CHAPTER
4

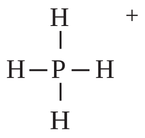
Chemical Bonding and Molecular Structure

4.1 Kössel-Lewis Approach to Chemical Bonding

1. In PO_4^{3-} ion, the formal charge on each oxygen atom and P—O bond order respectively are
(a) –0.75, 1.25 (b) –0.75, 1.0
(c) –0.75, 0.6 (d) –3, 1.25 *(1998)*

2. Among LiCl, $BeCl_2$, BCl_3 and CCl_4, the covalent bond character follows the order
(a) $BeCl_2 > BCl_3 > CCl_4 < LiCl$
(b) $BeCl_2 < BCl_3 < CCl_4 < LiCl$
(c) $LiCl < BeCl_2 < BCl_3 < CCl_4$
(d) $LiCl > BeCl_2 > BCl_3 > CCl_4$ *(1990)*

3. Which one of the following formulae does not correctly represent the bonding capacities of the two atoms involved?

(a)


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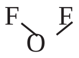

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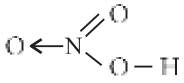

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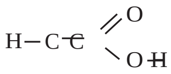


(1990)

4.2 Ionic or Electrovalent Bond

4. Among the following, which compound will show the highest lattice energy?
(a) KF (b) NaF
(c) CsF (d) RbF *(1993)*

4.3 Bond Parameters

5. Which of the following, set of molecules will have zero dipole moment?
(a) Ammonia, beryllium difluoride, water, 1, 4-dichlorobenzene
(b) Boron trifluoride, hydrogen fluoride, carbon dioxide, 1, 3-dichlorobenzene
(c) Nitrogen trifluoride, beryllium difluoride, water, 1, 3-dichlorobenzene
(d) Boron trifluoride, beryllium difluoride, carbon dioxide, 1, 4-dichlorobenzene *(NEET 2020)*

6. Which of the following is the correct order of dipole moment ?
(a) $NH_3 < BF_3 < NF_3 < H_2O$
(b) $BF_3 < NF_3 < NH_3 < H_2O$
(c) $BF_3 < NH_3 < NF_3 < H_2O$
(d) $H_2O < NF_3 < NH_3 < BF_3$ *(Odisha NEET 2019)*

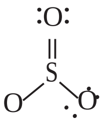
7. The species, having bond angles of 120° is
(a) ClF_3 (b) NCl_3
(c) BCl_3 (d) PH_3 *(NEET 2017)*

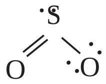
8. Consider the molecules CH_4, NH_3 and H_2O. Which of the given statements is false?
(a) The H — O — H bond angle in H_2O is smaller than the H — N — H bond angle in NH_3.
(b) The H — C — H bond angle in CH_4 is larger than the H — N — H bond angle in NH_3.
(c) The H — C — H bond angle in CH_4, the H — N — H bond angle in NH_3, and the H — O — H bond angle in H_2O are all greater than 90°.
(d) The H — O — H bond angle in H_2O is larger than the H — C — H bond angle in CH_4. *(NEET-I 2016)*

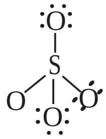
9. Which of the following molecules has the maximum dipole moment?
(a) CO_2 (b) CH_4
(c) NH_3 (d) NF_3 *(2014)*

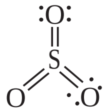
10. The correct order of increasing bond length of C – H, C – O, C – C and $C \equiv C$ is
(a) $C-H < C \equiv C < C-O < C-C$
(b) $C-C < C \equiv C < C-O < C-H$
(c) $C-O < C-H < C-C < C \equiv C$
(d) $C-H < C-O < C-C < C \equiv C$ *(2011)*

11. Which of the following structures is the most preferred and hence of lowest energy for SO_3?

(a) 

(b) 

(c) 

(d) 

(Mains 2011)

12. The correct order of increasing bond angles in the following triatomic species is

(a) $NO_2^+ < NO_2 < NO_2^-$ (b) $NO_2^+ < NO_2^- < NO_2$

(c) $NO_2^- < NO_2^+ < NO_2$ (d) $NO_2^- < NO_2 < NO_2^+$

(2008)

13. The correct order of C – O bond length among CO, CO_3^{2-}, CO_2 is

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

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

(2007)

14. The electronegativity difference between N and F is greater than that between N and H yet the dipole moment of NH_3 (1.5 D) is larger than that of NF_3 (0.2 D). This is because

(a) in NH_3 the atomic dipole and bond dipole are in the opposite directions whereas in NF_3 these are in the same direction

(b) in NH_3 as well as in NF_3 the atomic dipole and bond dipole are in the same direction

(c) in NH_3 the atomic dipole and bond dipole are in the same direction whereas in NF_3 these are in opposite directions

(d) in NH_3 as well as in NF_3 the atomic dipole and bond dipole are in opposite directions. *(2006)*

15. The correct order in which the O – O bond length increases in the following is

(a) $O_2 < H_2O_2 < O_3$ (b) $O_3 < H_2O_2 < O_2$

(c) $H_2O_2 < O_2 < O_3$ (d) $O_2 < O_3 < H_2O_2$

(2005, 1995)

16. The correct sequence of increasing covalent character is represented by

(a) $LiCl < NaCl < BeCl_2$

(b) $BeCl_2 < LiCl < NaCl$

(c) $NaCl < LiCl < BeCl_2$

(d) $BeCl_2 < NaCl < LiCl$ *(2005)*

17. Which of the following would have a permanent dipole moment?

(a) SiF_4 (b) SF_4

(c) XeF_4 (d) BF_3 *(2005)*

18. H_2O is dipolar, whereas BeF_2 is not. It is because

(a) the electronegativity of F is greater than that of O

(b) H_2O involves hydrogen bonding whereas BeF_2 is a discrete molecule

(c) H_2O is linear and BeF_2 is angular

(d) H_2O is angular and BeF_2 is linear. *(2004)*

19. Which of the following molecules does not possess a permanent dipole moment?

(a) CS_2 (b) SO_3

(c) H_2S (d) SO_2 *(1994)*

20. The table shown below gives the bond dissociation energies (E_{diss}) for single covalent bonds of carbon (C) atoms with element *A, B, C* and *D*. Which element has the smallest atoms?

Bond	E_{diss}(kJ mol^{-1})
C-*A*	240
C-*B*	328
C-*C*	276
C-*D*	485

(a) *C* (b) *D*

(c) *A* (d) *B* *(1994)*

21. Strongest bond is in between

(a) CsF (b) NaCl

(c) both (a) and (b) (d) none of the above.

(1993)

22. Which of the following bonds will be most polar?

(a) N – Cl (b) O – F

(c) N – F (d) N – N *(1992)*

4.4 The Valence Shell Electron Pair Repulsion (VSEPR) Theory

23. In the structure of ClF_3, the number of lone pairs of electrons on central atom 'Cl' is

(a) one (b) two

(c) four (d) three *(NEET 2018)*

24. Predict the correct order among the following:

(a) bond pair - bond pair > lone pair - bond pair > lone pair - lone pair

(b) lone pair - bond pair > bond pair - bond pair > lone pair - lone pair

(c) lone pair - lone pair > lone pair - bond pair > bond pair - bond pair

(d) lone pair - lone pair > bond pair - bond pair > lone pair - bond pair

(NEET-I 2016)

25. Which of the following species contains three bond pairs and one lone pair around the central atom?
(a) H_2O (b) BF_3
(c) NH_2^- (d) PCl_3 *(2012)*

26. Which of the following is not a correct statement?
(a) Multiple bonds are always shorter than corresponding single bonds.
(b) The electron-deficient molecules can act as Lewis acids.
(c) The canonical structures have no real existence.
(d) Every AB_5 molecule does in fact have square pyramid structure. *(2006)*

27. Which of the following is not isostructural with $SiCl_4$?
(a) NH_4^+ (b) SCl_4
(c) SO_4^{2-} (d) PO_4^{3-} *(2006)*

28. In which of the following molecules all the bonds are not equal?
(a) NF_3 (b) ClF_3
(c) BF_3 (d) AlF_3 *(2006)*

29. Which of the following molecules has trigonal planar geometry?
(a) BF_3 (b) NH_3
(c) PCl_3 (d) IF_3 *(2005)*

30. In a regular octahedral molecule, MX_6 the number of $X-M-X$ bonds at 180° is
(a) three (b) two
(c) six (d) four. *(2004)*

31. In BrF_3 molecule, the lone pairs occupy equatorial positions to minimize
(a) lone pair - bond pair repulsion only
(b) bond pair - bond pair repulsion only
(c) lone pair - lone pair repulsion and lone pair - bond pair repulsion
(d) lone pair - lone pair repulsion only. *(2004)*

