I. Multiple Choice Questions (Type-I)

1. Isostructural species are those which have the same shape and hybridisation. Among the given species identify the isostructural pairs.
(i) [NF_3 and BF_3]
(ii) [BF^{4-} and NH^{4+}]
(iii) [BCl_3 and $BrCl_3$]
(iv) [NH_3 and NO^{3-}]
Solution:
Option (ii) is the answer.

2. Polarity in a molecule and hence the dipole moment depends primarily on electronegativity of the constituent atoms and shape of a molecule. Which of Does the following have the highest dipole moment?
(i) CO_2
(ii) HI
(iii) H_2O
(iv) SO_2
Solution:
Option (iii) is the answer.

3. The types of hybrid orbitals of nitrogen in NO^{2+}, NO^{3-} and NH_4^+respectively are expected to be
(i) sp, sp3 and sp2
(ii) sp, sp2 and sp3
(iii) sp2, sp and sp3
(iv) sp2, sp3 and sp
Solution:
Option (ii) is the answer.

4. Hydrogen bonds are formed in many compounds e.g., H2O, HF, NH3. The boiling point of such compounds depends to a large extent on the strength of hydrogen bond and the number of hydrogen bonds. The correct decreasing order of the boiling points of the above compounds is :
(i) HF > H2O > NH3
(ii) H2O > HF > NH3
(iii) NH3 > HF > H2O
(iv) NH3 > H2O > HF
Solution:
Option (ii) is the answer.

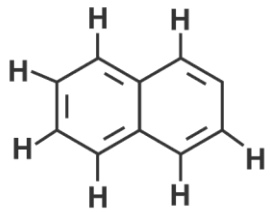
5. In $PO4^{3-}$ ion the formal charge on the oxygen atom of P–O bond is
(i) + 1
(ii) – 1
(iii) – 0.75
(iv) + 0.75

Solution:
Option (ii) is the answer.

6. In NO^{3-} ion, the number of bond pairs and lone pairs of electrons on the nitrogen atom is
(i) 2, 2
(ii) 3, 1
(iii) 1, 3
(iv) 4, 0
Solution:
Option (iv) is the answer.

7. Which of the following species has tetrahedral geometry?
(i) BH^{4-}
(ii) NH^{2-}
(iii) CO_3^{2-}
(iv) H_3O^+
Solution:
Option (i) is the answer.

8. Number of π bonds and σ bonds in the following structure is–



(i) 6, 19
(ii) 4, 20
(iii) 5, 19
(iv) 5, 20
Solution:
Option (iii) is the answer.

9. Which molecule/ion out of the following does not contain unpaired electrons?
(i) N^{2+}
(ii) O_2
(iii) O_2^{2-}
(iv) B_2
Solution:
Option (iii) is the answer.

10. In which of the following molecule/ion all the bonds are not equal?
(i) XeF_4
(ii) BF^{4-}

(iii) C_2H_4
(iv) SiF_4
Solution:
Option (iii) is the answer.

11. In which of the following substances will hydrogen bond be strongest?
(i) HCl
(ii) H2O
(iii) HI
(iv) H2S
Solution:
Option (ii) is the answer.

12. If the electronic configuration of an element is 1s2 2s2 2p6 3s2 3p6 3d2 4s2, the four electrons involved in chemical bond formation will be_____.
(i) 3p6
(ii) 3p6, 4s2
(iii) 3p6, 3d2
(iv) 3d2, 4s2
Solution:
Option (iv) is the answer.

13. Which of the following angle corresponds to sp2 hybridisation?
(i) 90°
(ii) 120°
(iii) 180°
(iv) 109°
Solution:
Option (ii) is the answer

The electronic configurations of three elements, A, B and C are given below. Answer the questions 14 to 17 on the basis of these configurations.
A 1s2 2s2 2p6
B 1s2 2s2 2p6 3s2 3p3
C 1s2 2s2 2p6 3s2 3p5

14. The stable form of A may be represented by the formula :
(i) A
(ii) A_2
(iii) A_3
(iv) A_4
Solution:
Option (i) is the answer.

15. The stable form of C may be represented by the formula :
(i) C

(ii) C_2
(iii) C_3
(iv) C_4
Solution:
Option (ii) is the answer.

