2		$\frac{2+1}{2} = 1.5$		$\frac{2+1+1}{3} = 1.33$
Bond length	NO_2^+	<	NO_2^-	<	NO_3^-

29. Which of the two, peroxide ion or superoxide ion has larger bond length?

Sol. The bond length in a molecule is dependent on bond order. The higher is the bond order, smaller will be the bond length.

Peroxide ion, O_2^{2-}

O_2^{2-} : K K $(\sigma 2s)^2(\sigma^* 2s)^2(\sigma 2p_z)^2(\pi 2p_y)^2(\pi 2p_x)^2(\pi^* 2p_y)^2(\pi^* 2p_x)^2$

Bond order = $\frac{8-6}{2} = 1$

Superoxide ion, O_2^-

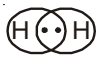
O_2^- : K K $(\sigma 2s)^2(\sigma^* 2s)^2(\sigma 2p_z)^2(\pi 2p_y)^2(\pi 2p_x)^2(\pi^* 2p_y)^2(\pi^* 2p_x)^1$

Bond order = $\frac{8-5}{2} = 1.5$

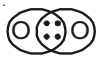
Bond order of superoxide ion is higher than peroxide ion, hence bond length of peroxide ion is larger.

30. Define a single covalent bond and double covalent bond.

Sol. A single covalent bond has only one shared pair of electrons between the two atoms.

For example : 

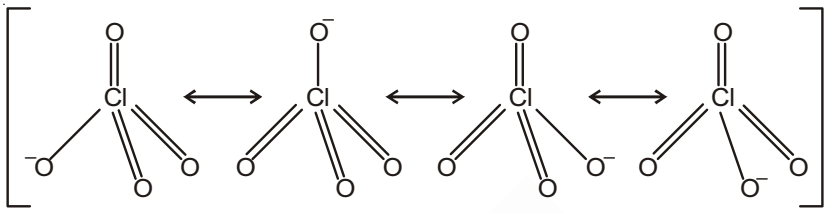
If two atoms share two pairs of electrons, the covalent bond between them is called a double covalent bond.

For example : 

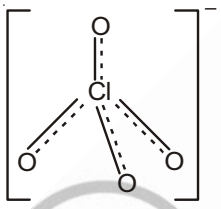
Long Answer Type Questions :

31. All the chlorine-oxygen bond distances in ClO_4^- are 144 pm. What explanation can be given for this?

Sol. ClO_4^- ion is resonance hybrid of the following structures:



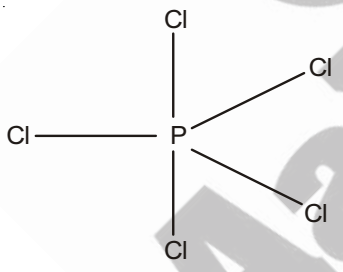
The probable hybrid structure is



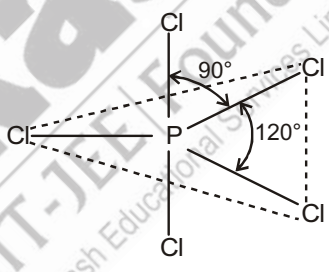
All the Cl–O bonds are equivalent having bond order = 1.75.

32. Using VSEPR theory draw molecular structure of PCl_5 and BrF_5 molecules.

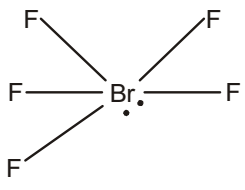
Sol.



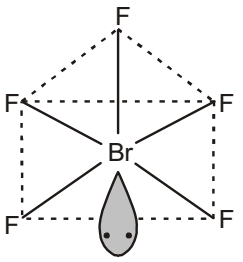
P atom has five bond pairs around it which assume trigonal bipyramidal arrangement.



Trigonal bipyramidal geometry angle around P = 90° and 120°. Axial P—Cl bonds are longer than equatorial bonds.



Br atom has 5 bond pairs and 1 lone pair around it. Hence five F atoms and one lone pair assume octahedral arrangement giving square pyramidal shape.



Square pyramidal shape

33. Arrange the following compound in the increasing order of bond length of O–O bond. O_2, $O_2(AsF_6)$, KO_2. Explain on the basis of ground state electronic configuration of dioxygen in these molecules.