32. In 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. *(2002)*

33. In which of the following bond angle is maximum?
(a) NH_3 (b) NH_4^+
(c) PCl_3 (d) SCl_2 *(2001)*

34. The BCl_3 is a planar molecule whereas NCl_3 is pyramidal because
(a) nitrogen atom is smaller than boron atom
(b) BCl_3 has no lone pair but NCl_3 has a lone pair of electrons
(c) B—Cl bond is more polar than N—Cl bond
(d) N—Cl bond is more covalent than B—Cl bond. *(1995)*

35. In compound X, all the bond angles are exactly 109°28′, X is
(a) chloromethane (b) carbontetrachloride
(c) iodoform (d) chloroform. *(1991)*

4.5 Valence Bond Theory

36. Which of the following species contains equal number of σ and π-bonds?
(a) $(CN)_2$ (b) $(CH)_2(CN)_2$
(c) HCO_3^- (d) XeO_4
(2015, Cancelled)

37. Which one of the following molecules contains no π bond?
(a) SO_2 (b) NO_2
(c) CO_2 (d) H_2O *(NEET 2013)*

38. Which one of the following statements is not correct for sigma- and pi- bonds formed between two carbon atoms?
(a) Sigma-bond is stronger than a pi-bond.
(b) Bond energies of sigma- and pi-bonds are of the order of 264 kJ/mol and 347 kJ/mol, respectively.
(c) Free rotation of atoms about a sigma-bond is allowed but not in case of a pi-bond.
(d) Sigma-bond determines the direction between carbon atoms but a pi-bond has no primary effect in this regard. *(2003)*

39. Main axis of a diatomic molecule is z, molecular orbital p_x and p_y overlap to form which of the following orbitals?
(a) π molecular orbital
(b) σ molecular orbital
(c) δ molecular orbital
(d) No bond will form. *(2001)*

40. Which statement is not correct?
(a) A sigma bond is weaker than a pi bond.
(b) A sigma bond is stronger than a pi bond.
(c) A double bond is stronger than a single bond.
(d) A double bond is shorter than a single bond. *(1990)*

41. Linear combination of two hybridized orbitals belonging to two atoms and each having one electron leads to the formation of
(a) sigma bond
(b) double bond
(c) co-ordinate covalent bond
(d) pi bond. *(1990)*

42. Which of the following does not apply to metallic bond?
(a) Overlapping valence orbitals
(b) Mobile valence electrons

(c) Delocalized electrons
(d) Highly directed bonds *(1989)*

43. The angle between the overlapping of one *s*-orbital and one *p*-orbital is
(a) 180° (b) 120°
(c) 109°28′ (d) 120°, 60° *(1988)*

4.6 Hybridisation

44. Which of the following pairs of compounds is isoelectronic and isostructural?
(a) TeI_2, XeF_2 (b) IBr_2^-, XeF_2
(c) IF_3, XeF_2 (d) $BeCl_2, XeF_2$
(NEET 2017)

45. The hybridizations of atomic orbitals of nitrogen in NO_2^+, NO_3^- and 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-II 2016)

46. Which of the following pairs of ions is isoelectronic and isostructural?
(a) CO_3^{2-}, NO_3^- (b) ClO_3^-, CO_3^{2-}
(c) SO_3^{2-}, NO_3^- (d) ClO_3^-, SO_3^{2-}
(NEET-II 2016)

47. The correct geometry and hybridization for XeF_4 are
(a) octahedral, sp^3d^2
(b) trigonal bipyramidal, sp^3d
(c) planar triangle, sp^3d^3
(d) square planar, sp^3d^2. *(NEET-II 2016)*

48. Among the following, which one is a wrong statement?
(a) PH_5 and $BiCl_5$ do not exist.
(b) $p\pi$-$d\pi$ bonds are present in SO_2.
(c) SeF_4 and CH_4 have same shape.
(d) I_3^+ has bent geometry. *(NEET-II 2016)*

49. In which of the following pairs, both the species are not isostructural?
(a) Diamond, Silicon carbide
(b) NH_3, PH_3
(c) XeF_4, XeO_4
(d) $SiCl_4, PCl_4^+$ *(2015)*

50. Maximum bond angle at nitrogen is present in which of the following?
(a) NO_2^+ (b) NO_3^-
(c) NO_2 (d) NO_2^-
(2015, Cancelled)

51. Which one of the following species has planar triangular shape?
(a) N_3 (b) NO_3^-
(c) NO_2^- (d) CO_2 *(2014)*

52. XeF_2 is isostructural with
(a) $SbCl_3$ (b) $BaCl_2$
(c) TeF_2 (d) ICl_2^- *(NEET 2013)*

53. Which of the following is a polar molecule?
(a) SiF_4 (b) XeF_4
(c) BF_3 (d) SF_4 *(NEET 2013)*

54. The outer orbitals of C in ethene molecule can be considered to be hybridized to give three equivalent sp^2 orbitals. The total number of sigma (σ) and pi (π) bonds in ethene molecule is
(a) 3 sigma (σ) and 2 pi (π) bonds
(b) 4 sigma (σ) and 1 pi (π) bonds
(c) 5 sigma (σ) and 1 pi (π) bonds
(d) 1 sigma (σ) and 2 pi (π) bonds.
(Karnataka NEET 2013)

55. In which of the following pairs both the species have sp^3 hybridization?
(a) SiF_4, BeH_2 (b) NF_3, H_2O
(c) NF_3, BF_3 (d) H_2S, BF_3
(Karnataka NEET 2013)

56. Which one of the following pairs is isostructural (*i.e.*, having the same shape and hybridization)?
(a) [BCl_3 and $BrCl_3$] (b) [NH_3 and NO_3^-]
(c) [NF_3 and BF_3] (d) [BF_4^- and NH_4^+]
(2012)

57. Which of the two ions from the list given below that have the geometry that is explained by the same hybridization of orbitals, NO_2^-, NO_3^-, NH_2^-, NH_4^+, SCN^- ?
(a) NO_2^- and NO_3^- (b) NH_4^+ and NO_3^-
(c) SCN^- and NH_2^- (d) NO_2^- and NH_2^- *(2011)*

58. In which of the following pairs of molecules/ions, the central atoms have sp^2 hybridisation?
(a) NO_2^- and NH_3 (b) BF_3 and NO_2^-
(c) NH_2^- and H_2O (d) BF_3 and NH_2^- *(2010)*

59. In which one of the following species the central atom has the type of hybridization which is not the same as that present in the other three?
(a) SF_4 (b) I_3^-
(c) $SbCl_5^{2-}$ (d) PCl_5 *(2010)*

60. In which of the following molecules the central atom does not have sp^3 hybridization?
(a) CH_4 (b) SF_4
(c) BF_4^- (d) NH_4^+ *(Mains 2010)*

61. Some of the properties of the two species, NO_3^- and H_3O^+ are described below. Which one of them is correct?
(a) Dissimilar in hybridization for the central atom with different structures.
(b) Isostructural with same hybridization for the central atom.
(c) Isostructural with different hybridization for the central atom.
(d) Similar in hybridization for the central atom with different structures. *(Mains 2010)*

62. In which of the following molecules/ions BF_3, NO_2^-, NH_2^- and H_2O, the central atom is sp^2 hybridised?
(a) NH_2^- and H_2O (b) NO_2^- and H_2O
(c) BF_3 and NO_2^- (d) NO_2^- and NH_2^- *(2009)*

63. In which of the following pairs, the two species are isostructural?
(a) SO_3^{2-} and NO_3^- (b) BF_3 and NF_3
(c) BrO_3^- and XeO_3 (d) SF_4 and XeF_4 *(2007)*

64. Which of the following species has a linear shape?
(a) O_3 (b) NO_2^-
(c) SO_2 (d) NO_2^+ *(2006)*

65. The correct order regarding the electronegativity of hybrid orbitals of carbon is
(a) $sp < sp^2 < sp^3$ (b) $sp > sp^2 < sp^3$
(c) $sp > sp^2 > sp^3$ (d) $sp < sp^2 > sp^3$ *(2006)*

66. Among the following, the pair in which the two species are not isostructural is
(a) SiF_4 and SF_4 (b) IO_3^- and XeO_3
(c) BH_4^- and NH_4^+ (d) PF_6^- and SF_6. *(2004)*

67. Which of the following has $p\pi - d\pi$ bonding?
(a) NO_3^- (b) SO_3^{2-}
(c) BO_3^{3-} (d) CO_3^{2-} *(2002)*

68. Which of the following two are isostructural?
(a) XeF_2, IF_2^- (b) NH_3, BF_3
(c) CO_3^{2-}, SO_3^{2-} (d) PCl_5, ICl_5 *(2001)*

69. The bond length between hybridised carbon atom and other carbon atom is minimum in
(a) propene (b) propyne
(c) propane (d) butane. *(1996)*