16. The molecular formula of the compound formed from B and C will be
(i) BC
(ii) B_2C
(iii) BC_2
(iv) BC_3
Solution:
Option (iv) is the answer.

17. The bond between B and C will be
(i) Ionic
(ii) Covalent
(iii) Hydrogen
(iv) Coordinate
Solution:
Option (ii) is the answer.

18. Which of the following order of energies of molecular orbitals of N2 is correct?
(i) (π2py) < (σ2pz) < (π*2px) ≈ (π*2py)
(ii) (π2py) > (σ2pz) > (π*2px) ≈ (π*2py)
(iii) (π2py) < (σ2pz) > (π*2px) ≈ (π*2py)
(iv) (π2py) > (σ2pz) < (π*2px) ≈ (π*2py)
Solution:
Option (i) is the answer.

19. Which of the following statement is not correct from the viewpoint of molecular orbital theory?
(i) Be^2 is not a stable molecule.
(ii) He^2 is not stable but He^{2+} is expected to exist.
(iii) Bond strength of N2 is maximum amongst the homonuclear diatomic molecules belonging to the second period.
(iv) The order of energies of molecular orbitals in N2 molecule is
σ2s < σ*2s < σ2pz< (π2px = π2py) < (π*2px= π*2py) < σ*2pz
Solution:
Option (iv) is the answer.

20. Which of the following options represents the correct bond order :
(i) O2–> O2 > O2+
(ii) O2–< O2 < O2+

(iii) $O_2^- > O_2 < O_2^+$
(iv) $O_2^- < O_2 > O_2$
Solution:
Option (ii) is the answer.

21. The electronic configuration of the outer most shell of the most electronegative element is
(i) $2s^2\ 2p^5$
(ii) $3s^2\ 3p^5$
(iii) $4s^2\ 4p^5$
(iv) $5s^2\ 5p$
Solution:
Option (i) is the answer.

22. Amongst the following elements whose electronic configurations are given below, the one having the highest ionisation enthalpy is
(i) $[Ne]3s^2\ 3p^1$
(ii) $[Ne]3s^2\ 3p^3$
(iii) $[Ne]3s^2\ 3p^2$
(iv) $[Ar]3d^{10}\ 4s^2\ 4p^3$
Solution:
Option (ii) is the answer.

II. Multiple Choice Questions (Type-II)

23. In the following questions, two or more options may be correct.
23. Which of the following have identical bond order?
(i) CN^-
(ii) NO^+
(iii) O_2^-
(iv) O_2
Solution:
Option (i) and (ii) are the answers.

24. Which of the following attain the linear structure:
(i) $BeCl_2$
(ii) NCO^+
(iii) NO_2
(iv) CS_2
Solution:
Option (i) and (iv) are the answers.

25. CO is isoelectronic with
(i) NO^+
(ii) N_2
(iii) $SnCl_2$

(iv) NO2
Solution:
Option (i) and (ii) are the answers.

26. Which of the following species have the same shape?
(i) CO2
(ii) CCl4
(iii) O3
(iv) NO2
Solution:
Option (iii) and (iv) are the answers.

27. Which of the following statements are correct about $CO3^{2-}$?
(i) The hybridisation of the central atom is sp3.
(ii) Its resonance structure has one C–O single bond and two C=O double bonds.
(iii) The average formal charge on each oxygen atom is 0.67 units.
(iv) All C–O bond lengths are equal.
Solution:
Option (iii) and (iv) are the answers.

28. Diamagnetic species are those which contain no unpaired electrons. Which among the following are diamagnetic?
(i) N_2
(ii) N_2^{2-}
(iii) O_2
(iv) O_2^{2-}
Solution:
Option (i) and (iv) are the answers

29. Species having same bond order are :
(i) N_2
(ii) N^{2-}
(iii) F^{2+}
(iv) O_2
Solution:
Option (iii) and (iv) are the answers.

30. Which of the following statements are not correct?
(i) NaCl being an ionic compound is a good conductor of electricity in the solid-state.
(ii) In canonical structures, there is a difference in the arrangement of atoms.
(iii) Hybrid orbitals form stronger bonds than pure orbitals.
(iv) VSEPR Theory can explain the square planar geometry of XeF4.
Solution:
Option (i) and (iii) are the answers.