Sol. In $O_2(AsF_6)$, oxygen is present as O_2^+ while in KO_2 it is present as O_2^- ions. Now M.O. electronic configuration of O_2, O_2^+ and O_2^- are

$$O_2 : K\,K\,(\sigma 2s)^2(\sigma^* 2s)^2(\sigma 2p_z)^2(\pi 2p_x)^2(\pi 2p_y)^2(\pi^* 2p_x)^1(\pi^* 2p_y)^1$$

Bond order = $(8 - 4) \times \frac{1}{2} = 2$

$$O_2^+ : K\,K\,(\sigma 2s)^2(\sigma^* 2s)^2(\sigma 2p_z)^2(\pi 2p_x)^2(\pi 2p_y)^2(\pi^* 2p_x)^1$$

Bond order = $(8 - 3) \times \frac{1}{2} = 2.5$

$$O_2^- : K\,K\,(\sigma 2s)^2(\sigma^* 2s)^2(\sigma 2p_z)^2(\pi 2p_x)^2(\pi 2p_y)^2(\pi^* 2p_x)^2(\pi^* 2p_y)^1$$

Bond order = $(8 - 5) \times \frac{1}{2} = 1.5$

Thus, increasing order of O–O bond length is

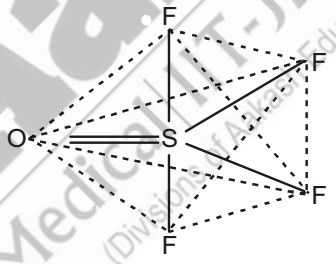
$KO_2 > O_2(AsF_6) > O_2$.

34. Using VSEPR theory draw the molecular structure of

(i) SOF_4

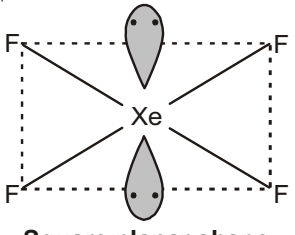
(ii) XeF_4 molecules.

Sol. (i) In OSF_4, there are four F atoms bonded to sulphur by σ bonds while O atom is bonded to sulphur by double bond. Thus the molecule adopts trigonal bipyramidal arrangement with S = O bond taking the equatorial position because of the relatively smaller repulsive interactions.



Trigonal bipyramidal arrangement

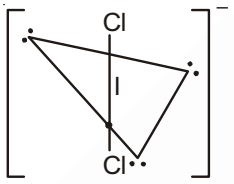
(ii) In XeF_4, Xe atom is surrounded by four bond pairs and two lone pairs. These four F atoms and two lone pairs adopt octahedral arrangement giving square, planar shape to the molecule. The lone pairs occupy diagonally opposite arrangement.



Square planar shape

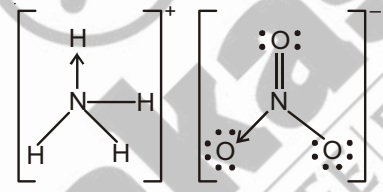
35. Explain the shape of ICl_2^- ion.

Sol. Type of hybridisation, H = $\frac{1}{2}$ [7 + 2 – 0 + 1] = 5, *i.e.*, sp^3d hybridisation. The central atom I undergoes sp^3d hybridization. The electronic configuration of I atom in ground state is $5s^2\ 5p_x^2\ 5p_y^2\ 5p_z^1\ 5d^0$. It undergoes hybridization giving 5 hybrid orbitals. Three hybrid orbitals contain lone pair of electrons each and occupy equatorial positions of the trigonal bipyramid. One hybrid orbital is half filled, it overlaps with an orbital of chlorine atom and forms a covalent bond. One hybrid empty orbital accepts an electron pair from Cl ion to form a co-ordinate bond. The Cl atoms are present on axial positions.



36. Indicate the type of bonds present in NH_4NO_3 and state mode of hybridization of two N-atoms in it.

Sol. NH_4NO_3 is an ionic compound in which cation is NH_4^+ ion and anion is NO_3^- ion. In NH_4^+ ion, three covalent bonds and one co-ordinate bond is present. The nitrogen is in sp^3 hybrid state, *i.e.*, the species is tetrahedral. In NO_3^-, nitrogen is in sp^3 hybrid state, *i.e.*, the species is trigonal planar. One oxygen is linked by a double bond, other by a covalent bond and third by a co-ordinate bond.

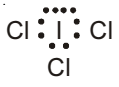


37. Apply VSEPR theory to predict the shapes of SF_4, ICl_3, $PbCl_2$ and NH_4^+.

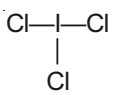
Sol. The Lewis structure of SF_4 is :

S atom is surrounded by five electron pairs (4 bonded and one lone pair) thus, the geometry is trigonal bipyramidal. The actual shape is see-saw.