70. Which of the following has sp^2-hybridisation?
(a) $BeCl_2$ (b) C_2H_2
(c) C_2H_6 (d) C_2H_4 *(1996)*

71. When the hybridization state of carbon atom changes from sp^3 to sp^2 and finally to sp, the angle between the hybridized orbitals
(a) decreases gradually
(b) decreases considerably
(c) is not affected
(d) increases progressively. *(1993)*

72. Which one of the following has the shortest carbon carbon bond length?
(a) Benzene (b) Ethene
(c) Ethyne (d) Ethane *(1992)*

73. Which structure is linear?
(a) SO_2 (b) CO_2
(c) CO_3^{2-} (d) SO_4^{2-} *(1992)*

74. A sp^3 hybrid orbital contains
(a) 1/4 *s*-character (b) 1/2 *s*-character
(c) 1/3 *s*-character (d) 2/3 *s*-character. *(1991)*

75. The complex ion $[Co(NH_3)_6]^{3+}$ is formed by sp^3d^2 hybridisation. Hence the ion should possess
(a) octahedral geometry
(b) tetrahedral geometry
(c) square planar geometry
(d) tetragonal geometry. *(1990)*

76. Which of the following molecules does not have a linear arrangement of atoms?
(a) H_2S (b) C_2H_2
(c) BeH_2 (d) CO_2 *(1989)*

77. In which one of the following molecules the central atom can be said to adopt sp^2 hybridization?
(a) BeF_2 (b) BF_3
(c) C_2H_2 (d) NH_3 *(1989)*

78. Equilateral shape has
(a) sp hybridisation (b) sp^2 hybridisation
(c) sp^3 hybridisation (d) dsp^3 hybridisation. *(1988)*

4.7 Molecular Orbital Theory

79. Consider the following species : CN^+, CN^-, NO and CN. Which one of these will have the highest bond order?
(a) NO (b) CN^-
(c) CN^+ (d) CN *(NEET 2018)*

80. Which one of the following pairs of species have the same bond order?
(a) O_2, NO^+ (b) CN^-, CO
(c) N_2, O_2^- (d) CO, NO *(NEET 2017)*

81. Which of the following is paramagnetic?
(a) CN^- (b) NO^+
(c) CO (d) O_2^- *(NEET 2013)*

82. The pair of species that has the same bond order in the following is
(a) CO, NO^+ (b) NO^-, CN^-
(c) O_2, N_2 (d) O_2, B_2
(Karnataka NEET 2013)

83. In which of the following ionization processes the bond energy increases and the magnetic behaviour changes from paramagnetic to diamagnetic?
(a) $O_2 \rightarrow O_2^+$ (b) $C_2 \rightarrow C_2^+$
(c) $NO \rightarrow NO^+$ (d) $N_2 \rightarrow N_2^+$
(Karnataka NEET 2013)

84. The pair of species with the same bond order is
(a) O_2^{2-}, B_2 (b) O_2^+, NO^+
(c) NO, CO (d) N_2, O_2 *(2012)*

85. During change of O_2 to O_2^- ion, the electron adds on which one of the following orbitals?
(a) π* orbital (b) π orbital
(c) σ* orbital (d) σ orbital *(Mains 2012)*

86. Four diatomic species are listed below. Identify the correct order in which the bond order is increasing in them.
(a) $NO < O_2^- < C_2^{2-} < He_2^+$
(b) $O_2^- < NO < C_2^{2-} < He_2^+$
(c) $C_2^{2-} < He_2^+ < O_2^- < NO$
(d) $He_2^+ < O_2^- < NO < C_2^{2-}$ *(Mains 2012, 2008)*

87. Which of the following is isoelectronic?
(a) CO_2, NO_2 (b) NO_2^-, CO_2
(c) CN^-, CO (d) SO_2, CO_2 *(2002)*

88. Which species does not exhibit paramagnetism?
(a) N_2^+ (b) O_2^-
(c) CO (d) NO *(2000)*

89. The number of anti-bonding electron pairs in O_2^{2-} molecular ion on the basis of molecular orbital theory is (Atomic number of O is 8.)
(a) 3 (b) 2
(c) 5 (d) 4 *(1998)*

90. Which of the following species is paramagnetic?
(a) CO (b) CN^-
(c) O_2^{2-} (d) NO *(1995)*

4.8 Bonding in Some Homonuclear Diatomic Molecules

91. Identify a molecule which does not exist.
(a) He (b) Li
(c) $C_2^{\ 2}$ (d) O_2^2 *(NEET 2020)*

92. Which of the following diatomic molecular species has only π bonds according to Molecular Orbital Theory?
(a) Be_2 (b) O_2
(c) N_2 (d) C_2 *(NEET 2019)*

93. Which of the following is paramagnetic?
(a) N_2 (b) H_2
(c) Li_2 (d) O_2
(Odisha NEET 2019)

94. Decreasing order of stability of O_2, O_2^-, O_2^+ and O_2^{2-} is
(a) $O_2^{2-} > O_2^- > O_2 > O_2^+$
(b) $O_2 > O_2^+ > O_2^{2-} > O_2^-$
(c) $O_2^- > O_2^{2-} > O_2^+ > O_2$
(d) $O_2^+ > O_2 > O_2^- > O_2^{2-}$ *(2015)*

95. The correct bond order in the following species is
(a) $O_2^+ < O_2^- < O_2^{2+}$ (b) $O_2^- < O_2^+ < O_2^{2+}$
(c) $O_2^{2+} < O_2^+ < O_2^-$ (d) $O_2^{2+} < O_2^- < O_2^+$
(2015, Cancelled)

96. Bond order of 1.5 is shown by
(a) O_2^+ (b) O_2^-
(c) O_2^{2-} (d) O_2 *(2012)*

97. Which of the following has the minimum bond length?
(a) O_2^+ (b) O_2^-
(c) O_2^{2-} (d) O_2 *(2011)*

98. The pairs of species of oxygen and their magnetic behaviour are noted below. Which of the following presents the correct description?
(a) O_2^-, O_2^{2-} - Both diamagnetic
(b) O^+, O_2^{2-} - Both paramagnetic
(c) O_2^+, O_2 - Both paramagnetic
(d) O, O_2^{2-} - Both paramagnetic *(2011)*

99. Which one of the following species does not exist under normal conditions?
(a) Be_2^+ (b) Be_2
(c) B_2 (d) Li_2 *(2010)*

100. According to MO theory which of the lists ranks the nitrogen species in terms of increasing bond order?
(a) $N_2^{2-} < N_2^- < N_2$ (b) $N_2 < N_2^{2-} < N_2^-$
(c) $N_2^- < N_2^{2-} < N_2$ (d) $N_2^- < N_2 < N_2^{2-}$
(2009)

101. Right order of dissociation energy N_2 and N_2^+ is
(a) $N_2 > N_2^+$ (b) $N_2 = N_2^+$ *(2000)*
(c) $N_2^+ > N_2$ (d) none.

102. N_2 and O_2 are converted into monocations, N_2^+ and O_2^+ respectively. Which is wrong?

(a) In O_2^+ paramagnetism decreases.
(b) N_2^+ becomes diamagnetic.
(c) In N_2^+, the N–N bond weakens.
(d) In O_2^+, the O–O bond order increases. *(1997)*

103. N_2 and O_2 are converted into monoanions N_2^- and O_2 respectively, which of the following statements is wrong?

(a) In O_2^-, bond length increases.
(b) N_2 becomes diamagnetic.
(c) In N_2^-, N–N bond weakens.
(d) In O_2^-, the O–O bond order decreases. *(1997)*

104. The ground state electronic configuration of valence shell electrons in nitrogen molecule (N_2) is written as $KK, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2 \sigma 2p_z^2$. Hence the bond order in nitrogen molecule is

(a) 2 (b) 3
(c) 0 (d) 1 *(1995)*

105. Which of the following molecules has the highest bond order?

(a) O_2^- (b) O_2
(c) O_2^+ (d) O_2^{2-} *(1994)*

4.9 Hydrogen Bonding

106. Which one of the following compounds shows the presence of intramolecular hydrogen bond?

(a) H_2O_2
(b) HCN
(c) Cellulose
(d) Concentrated acetic acid *(NEET-II 2016)*

107. What is the dominant intermolecular force or bond that must be overcome in converting liquid CH_3OH to a gas?

(a) Dipole-dipole interaction
(b) Covalent bonds
(c) London dispersion force
(d) Hydrogen bonding *(2009)*

