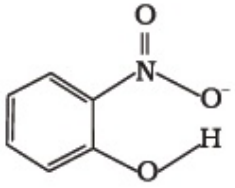
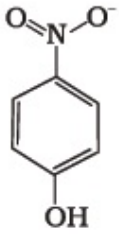
Chemical Bonding & Molecular Structure

Short Answer Type Questions

1. Explain the non linear shape of H2S and non planar shape of PCl_3 using valence shell electron pair repulsion theory.
2. Using molecular orbital theory, compare the bond energy and magnetic character of O_2^+ and O_2^- species.
3. Explain the shape of BrF_5.
4. Structures of molecules of two compounds are given below :



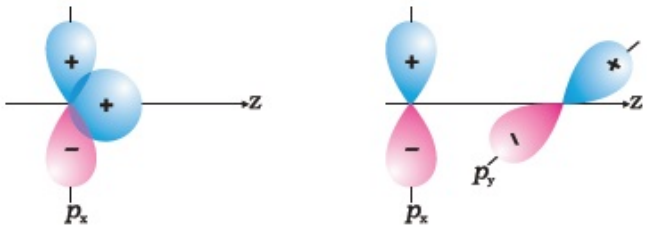
(I)



(II)

   - (a) Which of the two compounds will have intermolecular hydrogen bonding and which compound is expected to show intramolecular hydrogen bonding.
   - (b) The melting point of a compound depends on, among other things, the extent of hydrogen bonding. On this basis explain which of the above two compounds will show higher melting point.
   - (c) Solubility of compounds in water depends on power to form hydrogen bonds with water. Which of the above compounds will form hydrogen bond with water easily and be more soluble in it.

5. Why does type of overlap given in the following figure not result in bond formation?

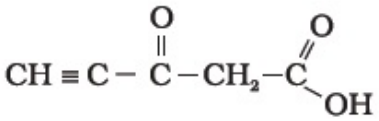


6. Explain why PCl_5 is trigonal bipyramidal whereas IF_5 is square pyramidal.
7. In both water and dimethyl ether (CH_3 — Ö — CH_3), oxygen atom is central atom, and has the same hybridisation, yet they have different bond angles.
   Which one has greater bond angle? Give reason.
8. Write Lewis structure of the following compounds and show formal charge on each atom.
   HNO_3, NO_2, H_2SO_4
9. The energy of $\sigma 2p_z$ molecular orbital is greater than $\pi 2p_x$ and $\pi 2p_y$ molecular orbitals in nitrogen molecule. Write the complete sequence of energy levels in the increasing order of energy in the molecule. Compare the relative stability and the magnetic behaviour of the following species :
   N_2, $N_2^{+>/sup>}$, N_2^- , N_2^{2+}
10. What is the effect of the following processes on the bond order in N_2 and O_2?
    - (i) $N_2 \rightarrow N_2^+ + e^-$
    - (ii) $O_2 \rightarrow O_2^+ + e^-$

11. Give reasons for the following :
    - (i) Covalent bonds are directional bonds while ionic bonds are nondirectional.
    - (ii) Water molecule has bent structure whereas carbon dioxide molecule is linear.
    - (iii) Ethyne molecule is linear.

12. What is an ionic bond? With two suitable examples explain the difference between an ionic and a covalent bond?
13. Arrange the following bonds in order of increasing ionic character giving reason.
    N—H, F—H, C—H and O—H

14. Explain why CO_3^{2-} ion cannot be represented by a single Lewis structure. How can it be best represented?
15. Predict the hybridisation of each carbon in the molecule of organic compound given below. Also indicate the total number of sigma and pi bonds in this molecule.



16. Group the following as linear and non-linear molecules :
    H_2O, HOCl, $BeCl_2$, Cl_2O
17. Elements X, Y and Z have 4, 5 and 7 valence electrons respectively.
    - (i) Write the molecular formula of the compounds formed by these elements individually with hydrogen.
    - (ii) Which of these compounds will have the highest dipole moment?

18. Draw the resonating structure of
    - (i) Ozone molecule
    - (ii) Nitrate ion

19. Predict the shapes of the following molecules on the basis of hybridisation.
    BCl_3, CH_4, CO_2, NH_3
20. All the C—O bonds in carbonate ion (CO_3^{2-}) are equal in length. Explain.
21. What is meant by the term average bond enthalpy? Why is there difference in bond enthalpy of O—H bond in ethanol (C_2H_5OH) and water?

Matching Type Questions

1. Match the species in Column I with the type of hybrid orbitals in Column II.

Column I	Column II
(i) SF_4	(a) sp^3d^2
(ii) IF_5	(b) d^2sp^3
(iii) NO_2^+	(c) sp^3d
(iv) NH_4^+	(d) sp^3
	(e) sp

2. Match the species in Column I with the geometry/shape in Column II.

Column I	Column II
(i) H_3O^+	(a) Linear
(ii) $HC \equiv CH$	(b) Angular
(iii) ClO_2^-	(c) Tetrahedral
(iv) NH_4^+	(d) Trigonal bipyramidal
	(e) Pyramidal

3. Match the species in Column I with the bond order in Column II.

Column I	Column II
(i) NO	(a) 1.5
(ii) CO	(b) 2.0
(iii) O_2^-	(c) 2.5
(iv) O_2	(d) 3.0

4. Match the items given in Column I with examples given in Column II.

Column I	Column II
(i) Hydrogen bond	(a) C
(ii) Resonance	(b) LiF
(iii) Ionic solid	(c) H_2
(iv) Covalent solid	(d) HF
	(e) O_3