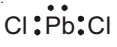
The Lewis structure of ICl_3 is :



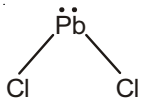
Iodine is surrounded by five electron pairs (3 bonded and two lone pairs). Thus, the geometry is trigonal bipyramidal. The actual shape is T-shape.



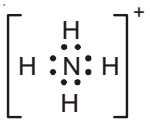
The Lewis structure of $PbCl_2$ is :



Pb is surrounded by three electron pairs (2 bonded and one lone pairs). Thus, the geometry is trigonal planar. The actual shape is V-shape, *i.e.*, bent structure.



The Lewis structure of NH_4^+ ion is :



Nitrogen is surrounded by four bonded pairs. The shape is thus tetrahedral.

38. Draw Lewis structures for

(i) H_2CO_3

(ii) SF_6

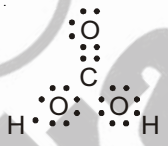
(iii) PF_5

(iv) IF_7

(v) CS_2.

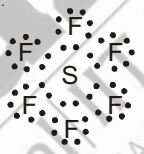
Is the octet rule obeyed in these cases?

Sol. (i) H_2CO_3



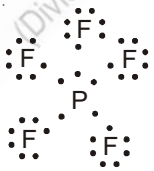
C and all three O atoms obeying octet rule. Only H-atom has two valence electrons.

(ii) SF_6



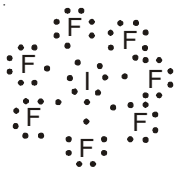
S-atom is not obeying the octet rule. S atom has 12 valence electrons.

(iii) PF_5



Phosphorus has an expanded octet and tatal 10 electrons.

(iv) IF_7



Iodine is not obeying the octet rule. It has total 14 electrons.

(v) CS_2

CS_2 is obeying the Lewis octet rule.

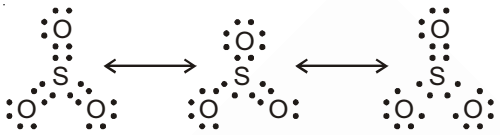
39. Write resonance structures for

(i) SO_3

(ii) NO_2

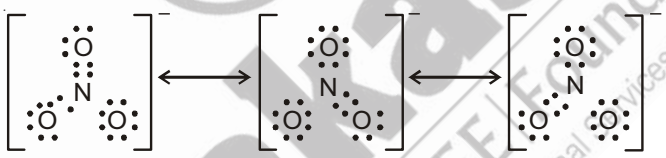
(iii) NO_3.

Sol. (i) SO_3



(ii) NO_2

(iii) NO_3^-



40. What do you understand by dipole moment? Give its SI units.

Sol. A dipole consists of a positive and negative charge (equal in magnitude) separated by a distance within a molecule. Dipole moment is defined as the product of the magnitude of charge on any one of the atoms and the distance between them.

Dipole moment is represented by μ (mu).

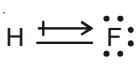
μ = charge (q) × distance of separation (r)

Dipole moment is usually expressed in debye units (D). The conversion factor is

$1D = 3.33564 \times 10^{-30}$ Cm

where C is coulomb and m is metre.

Dipole moment is a vector quantity and is depicted by a small arrow with tail on the positive centre and head pointing towards the negative centre. For example the dipole moment of HF may be represented as :



The shift in electron density is symbolised by crossed arrow ($\overset{+}{\longleftrightarrow}$) above the Lewis structure to indicate the direction of the shift.

41. Predict whether each of the following molecule is polar or non-polar.

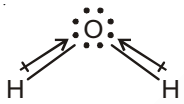
(i) H_2O

(ii) CCl_4

(iii) PCl_5

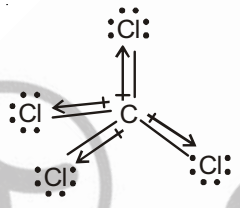
(iv) BF_3.

Sol. (i) **H_2O**



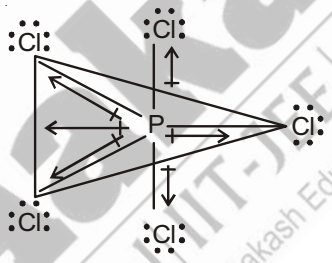
The bond dipole point from the H atoms towards the more electronegative O atom. The H_2O molecule has a non zero dipole moment, hence water molecule is polar.