108. In $X - H \cdots\cdots Y$, 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 increases. *(2001)*

109. Strongest hydrogen bond is shown by

(a) water
(b) ammonia
(c) hydrogen fluoride
(d) hydrogen sulphide. *(1992)*

110. Which one shows maximum hydrogen bonding?

(a) H_2O (b) H_2Se
(c) H_2S (d) HF *(1990)*

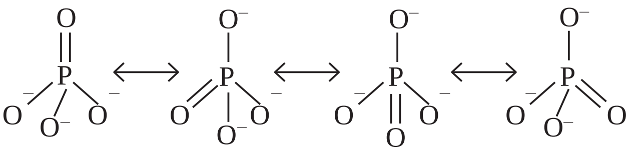
ANSWER KEY

1.	(a)	**2.**	(c)	**3.**	(d)	**4.**	(b)	**5.**	(d)	**6.**	(b)	**7.**	(c)	**8.**	(d)	**9.**	(c)	**10.**	(a)
11.	(d)	**12.**	(d)	**13.**	(c)	**14.**	(c)	**15.**	(d)	**16.**	(c)	**17.**	(b)	**18.**	(d)	**19.**	(a)	**20.**	(b)
21.	(a)	**22.**	(c)	**23.**	(b)	**24.**	(c)	**25.**	(d)	**26.**	(d)	**27.**	(b)	**28.**	(b)	**29.**	(a)	**30.**	(a)
31.	(d)	**32.**	(d)	**33.**	(b)	**34.**	(b)	**35.**	(b)	**36.**	(d)	**37.**	(d)	**38.**	(b)	**39.**	(a)	**40.**	(a)
41.	(a)	**42.**	(d)	**43.**	(a)	**44.**	(None)			**45.**	(c)	**46.**	(a,d)	**47.**	(a)	**48.**	(c)	**49.**	(c)
50.	(a)	**51.**	(b)	**52.**	(d)	**53.**	(d)	**54.**	(c)	**55.**	(b)	**56.**	(d)	**57.**	(a)	**58.**	(b)	**59.**	(c)
60.	(b)	**61.**	(a)	**62.**	(c)	**63.**	(c)	**64.**	(d)	**65.**	(c)	**66.**	(a)	**67.**	(b)	**68.**	(a)	**69.**	(b)
70.	(d)	**71.**	(d)	**72.**	(c)	**73.**	(b)	**74.**	(a)	**75.**	(a)	**76.**	(a)	**77.**	(b)	**78.**	(b)	**79.**	(b)
80.	(b)	**81.**	(d)	**82.**	(a)	**83.**	(c)	**84.**	(a)	**85.**	(a)	**86.**	(d)	**87.**	(c)	**88.**	(c)	**89.**	(d)
90.	(d)	**91.**	(a)	**92.**	(d)	**93.**	(d)	**94.**	(d)	**95.**	(b)	**96.**	(b)	**97.**	(a)	**98.**	(c)	**99.**	(b)
100.	(a)	**101.**	(a)	**102.**	(b)	**103.**	(b)	**104.**	(b)	**105.**	(c)	**106.**	(c)	**107.**	(d)	**108.**	(a)	**109.**	(c)
110.	(a)																		

Hints & Explanations

1. (a) : The total charge = –3

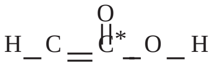
So, the average formal charge on each 'O' atom is –3/4 = –0.75



⇒ Average P—O bond order

$$= \frac{\text{Total no. of bonds}}{\text{Total no. of resonating structures}} = \frac{5}{4} = 1.25$$

2. (c) : Along the period, as we move from Li → Be → B → C, the electronegativity increases and hence the *EN* difference between the element and Cl decreases and accordingly, the covalent character increases. Thus $LiCl < BeCl_2 < BCl_3 < CCl_4$ is the correct order of covalent bond character.

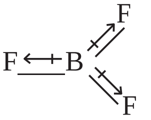
3. (d) : 

$H-C\equiv\overset{O}{\overset{\|}{C}}{}^*-O-H$

The asterisk (*) marked carbon has a valency of 5 and hence, this formula is not correct because carbon has a maximum valency of 4.

4. (b) : For compounds containing ions of same charge, lattice energy increases as the size of ions decreases. Thus, NaF has highest lattice energy.

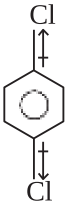
5. (d) :



Boron trifluoride
(μ = 0)

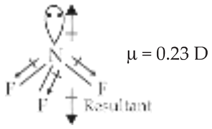
Beryllium difluoride
(μ = 0)

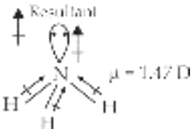
Carbon dioxide
(μ = 0)

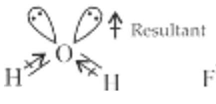


1, 4-Dichlorobenzene
(μ = 0)

6. (b) :





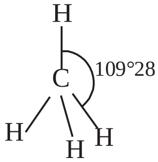


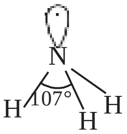
Water
μ = 1.85 D

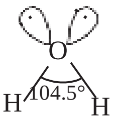
Boron trifluoride
μ = 0 D
Symmetrical molecule

7. (c) : BCl_3-Trigonal planar, sp^2-hybridised, 120° angle.

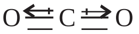
8. (d) :



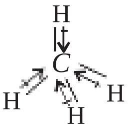




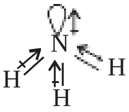
9. (c) :



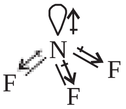
(= 0, symmetrical) ;



(= 0, symmetrical)



(0, pyramidal)

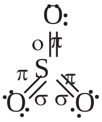


(0, pyramidal)

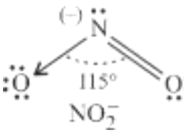
In NH_3, H is less electronegative than N and hence dipole moment of each N—H bond is towards N and create high net dipole moment whereas in NF_3, F is more electronegative than N, the dipole moment of each N—F bond is opposite to that of lone pair, hence reducing the net dipole moment.

10. (a) : Increasing order of bond length is

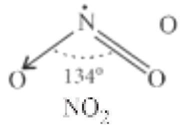
$$C-H < C\equiv C < C-O < C-C$$

11. (d) :  has maximum number of covalent bonds involving *pπ* – *dπ* bonding also.

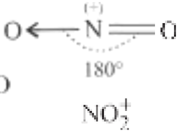
12. (d) : Structures of NO_2^-, NO_2 and NO_2^+ is given as



NO_2^-



NO_2

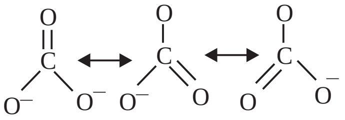


NO_2^+

The correct order of increasing bond angles in the following triatomic species is

$$NO_2^- < NO_2 < NO_2^+$$

13. (c) : $CO \Rightarrow :\overset{-}{C}\equiv\overset{+}{O}: \longleftrightarrow :C=O:$

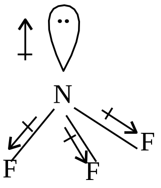
$CO_3^{2-} \Rightarrow$ 

$CO_2 \Rightarrow :\ddot{O}=C=\ddot{O}: \longleftrightarrow :\overset{+}{O}\equiv C-\overset{-}{O}: \longleftrightarrow :\overset{-}{O}-C\equiv\overset{+}{O}:$

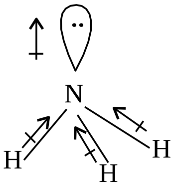
More single bond character in resonance hybrid, more is the bond length. Hence, the increasing bond length is

$CO < CO_2 < CO_3^{2-}$

14. (c) : The dipole moment of NF_3 is 0.24 D and of NH_3 is 1.48 D. The difference is due to fact that the dipole moment due to N – F bonds in NF_3 are in opposite directions to the direction of the dipole moment of the lone pair on N atom which partly cancel out. The dipole moment of N – H bonds in NH_3 are in the same direction of the dipole moment of the lone pair on N atom which adds up as shown :



NF_3



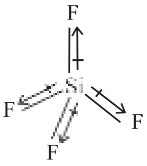
NH_3

15. (d) : Bond lengths of O – O in O_2 is 1.21 Å, in H_2O_2 is 1.48 Å and in O_3 is 1.28 Å. Therefore, correct order of the O – O bond length is $H_2O_2 > O_3 > O_2$.

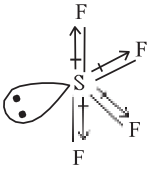
16. (c) : Covalent character in a compound is found by Fajan's rule.

Fajan's rule : The smaller the size of the cation and the larger the size of the anion, the greater is the covalent character of an ionic bond. The greater the charge on the cation, the greater is the covalent character of the ionic bond.

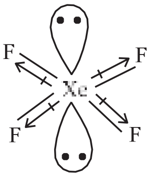
17. (b) : For dipole moment, we have to know the hybridisation and shape.