III. Short Answer Type

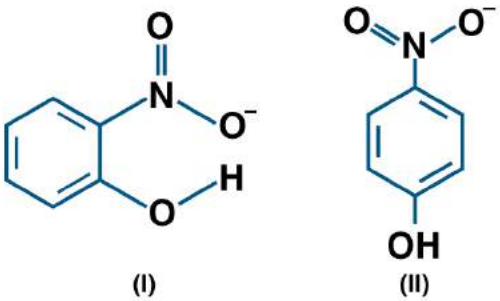
31. Explain the non-linear shape of H2 S and non-planar shape of PCl3 using valence shell electron pair repulsion theory.
Solution:
In H2S, the Sulphur atom is surrounded by the four electron pairs (two bond pairs and two lone pairs).
These four electron pairs adopt tetrahedral geometry.
The repulsion between the lone pair electrons brings distortion in the shape of the H2S.
Thus, H2Sis not linear in shape.

32. Using molecular orbital theory, compare the bond energy and magnetic character of O^{2+} and O^{2-} species.
Solution:
The Molecular Orbital configuration of O2+ and O-2 is given below:

O^{2+} (15): σ1s2 σ *1s2 σ 2s2 σ *2s2 σ 2pz2 π2px2 = π 2py2π *2px1
O^{2-} (17): σ1s2 σ *1s2 σ 2s2 σ *2s2 σ 2pz2 π2px2 = π 2py2π *2px2= π*2py1
Bond order for O2+ = 10-5/2 = 2.5
Bond order for O-2 = 10-7/2 = 1.5
According to Molecular Orbital Theory, the greater the bond order greater is the bond energy.
Thus, O^{2+} is more stable than O^{2-}

33. Explain the shape of BrF5.
Solution:
In BrF5 the central atom is bromine which has the hybridization sp3d2.
Br atom has 7 valence electrons out of which 5 are used to make pair with the F atoms and two are used to make lone pair of electrons.
The lone pair and bond pair repel each other. Thus, the shape is square pyramidal.

34. Structures of molecules of two compounds are given below :



(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 a higher melting point.

(c) The solubility of compounds in water depends on the power to form hydrogen bonds with water. Which of the above compounds will form a hydrogen bond with water easily and be more soluble in it?

Solution:

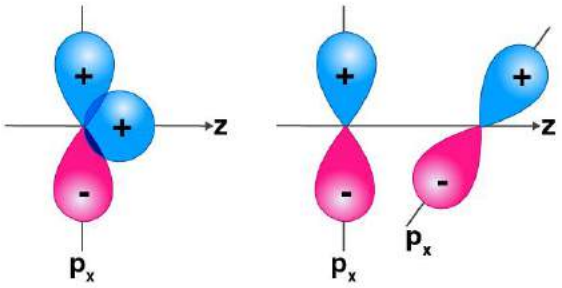
(a) Compound 1 will have intramolecular hydrogen bonding in o-nitrophenol

Compound (II) will have intermolecular hydrogen bonding in p-nitrophenol.

(b) The compound (II) has a higher melting point because of the intermolecular bonding, a large number of molecules that will get attached.

(c) The compound (II) will be more soluble in water because it will form hydrogen bonding with the water molecules easily.

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



Solution:

In the figure (i) the area of the contact of ++ overlap is equal to the area of the +- overlap. The so-net overlap is zero.

In figure (ii) there is no overlap of the orbitals due to the different symmetry.

36. Explain why PCl5 is trigonal bipyramidal whereas IF5 is square pyramidal.

Solution:

In PCl5, P has 5 valence electrons in orbitals and make 5 bonds with 5 Cl atoms, it will share one of its electrons from 3s to 3d orbital, therefore the hybridization will be sp3d and the geometry will be trigonal bipyramidal.

IF5, the Iodine atom has 7 valence electrons in molecular orbitals it will form 5 bonds with 5 Cl atoms using 5 electrons from its molecular orbital, two electrons will form one lone pair on Iodine atom, which gives the square pyramidal geometry.