(ii) **CCl_4 :** Tetrahedral in shape. The Lewis diagram is



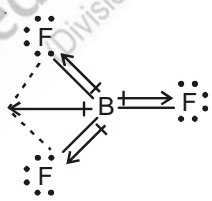
The molecule has a zero dipole moment and hence is a non-polar molecule.

(iii) **PCl_5 :** Trigonal bipyramid. The Lewis structure is



The net dipole moment is zero. So, the molecule is non-polar.

(iv) **BF_3 :** Trigonal planar

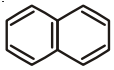


The net dipole moment is zero. So, the molecule is non-polar.

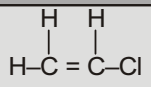
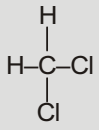
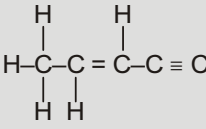
42. What is the total number of sigma bonds and pi-bonds in the following molecules?

(i) C_2H_3Cl

(ii) CH_2Cl_2

(iii) 

Sol.

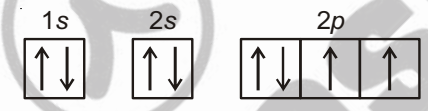
Molecule	Structure bonds	Sigma bonds	pi bonds
(i) C_2H_3Cl		5	1
(ii) CH_2Cl_2		4	0
(iii) $H_3C–CH = CH–C \equiv CH$		10	3

43. Draw orbital representation of the following molecules.

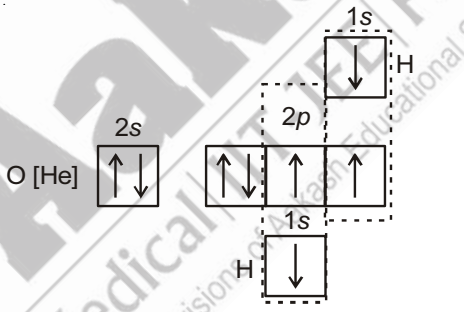
(i) Water

(ii) Nitrogen molecule.

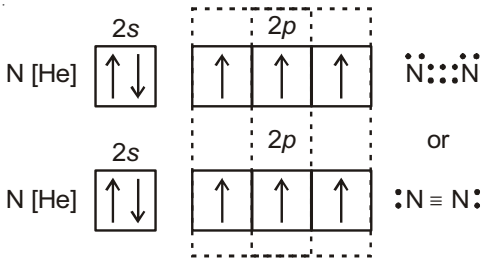
Sol. (i) **Water molecule :** The electronic configuration of an O atom is $1s^2\ 2s^2\ 2p^4$. There are six electrons in the valence orbitals of oxygen.



An oxygen atom can complete its octet by sharing two electron pairs. The overlap in H_2O molecule is between the 2*p* orbital of O and the 1*s* orbital of H.



(ii) Nitrogen molecule, N_2. The N atom has the configuration $1s^2\ 2s^2\ 2p^3$. Each of *p*-orbital is half filled. An N-atom join with another N-atom though the overlap of the six half filled 2*p*-orbitals resulting in sharing of three electron pairs.



44. Explain the following:

(i) CCl_4 and $SiCl_4$ both are tetrahedral.

(ii) BF_3 and NF_3 are not isostructural.

(iii) The HSH angle in H_2S is close to 90° while HOH angle in H_2O is 104.5°.

Sol. (i) In both CCl_4 and $SiCl_4$, the central atom is sp^3 hybridised. Both are AX_4 type molecules without any lone pair of electrons present on the central atom. Hence CCl_4 and $SiCl_4$, both are tetrahedral is shape.

(ii) In BF_3, the B atom is sp^2 hybridised (AX_3). The shape is trigonal planar. In NF_3, N atom is sp^3 hybridised due to the presence of one lone pair of electron on N atom, the shape is reduced from tetrahedral to trigonal pyramidal.

(iii) In H_2O, O atom is sp^3 hybridised. But due to the repulsion between lone pair-lone pair of electron on O-atom, the angle is reduced to 104.5° from 109°. In H_2S, S is less electronegative than O atom, so bond pair-bond pair repulsion is less than H_2O.