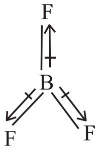
$\mu = 0$



$\mu \neq 0$

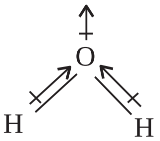


$\mu = 0$



$\mu = 0$

18. (d) : The overall value of the dipole moment of a polar molecule depends on its geometry and shape, *i.e.* vectorial addition of dipole moment of the constituent bonds. Water has angular structure with bond angle 105°, it has dipole moment. However BeF_2 is a linear molecule thus, dipole moment summation of all the bonds present in the molecule cancel each other.



$\mu \neq 0$

$\mu = 0$

19. (a) : The structure of CS_2 is linear and therefore it does not have permanent dipole moment. It is represented as S€ S=

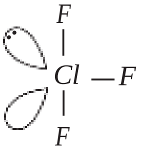
20. (b) : Smaller the atom, stronger is the bond and greater is the bond dissociation energy. Therefore, the bond C-*D* has the greatest energy or *D* has smallest atoms.

21. (a) : According to Fajans rule, ionic character increases with increase in size of the cation, (Cs > Rb > K > Na) and with decrease in size of the anion (F > Cl > Br > I). Thus, CsF has higher ionic character than NaCl and hence, bond in CsF is stronger than in NaCl.

22. (c) : Polarity of the bond depends upon the electronegativity difference of the two atoms forming the bond. Greater the electronegativity difference, more is the polarity of the bond.

N – Cl	O – F	N – F	N – N
3.04–3.16	3.5–4.0	3.04–4.0	3.04–3.04

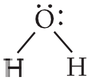
23. (b) : The structure of ClF_3 is



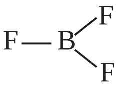
Hence, Cl has 2 lone pairs of electrons.

24. (c) : According to VSEPR theory, the repulsive forces between lone pair and lone pair are greater than between lone pair and bond pair which are further greater than bond pair and bond pair.

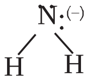
25. (d) :



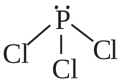
2 bond pairs, 2 lone pairs



3 bond pairs, 0 lone pair

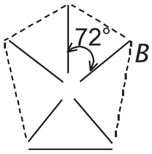


2 bond pairs, 2 lone pairs

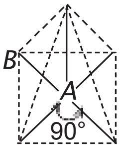


3 bond pairs, 1 lone pair

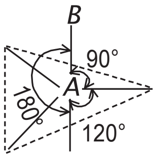
26. (d) : For AB_5 molecules, there are three possible geometries *i.e.* planar pentagonal, square pyramidal and trigonal bipyramidal.



planar pentagonal



square pyramidal



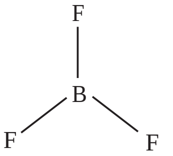
trigonal bipyramidal

Out of these three geometries, it is only trigonal bipyramidal shape in which bond pair-bond pair repulsions are minimum and hence, this geometry is the most probable geometry of AB_5 molecule.

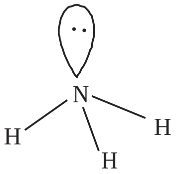
27. (b) : $SiCl_4$, NH_4^+, SO_4^{2-} and PO_4^{3-} ions are the examples of molecules/ions which are of AB_4 type and have tetrahedral structures. SCl_4 is AB_4 (lone pair) type species. Although the arrangement of five sp^3d hybrid orbitals in space is trigonal bipyramidal, due to the presence of one lone pair of electrons in the basal hybrid orbital, the shape of AB_4 (lone pair) species gets distorted and becomes distorted tetrahedral or see-saw.

28. (b) : The Cl – F (Cl – F_{eq}) bond length is equal to 1.60 Å while each of the two axial Cl – F (Cl – F_a) bond length is equal to 1.70 Å.

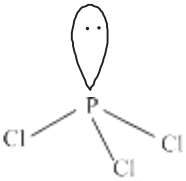
29. (a) :



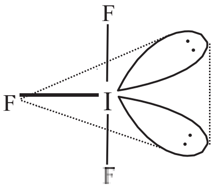
trigonal planar



pyramidal

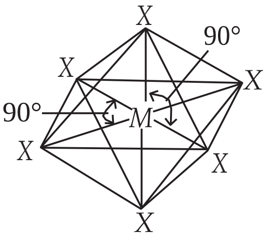


pyramidal

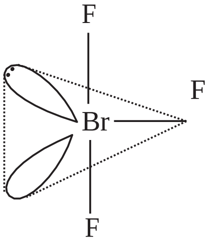


T-shape

30. (a) : In octahedral molecule, six hybrid orbitals directed towards the corners of a regular octahedron with a bond angle of 90°. According to this geometry, the number of X – M – X bonds at 180° must be three.

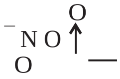


31. (d) :



Bent T-shaped geometry in which both lone pairs occupy the equatorial positions of the trigonal bipyramid. Here (*lp* - *lp*) repulsion = 0, (*lp* - *bp*) repulsion = 4 and (*bp* - *bp*) repulsion = 2.

32. (d) :



In NO_3^- ion, nitrogen has 4 bond pairs of electrons and no lone pair of electrons.

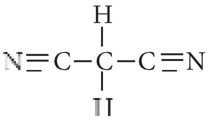
33. (b) : Bond angle is maximum in NH_4^+ tetrahedral molecule with bond angle 109°.

34. (b) : There is no lone pair on boron in BCl_3 hence, no repulsion takes place. There is a lone pair on nitrogen in NCl_3 hence, repulsion takes place. Therefore, BCl_3 is planar molecule but NCl_3 is pyramidal molecule.

35. (b) : As all C – Cl bonds are directed towards the corner of a regular tetrahedron.

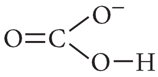
36. (d) : $(CN)_2$, N≡C — C≡N (3 σ + 4 π)

$CH_2(CN)_2$,



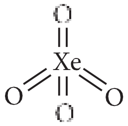
$N{\equiv}C{-}\overset{\displaystyle H}{\underset{\displaystyle H}{C}}{-}C{\equiv}N$ (6 σ + 4 π)

HCO_3^-,



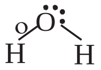
(4 σ + 1 π)

XeO_4,



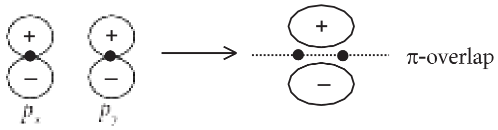
(4 σ + 4 π)

37. (d) :



38. (b) : Sigma bond dissociation energy = 347 kJ/mol
Pi-bond dissociation energy = 264 kJ/mol

39. (a) : For π overlap, the lobes of the atomic orbitals are perpendicular to the line joining the nuclei.



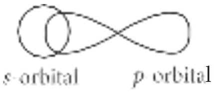
Hence, only sidewise overlapping takes place.

40. (a) : A σ-bond is stronger than a π-bond.

41. (a)

42. (d) : Metallic bonds have electrostatic attractions on all sides and hence, do not have directional characteristics.

43. (a) : The type of overlapping between *s* - and *p*-orbitals occurs along internuclear axis and hence, the angle is 180°.



s-p overlapping

44. (None) :

Species	No. of electrons	Structure
TeI_2 XeF_2	158 72	Bent Linear
IBr_2^- XeF_2	124 72	Linear Linear
IF_3 XeF_2	80 72	T-shaped Linear
$BeCl_2$ XeF_2	38 72	Linear Linear

Note : In this question, in place of isoelectronic there should be same number of valence electrons.

45. (c) : $X = \frac{1}{2}(VE + MA - c + a)$

For NO_2^+, $X = \frac{1}{2}(5 + 0 - 1) = 2$ *i.e.*, sp hybridisation

For NO_3^-, $X = \frac{1}{2}(5 + 0 + 1) = 3$ *i.e.*, sp^2 hybridisation

For NH_4^+, $X = \frac{1}{2}(5 + 4 - 1) = 4$ *i.e.*, sp^3 hybridisation

46. (a, d) : (a) CO_3^{2-} : $6 + 24 + 2 = 32$; sp^2; trigonal planar

NO_3^- : $7 + 24 + 1 = 32$; sp^2; trigonal planar

Hence, these are isoelectronic as well as isostructural.

(b) ClO_3^- : $17 + 24 + 1 = 42$; sp^3, trigonal pyramidal

CO_3^{2-} : $6 + 24 + 2 = 32$; sp^2, trigonal planar

Hence, these are neither isoelectronic nor isostructural.

(c) SO_3^{2-} : $16 + 24 + 2 = 42$; sp^3, trigonal pyramidal

NO_3^- : $7 + 24 + 1 = 32$; sp^2, trigonal planar

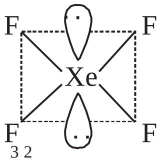
These are neither isoelectronic nor isostructural.

(d) ClO_3^- : $17 + 24 + 1 = 42$; sp^3, trigonal pyramidal

SO_3^{2-} : $16 + 24 + 2 = 42$; sp^3, trigonal pyramidal

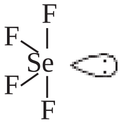
Hence, these are isoelectronic as well as isostructural.