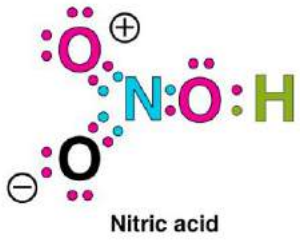
37. In both water and dimethyl ether ($CH_3—O—CH_3$), the oxygen atom is the central atom and has the same hybridization, yet they have different bond angles. Which one has a greater bond angle? Give reason.

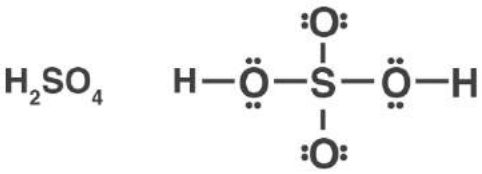
Solution:

Dimethyl ether will have a greater bond angle. There will be more repulsion between bond pairs of CH3 groups attached in ether than between bond pairs of hydrogen atoms attached to oxygen in the water.

38. Write Lewis structure of the following compounds and show a formal charge

on each atom.
HNO3, NO2, H2SO4
Solution:





The formal charge is calculated by
Formal charge = ½ [total no: of bonding or shared electrons]
Add image of NO2
The formal charge on the oxygen with single bond =6-6-2/2 = -1
The formal charge on the oxygen with double bond 6-4-4/2 = 0
The formal charge on nitrogen=5-2-6/2 = 0
Add image of H2SO4
The formal charge on oxygen 1 and 4 = 6-4-4/2= 0
The formal charge on oxygen 2 and 3 = 6-4-4/2=0
The formal charge on hydrogen 1 and 2 = 1-0-2/2=0
The formal charge on sulfur =6-0-12/2 = 0

39. The energy of σ2pz molecular orbital is greater than π2px and π2py 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+} , N^{2-} , N_2^{2+}
Solution:
The general sequence of the energy level of the molecular orbital is
σ1s < σ*1s < σ2s< σ*2s < π2px = π2py < σ2pz

N2 σ1s2 σ*1s2 σ2s2 σ*2s2 π2p2x = π2p2y σ2p2z
N2+ σ1s2 σ*1s2 σ2s2 σ*2s2 π2p2x = π2p2y σ2p1z

N2- σ1s2 σ*1s2 σ2s2 σ*2s2 π2p2x = π2p2y σ2p2z σ2p2x
N22+ σ1s2 σ*1s2 σ2s2 σ*2s2 π2p2x = π2p2y

Bond order = ½[electrons in BMO – electrons in ABMO]
For N2 = 10-4/2 = 3
Bond order for N2+= 9-4/2 = 2.5
Bond order for N2-= 10-5/2 = 2.5
Bond order for $N_2$2+= 8-4/2 = 2
Thus, the order of stability is:
N2> N2- > N2+> $N_2$2+

40. What is the effect of the following processes on the bond order in N2 and O2?

(i) N2→ N2+ + e-
(ii) O2→ O2+ + e-
Solution:
(i) N2 is having 14 electrons when it donates one electron, these electrons are removed from the Bonding molecular orbital. BO for N2 = 3
(ii) O2 has 16 electrons, 8 electrons in the molecular orbitals and 4 in the antibonding molecular orbitals. BO for O2 = 2

41. Give reasons for the following :

(i) Covalent bonds are directional bonds while ionic bonds are nondirectional.
(ii) The water molecule has a bent structure whereas carbon dioxide molecule is linear.
(iii) Ethyne molecule is linear.
Solution:
(i) A covalent bond is formed by the overlapping of atomic orbitals. The direction of overlapping gives the direction of the bond.
(ii) In a water molecule, the oxygen atom is sp3 hybridized and has two lone pairs of electrons.
(iii) In the ethyne molecule, both the carbon atoms are sp hybridized. The two sp hybrid orbitals of both the carbon atoms are oriented in the opposite direction forming an angle of 180°.

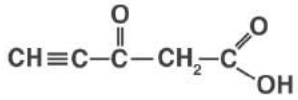
42. What is an ionic bond? With two suitable examples explain the difference between an ionic and a covalent bond?
Solution:
when a positively charged ion forms a bond with a negatively charged ions and one atom transfers electrons to another. An example of an ionic bond is the chemical compound Sodium Chloride (NaCl). The difference between an ionic bond and covalent bond is that An ionic bond essentially donates an electron to the other atom participating in the bond, while electrons in a covalent bond are shared equally between the atoms.