45. Why in case of polyatomic molecules, the measurement of bond strength is complicated?

Sol. In case of polyatomic molecules, the measurement of bond strength is more complicated. For example in case of H_2O molecule, the enthalpy needed to break the two O–H bonds is not the same.

$$H_2O(g) \longrightarrow H(g) + OH(g) \; ; \; \Delta_a H_1^\circ = 502 \text{ kJ mol}^{-1}$$

$$OH(g) \longrightarrow H(g) + O(g) \; ; \; \Delta_a H_2^\circ = 427 \text{ kJ mol}^{-1}$$

The difference in the $\Delta_a H^\ominus$ value shows that the second O–H bond undergoes some change because of changed chemical environment. This is the reason for some difference in energy of the same O–H bond in different molecules like C_2H_5OH (ethanol) and water. Therefore in polyatomic molecules the term mean or average bond enthalpy is used. It is obtained by dividing total bond dissociation enthalpy by the number of bonds broken as explained below in case of water molecule.

Average bond enthalpy = $\frac{502 + 427}{2}$ = 464.5 kJ mol^{-1}.

Due to these reasons the measurement of bond strength is complicated in polyatomic molecules.

❑ ❑ ❑

Chapter 4

Chemical Bonding and Molecular Structure

Solutions (Set-2)

[Lewis Structure and Type of Bond]

1. Which of the following is electron deficient (Lewis acid)?

(1) $CaCl_2$ (2) BF_3 (3) Al_2Cl_6 (4) CCl_4

Sol. Answer (2)

Except BF_3, all molecules have complete octet hence only BF_3 can act as Lewis acid.

2. The molecule that contains both ionic and covalent bonds are

(1) KCN (2) KCl (3) K_2S (4) H_2O_2

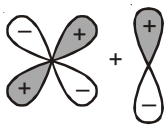
Sol. Answer (1)

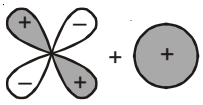
$K^+C \equiv N^-$

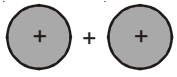
KCN has ionic and covalent bonds.

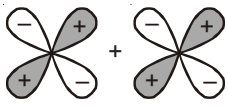
[V.B.T. and Hybridisation]

3. Which of the following combination of orbitals will form a nonbonding molecular orbital ?

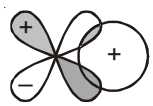
(1) 

(2) 

(3) 

(4) 

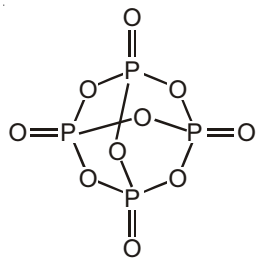
Sol. Answer (2)

 ⟶ Non-bonding overlap

4. In P_4O_{10} number of oxygen atoms attached to each phosphorus are

(1) 2 (2) 3 (3) 2.5 (4) 4

Sol. Answer (4)



Each P is attached to 4 oxygen atoms.

5. The hybridisation of S in SO_4^{2-} is same as

(1) I in ICl_4^- (2) S in SO_3 (3) P in PO_4^{3-} (4) N in NO_3^-

Sol. Answer (3)

Both S and P are sp^3 hybridized in SO_4^{2-} and PO_4^{3-} respectively.

6. Which of the following pairs have same hybridisation?

(1) CH_3^- and CH_3^+ (2) NH_3 and SO_2 (3) SO_4^{2-} and BF_4^- (4) BF_3 and NF_3

Sol. Answer (3)

Both SO_4^{2-} and BF_4^- have sp^3 hybridization.

7. Which of the following compounds has a central atom assuming sp^3 hybridisation?

(1) SO_3 (2) PCl_5 (3) NH_3 (4) CO_3^{2-}

Sol. Answer (3)

NH_3

$$VSEP = \frac{1}{2}(V + M - C + A)$$

$$= \frac{1}{2}(5 + 3 - 0 + 0) = 4 \Rightarrow sp^3$$

8. The type of hybrid orbitals used by chlorine atom in ClO_2^- is

(1) sp^3 (2) sp^2 (3) sp (4) sp^3d

Sol. Answer (1)

ClO_2^-

$$VSEP = \frac{1}{2}(V + M - C + A)$$

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

$$= \frac{8}{2} = 4$$

$\Rightarrow$ sp^3

9. In which of the following reactions hybridisation of underlined species is not changing?

(1) $\underline{N}H_3 + H^+ \rightarrow \underline{N}H_4^+$ (2) $\underline{B}F_3 + F^- \rightarrow \underline{B}F_4^-$