47. (a) :

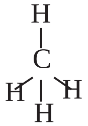


sp^3d^2 hybridisation
(octahedral geometry, square planar shape)

48. (c) :



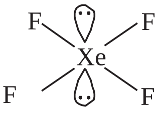
sp^3d hybridisation
(see-saw shape)



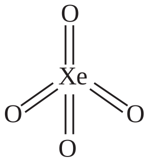
sp^3 hybridisation
(tetrahedral)

49. (c) : In diamond and silicon carbide, central atom is sp^3 hybridised and hence, both are isostructural. NH_3 and PH_3, both are pyramidal and central atom in both cases is sp^3 hybridised. $SiCl_4$ and PCl_4^+, both are tetrahedral and central atom in both cases is sp^3 hybridised.

In XeF_4, Xe is sp^3d^2 hybridised and structure is square planar while in XeO_4, Xe is sp^3 hybridised and structure is tetrahedral.



XeF_4



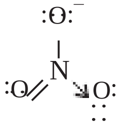
Xe O_4

50. (a) :

Species	NO_3^-	NO_2	NO_2^-	NO_2^+
Hybridisation	sp^2	sp^2	sp^2	sp
Bond angle	120°	134°	115°	180°

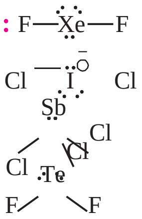
So, NO_2^+ has maximum bond angle.

51. (b) :



(sp^2-hybridised, trigonal planar)

52. (d) :

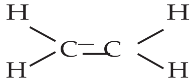


sp^3d, Linear
sp^3d, Linear
sp^3, Pyramidal
sp^3, V-shaped

53. (d) : SF_4 has sp^3d-hybridisation and see-saw shape with (4 *bp* + 1*lp*)

and resultant $\mu \neq 0$.

54. (c) :



5 -bond and 1 -bond

55. (b) : NF_3 and H_2O are sp^3-hybridised.

56. (d) : BCl_3 $\Rightarrow$ sp^2, trigonal planar
$BrCl_3$ $\Rightarrow$ sp^3d, T-shaped
NH_3 $\Rightarrow$ sp^3, pyramidal
NO_3^- $\Rightarrow$ sp^2, trigonal planar
NF_3 $\Rightarrow$ sp^3, pyramidal
BF_3 $\Rightarrow$ sp^2, trigonal planar
BF_4^- $\Rightarrow$ sp^3, tetrahedral
NH_4^+ $\Rightarrow$ sp^3, tetrahedral

57. (a) :

Ions	**Hybridisation**
NO_2^-	sp^2
NO_3^-	sp^2
NH_2^-	sp^3
NH_4^+	sp^3
SCN^-	sp

58. (b) : The hybridisation of the central atom can be calculated as

$$H = \frac{1}{2}\left[\begin{pmatrix}\text{No. of electrons}\\ \text{in valence shell}\\ \text{of atom}\end{pmatrix} + \begin{pmatrix}\text{No. of monovalent}\\ \text{atoms around}\\ \text{central atom}\end{pmatrix} - \begin{pmatrix}\text{Charge on}\\ \text{cation}\end{pmatrix} + \begin{pmatrix}\text{Charge on}\\ \text{anion}\end{pmatrix}\right]$$

$\therefore$ For BF_3, $H = \frac{1}{2}[(3) + (3) - (0) + (0)]$

$= 3 \Rightarrow sp^2$ hybridisation.

For NO_2^-, $H = \frac{1}{2}[(5) + (0) - (0) + (1)]$

$= 3 \Rightarrow sp^2$ hybridisation.

59. (c) : Hybridisation of the central atom can be calculated as:

$$H = \frac{1}{2}\left[\begin{pmatrix}\text{No. of valence}\\ \text{electrons in the}\\ \text{central atom}\end{pmatrix} + \begin{pmatrix}\text{No. of monovalent}\\ \text{atoms around}\\ \text{central atom}\end{pmatrix} - \begin{pmatrix}\text{Charge on}\\ \text{cation}\end{pmatrix} + \begin{pmatrix}\text{Charge on}\\ \text{anion}\end{pmatrix}\right]$$

Applying this formula we find that all the given species except $[SbCl_5]^{2-}$ have central atom with sp^3d (corresponding to $H = 5$) hybridization. In $[SbCl_5]^{2-}$, Sb is sp^3d^2 hybridized.

60. (b) : For neutral molecules,

No. of electron pairs = No. of atoms bonded to it + 1/2[Gp. no. of central atom – Valency of central atom]

$\therefore$ For CH_4, no. of e^- pairs $= 4 + \frac{1}{2}[4 - 4]$

$= 4$ (sp^3 hybridisation)

For SF_4, no. of e^- pairs $= 4 + \frac{1}{2}[6 - 4]$

$= 5$ (sp^3d hybridisation)

For ions,

No. of electron pairs = No. of atoms bonded to it + 1/2[Gp. no. of central atom – Valency of central atom ± No. of electrons equals to the units of charge]

$\therefore$ For BF_4^-, no. of e^- pairs $= 4 + \frac{1}{2}[3 - 4 + 1]$

$= 4$ (sp^3 hybridisation)

For NH_4^+, no. of e^- pairs $= 4 + \frac{1}{2}[5 - 4 - 1]$

$= 4$ (sp^3 hybridisation)

61. (a) : No. of electron pairs at the central atom = No. of atoms bonded to it + 1/2[Group number of central atom – Valency of the central atom ± No. of electrons equals to the units of charge]

No. of electron pairs at the central atom in NO_3^-

$= 3 + \frac{1}{2}[5 - 6 + 1] = 3$ (sp^2 hybridisation).

No. of electron pairs at the central atom in

$H_3O^+ = 3 + \frac{1}{2}[6 - 3 - 1] = 4$ (sp^3 hybridisation).

62. (c) : $BF_3 \rightarrow sp^2$, $NO_2^- \rightarrow sp^2$, $NH_2^- \rightarrow sp^3$, $H_2O \rightarrow sp^3$

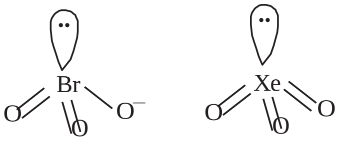
63. (c) : Hybridisation of Br in BrO_3^- :

$H = 1/2(7 + 0 - 0 + 1) = 4$ *i.e.* sp^3 hybridisation

Hybridisation of Xe in XeO_3 :

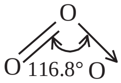
$H = \frac{1}{2}(8 + 0 - 0 + 0) = 4$ *i.e.* sp^3 hybridisation

In both BrO_3^- and XeO_3, the central atom is sp^3 hybridised and contains one lone pair of electrons, hence in both the cases, the structure is trigonal pyramidal.



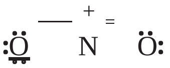
BrO_3^- XeO_3

64. (d) : NO_2^-: Due to sp^2 hybridisation of N-atom and the presence of one lone pair on it, NO_2^- has angular shape.

O_3 :  V-shaped

SO_2 : Due to the presence of one lone pair of electrons in one of the three sp^2-hybrid orbitals, SO_2 molecule has angular (V-shaped) structure.

NO_2^+ : Due to sp hybridisation of N^+, NO_2^+ ion has linear shape.



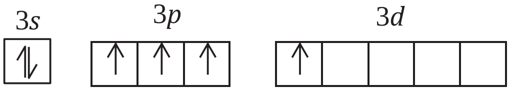
65. (c) : Electronegativity of carbon atom is not fixed. It varies with the state of hybridisation. Electronegativity of carbon increases as the *s*-character of the hybrid orbital increases.

C (sp) > C (sp^2) > C (sp^3)

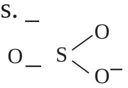
66. (a) : SiF_4 has symmetrical tetrahedral shape which is due to sp^3 hybridisation of the central silicon atom. SF_4 has distorted tetrahedral or see-saw geometry which arises due to sp^3d hybridisation of central sulphur atom and due to the presence of one lone pair of electrons in one of the equatorial hybrid orbital.

67. (b) : In sulphite ion, the central atom sulphur is sp^3 hybridised.

Electronic structure of S atom in excited state



The three p electrons form σ bonds with three oxygen atoms - with one position (of the tetrahedron) being occupied by a lone pair. The d electron (excluded from hybridisation) forms π bond with one oxygen atom. *i.e.* $p\pi$ - $d\pi$ bonding occurs.



68. (a) : Compounds having same shape with same hybridisation are known as isostructural.

XeF_2, IF_2^- → both are sp^3d hybridised linear molecules.