5. Match the shape of molecules in Column I with the type of hybridisation in Column II.

	Column I	Column II
(i)	Tetrahedral	(a) sp^2
(ii)	Trigonal	(b) sp
(iii)	Linear	(c) sp^3

Assertion and Reason Type Questions

In the following questions a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

1. Assertion (A) : Sodium chloride formed by the action of chlorine gas on sodium metal is a stable compound.
   Reason (R) : This is because sodium and chloride ions acquire octet in sodium chloride formation.
   - (i) A and R both are correct, and R is the correct explanation of A.
   - (ii) A and R both are correct, but R is not the correct explanation of A.
   - (iii) A is true but R is false.
   - (iv) A and R both are false.

2. Assertion (A) : Though the central atom of both NH_3 and H_2O molecules are sp3 hybridised, yet H–N–H bond angle is greater than that of H–O–H.
   Reason (R) : This is because nitrogen atom has one lone pair and oxygen atom has two lone pairs.
   - (i) A and R both are correct, and R is the correct explanation of A.
   - (ii) A and R both are correct, but R is not the correct explanation of A.
   - (iii) A is true but R is false.
   - (iv) A and R both are false.

3. Assertion (A): Among the two O–H bonds in H2O molecule, the energy required to break

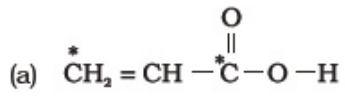
the first O–H bond and the other O–H bond is the same.

Reason (R) : This is because the electronic environment around oxygen is the same even after breakage of one O–H bond.

- (i) A and R both are correct, and R is correct explanation of A.
- (ii) A and R both are correct, but R is not the correct explanation of A.
- (iii) A is true but R is false.
- (iv) A and R both are false.

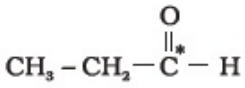
Long Answer Type Questions

1. i) Discuss the significance/ applications of dipole moment.
   (ii) Represent diagrammatically the bond moments and the resultant dipole moment in CO_2, NF_3 and $CHCl_3$.
2. Use the molecular orbital energy level diagram to show that N_2 would be expected to have a triple bond, F_2, a single bond and Ne_2, no bond.
3. Briefly describe the valence bond theory of covalent bond formation by taking an example of hydrogen. How can you interpret energy changes taking place in the formation of dihydrogen?
4. Describe hybridisation in the case of PCl_5 and SF_6. The axial bonds are longer as compared to equatorial bonds in PCl_5 whereas in SF_6 both axial bonds and equatorial bonds have the same bond length. Explain.
5. 64. (i) Discuss the concept of hybridisation. What are its different types in a carbon atom.
   (ii) What is the type of hybridisation of carbon atoms marked with star.



(a)

(b)



(c)

(d) $\overset{*}{C}H_3 - CH = CH - CH_3$

(e) $CH_3 - \overset{*}{C} \equiv CH$

Comprehension given below is followed by some multiple choice questions. Each question has one correct option. Choose the correct option.

Molecular orbitals are formed by the overlap of atomic orbitals. Two atomic orbitals combine to form two molecular orbitals called bonding molecular orbital (BMO) and anti bonding molecular orbital (ABMO). Energy of anti bonding orbital is raised above the parent atomic orbitals that have combined and the energy of the bonding orbital is lowered than the parent atomic orbitals. Energies of various molecular orbitals for elements hydrogen to nitrogen increase in the order :

$\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < (\pi 2p_x \approx \pi 2p_y) < \sigma 2p_z < (\pi^* 2p_x \approx \pi^* 2p_y) < \sigma^* 2p_z$ and for oxygen and fluorine order of energy of molecular orbitals is given below :

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

Different atomic orbitals of one atom combine with those atomic orbitals of the second atom which have comparable energies and proper orientation. Further, if the overlapping is head on, the molecular orbital is called 'Sigma', (σ) and if the overlap is lateral, the molecular orbital is called 'pi', (π). The molecular orbitals are filled with electrons according to the same rules as followed for filling of atomic orbitals. However, the order for filling is not the same for all molecules or their ions. Bond order is one of the most important parameters to compare the strength of bonds.

6. Which of the following statements is correct?
   - (i) In the formation of dioxygen from oxygen atoms 10 molecular orbitals will be formed.
   - (ii) All the molecular orbitals in the dioxygen will be completely filled.
   - (iii) Total number of bonding molecular orbitals will not be same as total number of anti bonding orbitals in dioxygen.

- (iv) Number of filled bonding orbitals will be same as number of filled antibonding orbitals.

7. Which of the following molecular orbitals has maximum number of nodal planes?
   - (i) $\sigma^{*}1s$
   - (ii) $\sigma^{*}2p_z$
   - (iii) $\pi 2p_x$
   - (iv) $\pi^{*}2p_y$

8. Which of the following pair is expected to have the same bond order?
   - (i) O_2 , N_2
   - (ii) O_2^{+}, N_2^{-}
   - (iii) O_2^{-} , N_2^{+}
   - (iv) O_2^{-}, N_2^{-}

9. In which of the following molecules, $\sigma 2p_z$ molecular orbital is filled after $\pi 2p_x$ and $\pi 2p_y$ molecular orbitals?
   - (i) O_2
   - (ii) Ne_2
   - (iii) N_2
   - (iv) F_2