(3) $\underline{C_2}H_2 + H_2 \rightarrow \underline{C_2}H_6$ (4) All of these

Sol. Answer (1)

$$\underset{sp^3}{NH_3} + H^{\oplus} \longrightarrow \overset{\oplus}{\underset{sp^3}{N}}H_4$$

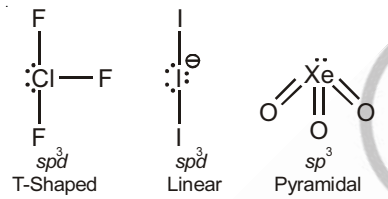
[V.S.E.P.R. Theory]

10. Molecular shapes of ClF_3, I_3^- and XeO_3 respectively are

(1) T-shape, Linear, Pyramidal (2) Planar, Linear, Tetrahedral

(3) T-shape, Planar, Pyramidal (4) Trigonal bipyramidal, Linear, Tetrahedral

Sol. Answer (1)



11. When NH_3 is treated with HCl, H–N–H bond angle

(1) Increases (2) Decreases

(3) Remains same (4) Depends upon temperature

Sol. Answer (1)

$$NH_3 + HCl \longrightarrow NH_4^+Cl^-$$

When NH_3 converts into NH_4^+ number of lone pair decreases, hence, bond angle increases.

12. In which of the following set of compounds, bond angle remains constant for all members ?

(1) NH_3, PH_3, AsH_3 (2) PF_3, PCl_3, PBr_3

(3) OH_2, OF_2, OCl_2 (4) BF_3, BCl_3, BBr_3

Sol. Answer (4)

All are sp^2 hybridized with 120° bond angle.

13. Which of the following molecule is of T-shape?

(1) I_3^- (2) ClF_3 (3) SF_4 (4) XeF_4

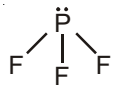
Sol. Answer (2)

ClF_3 is T-shaped.

14. The molecule which has pyramidal shape is

(1) SO_3 (2) NO_3^- (3) CO_3^{-2} (4) PF_3

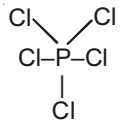
Sol. Answer (4)

 is pyramidal with one lone and three bond pairs.

15. In which of the following, central atom does not have one lone pair of electron?

(1) PCl_5 (2) NH_3 (3) PCl_3 (4) XeF_6

Sol. Answer (1)



Since P-has $5e^-$ in its outermost shell and is forming 5 bonds hence all the $5e^-$ are consumed and no lone pair will remain.

16. Which of the following pairs are iso-structural?

(1) CH_3^- and CH_3 (2) NH_4^+ and BH_4^- (3) SO_4^{2-} and BF_3 (4) NH_2^- and BeF_2

Sol. Answer (2)

$NH_4^+ = 7 + 4 - 1 = 10e^-$

$BH_4^- = 5 + 4 + 1 = 10e^-$

Both have same number of electrons and same total number of atoms, hence, isostructural.

17. In case of XeO_2F_2 and XeF_6, Xe is with

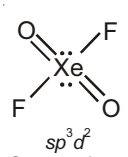
(1) Same hybridization but with different geometry

(2) Different hybridization with same geometry

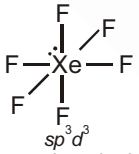
(3) Different hybridization and different geometry

(4) Same geometry and same hybridization

Sol. Answer (3)



sp^3d^2
Square planar



sp^3d^3
Distorted octahedral

18. The ion which is isoelectronic with CO is

(1) CN^- (2) O_2^+ (3) O_2^- (4) N_2^+

Sol. Answer (1)

$CN^- = 6 + 7 + 1 = 14$

$CO = 6 + 8 = 14$

Both have same number of electrons and same number of atoms.

19. CO_2 is isostructural with

(1) NO_2^+ (2) $SnCl_2$ (3) C_2H_4 (4) NO_2

Sol. Answer (1)

$CO_2 = 6 + 2 \times 8 = 22$

$NO_2^+ = 7 + 8 \times 2 - 1 = 22$

Both have same number of atoms and electrons, hence, isostructural.

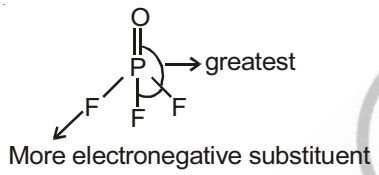
20. Correct order of bond angle for O—P—X (P  angle) in the given molecules is

$\underset{I}{POF_3}$ $\underset{II}{POCl_3}$ $\underset{III}{POBr_3}$ $\underset{IV}{POI_3}$

are

(1) I > II > III > IV (2) IV > III > II > I (3) II > III > I > IV (4) III > II > IV > I

Sol. Answer (1)



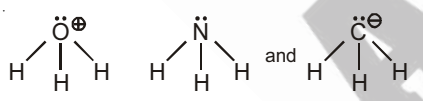
21. Pick out the isoelectronic structures from the following.