69. (b) : The C–C bond length = 1.54 Å, C ═ C bond length = 1.34 Å and C≡C bond length = 1.20 Å.

Since propyne has a triple bond, therefore it has minimum bond length.

70. (d) : $BeCl_2$ and C_2H_2 have sp-hybridisation and C_2H_6 has sp^3-hybridisation. C_2H_4 has sp^2 hybridisation.

71. (d) : Angle increases progressively,

sp^3 (109° 28′), sp^2 (120°), sp (180°).

72. (c) : There is a triple bond in ethyne molecule

(H — C ≡ C — H) and due to this triple bond, carbon-carbon bond distance is shortest in ethyne.

73. (b) : CO_2 molecule is sp-hybridised and thus, it is linear, while CO_3^{2-} is planar (sp^2 -hybridised), SO_2 is an angular molecule with sp^2 hybridisation and SO_4^{2-} is tetrahedral (sp^3-hybridised).

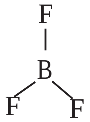
74. (a) : sp^3 orbital has 1/4 (25%) s-character.

75. (a) : According to VSEPR theory, a molecule with 6 bond pairs must be octahedral.

76. (a) : For linear arrangement of atoms the hybridisation is sp (bond angle = 180°).

Only H_2S has sp^3-hybridisation and hence it has angular shape while C_2H_2, BeH_2 and CO_2 all involve sp-hybridisation and hence, have linear arrangement of atoms.

77. (b) : BF_3 involves sp^2-hybridisation.



78. (b) : Equilateral or triangular planar shape involves sp^2 hybridisation, *e.g.*, BCl_3.

79. (b) : NO(15) : $(\sigma 1s)^2, (\sigma^*1s)^2, (\sigma 2s)^2, (\sigma^*2s)^2, (\sigma 2p_z)^2, (\pi 2p_x)^2 = (\pi 2p_y)^2, (\pi^*2p_x)^1 = (\pi^*2p_y)^0$

$$\text{B.O.} = \frac{10-5}{2} = 2.5$$

$CN^-(14)$: $(\sigma 1s)^2, (\sigma^*1s)^2, (\sigma 2s)^2, (\sigma^*2s)^2, (\pi 2p_x)^2 = (\pi 2p_y)^2, (\sigma 2p_z)^2$

$$\text{B.O.} = \frac{10-4}{2} = 3$$

CN(13) : $(\sigma 1s)^2, (\sigma^*1s)^2, (\sigma 2s)^2, (\sigma^*2s)^2, (\pi 2p_x)^2 = (\pi 2p_y)^2, (\sigma 2p_z)^1$

$$\text{B.O.} = \frac{9-4}{2} = 2.5$$

CN^+ (12) : $(\sigma 1s)^2, (\sigma^*1s)^2, (\sigma 2s)^2, (\sigma^*2s)^2, (\pi 2p_x)^2 = (\pi 2p_y)^2$

$$\text{B.O.} = \frac{8-4}{2} = 2$$

Hence, CN^- has highest bond order.

80. (b) : Molecular orbital electronic configurations and bond order values are :

O_2 (16) : $\sigma 1s^2, \sigma^*1s^2, \sigma 2s^2, \sigma^*2s^2, \sigma 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2, \pi^*2p_x^1 = \pi^*2p_y^1$

$$\text{B.O.} = \frac{1}{2}(N_b - N_a) = \frac{1}{2}(10-6) = 2$$

NO^+ (14) : $\sigma 1s^2, \sigma^*1s^2, \sigma 2s^2, \sigma^*2s^2, \sigma 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2$

$$\text{B.O.} = \frac{1}{2}(10-4) = 3$$

CN^- (14) : $\sigma 1s^2, \sigma^*1s^2, \sigma 2s^2, \sigma^*2s^2, \pi 2p_x^2 = \pi 2p_y^2, \sigma 2p_z^2$

$$\text{B.O.} = \frac{1}{2}(10-4) = 3$$

CO(14) : $\sigma 1s^2, \sigma^*1s^2, \sigma 2s^2, \sigma^*2s^2, \pi 2p_x^2 = \pi 2p_y^2, \sigma 2p_z^2$

$$\text{B.O.} = \frac{1}{2}(10-4) = 3$$

N_2 (14) : $\sigma 1s^2, \sigma^*1s^2, \sigma 2s^2, \sigma^*2s^2, \pi 2p_x^2 = \pi 2p_y^2, \sigma 2p_z^2$

$$\text{B.O.} = \frac{1}{2}(10-4) = 3$$

O_2^- (17) = $\sigma 1s^2, \sigma^*1s^2, \sigma 2s^2, \sigma^*2s^2, \sigma 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2, \pi^*2p_x^2 = \pi^*2p_y^1$

$$\text{B.O.} = \frac{1}{2}(10-7) = 1.5$$

NO(15) : $\sigma 1s^2, \sigma^*1s^2, \sigma 2s^2, \sigma^*2s^2, \sigma 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2, \pi^*2p_x^1$

$$\text{B.O.} = \frac{1}{2}(10-5) = 2.5$$

81. (d) : O_2^- (17) superoxide has one unpaired electron.

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

82. (a) : CO = 6 + 8 = 14 electrons

NO^+ = 7 + 8 – 1 = 14 electrons

Electronic configuration of NO^+:

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

Electronic configuration of CO :

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

$$\text{So, both have bond order} = \frac{10-4}{2} = 3$$

83. (c) : Molecular orbital configuration of

O_2 (16) : $\sigma 1s^2\ \sigma^*1s^2\ \sigma 2s^2\ \sigma^*2s^2\ \sigma 2p_z^2\ \pi 2p_x^2\ \pi 2p_y^2\ \pi^*2p_x^1\ \pi^*2p_y^1$

⇒ Paramagnetic

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

O_2^+ (15) : $\sigma 1s^2\ \sigma^*1s^2\ \sigma 2s^2\ \sigma^*2s^2\ \sigma 2p_z^2\ \pi 2p_x^2\ \pi 2p_y^2\ \pi^*2p_x^1$

$\Rightarrow$ Paramagnetic

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

$C_2\,(12) : \sigma 1s^2\,\sigma^*1s^2\,\sigma 2s^2\,\sigma^*2s^2\,\pi 2p_x^{\,2}\,\pi 2p_y^{\,2}$

$\Rightarrow$ Diamagnetic

Bond order $= \frac{8-4}{2} = 2$

$C_2^+(11) : \sigma 1s^2\,\sigma^*1s^2\,\sigma 2s^2\,\sigma^*2s^2\,\pi 2p_x^{\,2}\,\pi 2p_y^{\,1}$

$\Rightarrow$ Paramagnetic

Bond order $= \frac{7-4}{2} = 1.5$

$NO(15) : \sigma 1s^2\,\sigma^*1s^2\,\sigma 2s^2\,\sigma^*2s^2\,\sigma 2p_z^2\,\pi 2p_x^{\,2}\,\pi 2p_y^{\,2}\,\pi^*2p_x^{\,1}$

$\Rightarrow$ Paramagnetic

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

$NO^+(14) : \sigma 1s^2\,\sigma^*1s^2\,\sigma 2s^2\,\sigma^*2s^2\,\sigma 2p_z^{\,2}\,\pi 2p_x^{\,2}\,\pi 2p_y^{\,2}$

$\Rightarrow$ Diamagnetic

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

$N_2(14) : \sigma 1s^2\,\sigma^*1s^2\,\sigma 2s^2\,\sigma^*2s^2\,\pi 2p_x^{\,2}\,\pi 2p_y^{\,2}\,\sigma 2p_z^{\,2}$

$\Rightarrow$ Diamagnetic

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

$N_2^+(13) : \sigma 1s^2\,\sigma^*1s^2\,\sigma 2s^2\,\sigma^*2s^2\,\pi 2p_x^{\,2}\,\pi 2p_y^{\,2}\,\sigma 2p_z^{\,1}$

$\Rightarrow$ Paramagnetic

Bond order $= \frac{9-4}{2} = 2.5$

Thus from NO → NO^+, bond order increases *i.e.*, bond energy increases and magnetic behaviour changes from paramagnetic to diamagnetic.

84. (a) : $O_2^{2-} \rightarrow 1.0$ $\quad B_2 \rightarrow 1.0$
$O_2^+ \rightarrow 2.5$ $\quad NO^+ \rightarrow 3.0$
$NO \rightarrow 2.5$ $\quad CO \rightarrow 3.0$
$N_2 \rightarrow 3.0$ $\quad O_2 \rightarrow 2.0$

85. (a) : Electronic configuration of O (16)

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

Thus, the incoming electron will enter in π^*2p_x to form O_2^-.