43. Arrange the following bonds in order of increasing ionic character giving a reason
N—H, F—H, C—H and O—H
Solution:
The ionic character is greater in the molecules that are having the greatest electronegativity difference

because the electron pair shifts toward a more electronegative atom increasing the ionic character.
Thus, the ionic character order will be:
C-H<N-H<O-H< F-H

44. Explain why CO_3^{2-} ion cannot be represented by a single Lewis structure. How can it be best represented?
Solution:
Carbonate ion is present in the form of a resonating hybrid structure. These structures are equivalent.
Resonance all 3 C-O bonds get a double character in one of the resonating structures.
Thus, all the bonds are equivalent and have equal length hence carbonate ion cannot be represented by a single Lewis structure.

45. Predict the hybridisation of each carbon in the molecule of the organic compound given below. Also indicate the total number of sigma and pi bonds in this molecule.



Solution:
The hybridization of Carbon 1 is sp, carbon 2 is sp, carbon 3 sp2, carbon 4 is sp3 and carbon 5 is sp2.
The triple bond has 2 pie bonds and one sigma bond.
Each double bond has one sigma and one pie bond.
Every single bond is a sigma bond.
Thus, the total number of sigma bonds is 11 and pie bonds are 4.

46. Group the following as linear and non-linear molecules :
H_2O, HOCl, $BeCl_2$, Cl_2O
Solution:
$BeCl_2$ has a linear structure
HOCl is also non-linear in structure.
H_2O has a V-shaped structure.
Cl_2O has a V-shaped structure.

47. Elements X, Y and Z have 4, 5 and 7 valence electrons respectively.

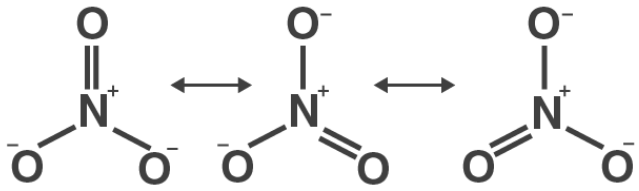
(i) Write the molecular formula of the compounds formed by these elements individually with hydrogen.
(ii) Which of these compounds will have the highest dipole moment?
Solution:
(i); XH4, H3Y, and HZ

Hydrogen has only one electron in its outermost shell it shares one electron to form a covalent bond or accepts or donates one electron to form an ionic bond.
(ii) The compound HZ has a linear shape and the difference in the electronegativity of Hydrogen and element Z is maximum.

48. Draw the resonating structure of

(i) Ozone molecule
(ii) Nitrate ion
Solution:

Resonating structure of Ozone



Nitrate resonating structure

49. Predict the shapes of the following molecules based on hybridisation.
BCl_3, CH_4, CO_2, NH_3
Solution:
In compound BCl_3, Boron has sp2-hybridisation and the shape is Triangular Planar.
In methane CH_4, Carbon has sp3 -hybridization and shape are Tetrahedral.
In carbon dioxide CO_2, carbon has sp-hybridisation and shape is Linear.
In ammonia NH_3, nitrogen has sp3-hybridisation and shape is Pyramidal.

50. All the C—O bonds in carbonate ion ($CO2^{-3}$) are equal in length. Explain
Solution:
Carbonate ion is present in the form of a resonating structure. These structures are equivalenting to nature. Resonance all 3 C-O bonds get a double character in one of the resonating structures.

51. What is meant by the term average bond enthalpy? Why is there a difference in bond enthalpy of O—H bond in ethanol (C_2H_5OH) and water?
Solution:
Similar bonds in a molecule do not have the same bond enthalpies. Mainly the term average bond enthalpy is used in polyatomic molecules. It is obtained by dividing bond dissociation enthalpy by the number of bonds broken. The bond enthalpy of OH bond is different in ethanol and water because of the difference in electronegativity of hydrogen and carbon. As electronegativity differs in hydrogen and oxygen is higher than that in carbon and oxygen, so the O-H bond in water has more bond enthalpy than in ethanol.