(i) CH_3^+ (ii) H_3O^+

(iii) NH_3 (iv) CH_3^-

(1) (i) and (ii) (2) (iii) and (iv) (3) (i) and (iii) (4) (ii), (iii) and (iv)

Sol. Answer (4)



22. Which of the following is non-linear?

(1) I_3^- (2) XeF_2 (3) SO_2 (4) $CH \equiv C - C \equiv CH$

Sol. Answer (3)

I_3^-, BP = 2, LP = 3 $\Rightarrow$ Total no. of hybridized orbital = 5

(5, 2, 3) linear

XeF_2, BP = 2, LP = 3 $\Rightarrow$ Total no. of hybridized orbital = 5

(5, 2, 3) linear

SO_2, $O = \ddot{S} = O$, BP = 2, LP = 1 $\Rightarrow$ Total no. of hybridized orbital = 3

(3, 2, 1) sp^2 bent or V shaped or angular

CH≡C–C≡CH linear

[Dipole Moment and Fajan's Rule]

23. Which of the following has zero dipole moment?

(1) CO_2 (2) NH_3 (3) NF_3 (4) H_2O

Sol. Answer (1)

$\overleftarrow{O} = C = \overrightarrow{O}$

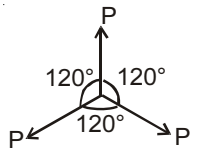
Linear molecule with two equal and opposite dipoles.

24. Which of the following compounds have zero dipole moment?

(1) BF_3 (2) $SnCl_2$ (3) H_2O (4) NH_3

Sol. Answer (1)

BF_3 has sp^2 hybridization hence 3 dipole moment vectors of equal magnitude are at 120° from each other. Hence $\mu = 0$



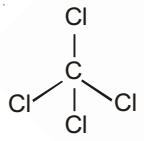
$\mu = 0$

25. Which of the following compounds is non-polar?

(1) CCl_4 (2) CH_2Cl_2 (3) $CHCl_3$ (4) CH_3Cl

Sol. Answer (1)

CCl_4 ;



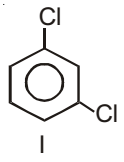
All atoms in surrounding are same and no lone pairs present on central atom.

Hence $\mu = 0$

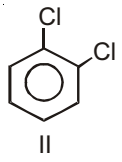
26. Arrange the following compounds in order of increasing dipole moment → m-dichlorobenzene (I), o-dichlorobenzene (II), p-dichlorobenzene (III)

(1) I < II < III (2) II < III < I (3) I < III < II (4) III < I < II

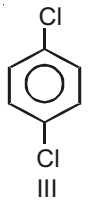
Sol. Answer (4)



I



II



III

II < I < III (increasing order of Bond angle)

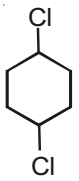
$\mu \propto \frac{1}{\theta}$

III < I < II (Increasing order of dipole moment μ).

27. Which of the compounds do not have zero dipole moment?

(1)  (2)  (3) PCl_5 (4) $ICl_2^{\ominus}$

Sol. Answer (1)

 compound s not planar while  is planar.

28. Which is the correct arrangement of molecules regarding dipole moment?

(1) $BF_3 = NH_3 = NF_3$ (2) $BF_3 > NH_3 > NF_3$

(3) $BF_3 < NH_3 < NF_3$ (4) $BF_3 < NF_3 < NH_3$

Sol. Answer (4)

BF_3 , $\mu = 0$

NH_3 has greater dipole moment than NF_3 hence order is

$BF_3 < NF_3 < NH_3$

29. Which of the following has maximum ionic character?

(1) LiCl (2) NaCl (3) KCl (4) CsCl

Sol. Answer (4)

Cl^- is common hence larger the cation more will be the ionic character (Fajan's rule). Hence, CsCl will have highest ionic character.

30. Polarization is the distortion of shape of an anion by the cation. Which statement is correct?

(1) Maximum polarization is done by cation of high charge

(2) A large cation is likely to bring larger degree of polarization

(3) A smaller anion is likely to undergo a higher degree of polarization

(4) Minimum polarization is done by cation of small size

Sol. Answer (1)

Smaller the cation and larger the anion, higher is polarization.