86. (d) :

Diatomic species	Bond order
NO	2.5
O_2^-	1.5
C_2^{2-}	3.0
He_2^+	0.5

Thus, bond order increases as : $He_2^+ < O_2^- < NO < C_2^{2-}$

87. (c) : In CO, the number of electrons = 6 + 8 = 14

Molecular orbital electronic configuration of

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

CN^- have also get (6 + 7 + 1) 14 electrons and the configuration is similar to that of CO.

CN^- and CO are isoelectronic species.

88. (c) : In 'CO' (14 electrons), there is no unpaired electron in its molecular orbital. Therefore, this does not exhibit paramagnetism.

89. (d) : $O_2^{2-}(18) : (\sigma 1s)^2, (\sigma^*1s)^2, (\sigma 2s)^2, (\sigma^*2s)^2, (\sigma 2p_z)^2, (\pi 2p_x)^2, (\pi 2p_y)^2, (\pi^*2p_x)^2, (\pi^*2p_y)^2$

Thus, the no. of antibonding electrons in O_2^{2-} ion is 8(4 pairs).

90. (d) : As per their molecular orbital electronic configurations CO, CN^- and O_2^{2-} are diamagnetic and NO is paramagnetic.

91. (a) : He_2 does not exist as it has zero bond order.

$He_2 : \sigma 1s^2, \sigma^*1s^2$

Bond order $= \frac{1}{2}(N_b - N_a) = \frac{1}{2}(2-2) = 0$

92. (d) : $Be_2(8) : KK\,\sigma(2s)^2\,\sigma^*(2s)^2$

$O_2(16) : KK\sigma(2s)^2\,\sigma^*(2s)^2\,\sigma(2p_z)^2\pi(2p_x)^2\,\pi(2p_y)^2\,\pi^*(2p_x)^1\,\pi^*(2p_y)^1$

$N_2(14) : KK\,\sigma(2s)^2\,\sigma^*(2s)^2\,\pi(2p_x)^2\,\pi(2p_y)^2\,\sigma(2p_z)^2$

$C_2(12) : KK\,\sigma(2s)^2\,\sigma^*(2s)^2\,\pi(2p_x)^2\,\pi(2p_y)^2$

Therefore, C_2 contains 2 π bonds as it has 4 electrons in two pi-molecular orbitals.

93. (d) : $N_2\,(14) : KK\,\sigma 2s^2\sigma^*2s^2\pi 2p_x^2 = \pi 2p_y^{\,2}\sigma 2p_z^2$; Diamagnetic

$H_2(2) : \sigma 1s^2$; Diamagnetic

$Li_2(6) : \sigma 1s^2\sigma^*1s^2\sigma 2s^2$; Diamagnetic

$O_2(16) : \sigma 1s^2\sigma^*1s^2\sigma 2s^2\sigma^*2s^2\sigma 2p_z^2\pi 2p_x^2 = \pi 2p_y^2\,\pi^*2p_x^1 = \pi^*2p_y^1$; Paramagnetic

94. (d) : $O_2(16) : KK\,\sigma 2s^2\,\sigma^*2s^2\,\sigma 2p_z^2\,\pi 2p_x^2 = \pi 2p_y^2\,\pi^*2p_x^{\,1} = \pi^*2p_y^{\,1}$

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

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

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

$O_2^-(17) : KK\,\sigma 2s^2\,\sigma^*2s^2\,\sigma 2p_z^{\,2}\,\pi 2p_x^{\,2} = \pi 2p_y^2\,\pi^*2p_x^2 = \pi^*2p_y^1$

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

$O_2^+(15) : KK\,\sigma 2s^2\,\sigma^*2s^2\,\sigma 2p_z^{\,2}\,\pi 2p_x^{\,2} = \pi 2p_y^{\,2}\,\pi^*2p_x^{\,1}$

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

As, bond order ∝ stability

The decreasing order of stability is

$O_2^+ > O_2 > O_2^- > O_2^{2-}$

95. (b) : $O_2^- < O_2^+ < O_2^{2+}$

B.O. : 1.5 2.5 3.0

96. (b) : Configuration of O_2 (16) :
$\sigma 1s^2\,\sigma^*1s^2\,\sigma 2s^2\,\sigma^*2s^2\,\sigma 2p_z^2\,\pi 2p_x^2\,\pi 2p_y^2\,\pi^*2p_x^1\,\pi^*2p_y^1$

$$\text{Bond order} = \frac{\text{No. of } e^- \text{ in bonding M.O.} - \text{No. of } e^- \text{ in antibonding M.O.}}{2}$$

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

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

$$\text{Bond order of } O_2^{2-} = \frac{10-8}{2} = 1.0$$

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

97. (a) : Electronic configuration

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

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

$$O_2^+ : \text{Bond order} = \frac{1}{2}(8-3) = 2\frac{1}{2}$$

$$O_2^- : \text{Bond order} = \frac{1}{2}(8-5) = 1\frac{1}{2}$$

$$O_2^{2-} : \text{Bond order} = \frac{1}{2}(8-6) = 1$$

As bond order increases, bond length decreases.

98. (c) : O_2^+ and O_2 are paramagnetic in nature as they contain one and two unpaired electrons respectively.

99. (b) : Be_2 does not exist.

Be_2 has an electronic configuration of :

$\sigma 1s^2\,\sigma^*1s^2\,\sigma 2s^2\,\sigma^*2s^2$

$$\therefore \quad \text{Bond order} = \frac{4-4}{2} = 0$$

Thus, Be_2 does not exist.

100. (a) : According to MOT, the molecular orbital electronic configuration of

$N_2\,(14) : (\sigma 1s)^2(\sigma^*1s)^2(\sigma 2s)^2(\sigma^*2s)^2(\pi 2p_x)^2(\pi 2p_y)^2(\sigma 2p_z)^2$

$$\therefore \text{B.O} = \frac{10-4}{2} = 3$$

$N_2^-\,(15) : (\sigma 1s)^2(\sigma^*1s)^2(\sigma 2s)^2(\sigma^*2s)^2(\pi 2p_x)^2(\pi 2p_y)^2(\sigma 2p_z)^2(\pi^*2p_x)^1$

$$\therefore \text{B.O} = \frac{10-5}{2} = 2.5$$

$N_2^{2-}\,(16) : (\sigma 1s)^2(\sigma^*1s)^2(\sigma 2s)^2(\sigma^*2s)^2(\pi 2p_x)^2(\pi 2p_y)^2$
$(\sigma 2p_z)^2(\pi^*2p_x)^1(\pi^*2p_y)^1$

$$\therefore \text{B.O.} = \frac{10-6}{2} = 2$$

Hence, bond order increases as : $N_2^{2-} < N_2^- < N_2$

101. (a) : $N_2(14) : (\sigma 1s)^2, (\sigma^*1s)^2, (\sigma 2s)^2, (\sigma^*2s)^2$
$(\pi 2p_x)^2, (\pi 2p_y)^2, (\sigma 2p_z)^2$

$$\text{In } N_2\text{, bond order} = \frac{N_b - N_a}{2} = \frac{10-4}{2} = 3$$

$$\text{In } N_2^+\text{, bond order} = \frac{9-4}{2} = 2\cdot 5$$

As the bond order in N_2 is more than N_2^+ so the dissociation energy of N_2 is higher than N_2^+.

102. (b) : Diamagnetism is caused due to the absence of unpaired electrons. But in N_2^+, there is unpaired electron. So, it is paramagnetic.

103. (b) : N_2^- becomes paramagnetic due to one unpaired electron in π^*2p_x orbital.

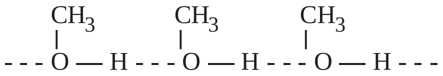
104. (b) : Number of electrons in bonding orbitals $N_b = 10$ and number of electrons in antibonding orbitals $N_a = 4$.

Therefore bond order $= 1/2(N_b - N_a) = 1/2(10-4) = 3$

105. (c) : The bond order of $O_2^+ = 2.5$, $O_2^{2-} = 1$, $O_2^- = 1.5$ and that of $O_2 = 2$.

106. (c) : H_2O_2, HCN and conc. CH_3COOH form intermolecular hydrogen bonding while cellulose has intramolecular hydrogen bonding.

107. (d) : Methanol can undergo intermolecular association through H-bonding as the – OH group in alcohols is highly polarised.



$$\cdots O(CH_3)-H\cdots O(CH_3)-H\cdots O(CH_3)-H\cdots$$

As a result, in order to convert liquid CH_3OH to gaseous state, the strong hydrogen bonds must be broken.

108. (a) : $^{\delta-}X - H^{\delta+}\cdots\cdots\cdots Y$, the electrons of the covalent bond are shited towards the more electronegative atom. This partially positively charged H-atom forms hydrogen bond with the other more electronegative atom.

109. (c) : H – F shows strongest H-bonds because fluorine is most electronegative.

110. (a) : H_2O shows maximum H-bonding because each H_2O molecule is linked to four H_2O molecules through H-bonds.