[M.O.T. and H-bonding]

31. Paramagnetism is not shown by

(1) O_2 (2) O_2^- (3) H_2^+ (4) O_2^{2-}

Sol. Answer (4)

O_2^{-2} has zero unpaired electrons.

32. O_2 and N_2 are respectively

(1) Diamagnetic, Paramagnetic (2) Paramagnetic, Diamagnetic

(3) Both the paramagnetic (4) Both are diamagnetic

Sol. Answer (2)

O_2 is paramagnetic because it contains unpaired electrons. N_2 does not have unpaired electrons hence it is diamagnetic.

33. Among KO_2, AlO_2^+, BaO_2 and NO_2^+ unpaired electron is present in

(1) NO_2^+ and BaO_2 (2) KO_2 and AlO_2^+ (3) KO_2 only (4) BaO_2 only

Sol. Answer (3)

$KO_2 \longrightarrow K^+ + O_2^-$

$AlO_2^+ \longrightarrow Al^{+3} + O_2^{-2}$

$BaO_2 \longrightarrow Ba^{+2} + O_2^{-2}$

NO_2^+ $\quad O = \overset{+}{N} = O$

Species	Bond order	No. of unpaired electron
O_2^-	$\frac{3}{2}$	1
O_2^{-2}	1	0

Only KO_2 has unpaired electrons.

34. Arrange the given species in increasing order of O—O bond length

$\underset{I}{H_2O_2}$, $\underset{II}{KO_2}$, $\underset{III}{Na_2O_2}$, $\underset{IV}{O_2}$

(1) I < III < IV < II (2) II < I < IV < III (3) IV < I < III < II (4) IV < II < I < III

Sol. Answer (4)

$$\xrightarrow[\uparrow \text{Increasing O—O bond length}]{O_2 < KO_2 < H_2O_2 < Na_2O_2}$$

35. Correct order for N — O bond length in the given species is

$\underset{I}{NO}$ $\underset{II}{NO^+}$ $\underset{III}{NO_2^-}$ $\underset{IV}{NO_3^-}$

(1) I < II < III < IV (2) II < I < III < IV (3) II < III < IV < I (4) I < III < IV < II

Sol. Answer (2)

Compound	Bond order
NO	2.5
NO^+	3
NO_2^-	$\frac{3}{2}$
NO_3^-	$\frac{4}{3}$

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

36. In which conversion, bond length decreases?

(1) $N_2 \longrightarrow N_2^+$ (2) $N_2 \longrightarrow N_2^-$ (3) $CO \longrightarrow CO^+$ (4) $O_2 \longrightarrow O_2^-$

Sol. Answer (3)

$$\underset{\text{Bond length}\atop 1.128\ \text{Å}}{CO} \longrightarrow \underset{1.115\ \text{Å}}{CO^{\oplus}}$$

37. Strongest hydrogen bonding is present in

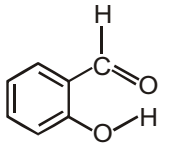
(1) HF (2) NH_3 (3) C_2H_5OH (4) H_2O

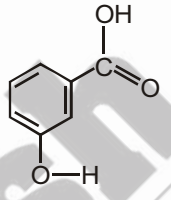
Sol. Answer (1)

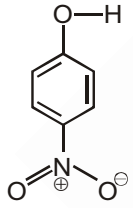
Difference of electronegativity is maximum between H and F in H.

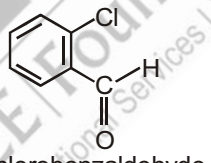
$\therefore$ It will form strongest H-Bond.

38. Which of the following species will have intramolecular hydrogen bonding ?

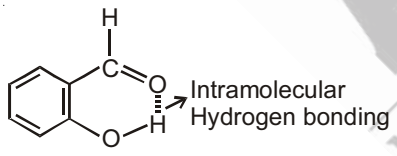
(1) 
o-Hydroxybenzaldehyde

(2) 
m-Hydroxybenzoic acid

(3) 
p-Nitrophenol

(4) 
o-Chlorobenzaldehyde

Sol. Answer (1)



39. Hydrogen bond

(1) Have energy of the order of 100 kJ/mol

(2) Have a powerful effect on the structures and properties of many compounds

(3) Is the interaction between lone pair of electrons with all atoms

(4) In HCl is maximum

Sol. Answer (2)

Due to H-bonding, boiling point and solubility in water increases.

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