CHAPTER

Chemical Bonding and Molecular Structure

According to molecular orbital theory, which of the following will not be a viable molecule?
 (a) He₂²⁺
 (b) He₂⁺
 (c) H₂⁻
 (d) H₂²⁻

) He_2^{2+} (b) He_2^+ (c) H_2^- (d) H_2^{2-} (2018)

- Which of the following compounds contain(s) no covalent bond(s)? KCl, PH₃, O₂, B₂H₆, H₂SO₄
 - (a) KCl, B_2H_6 , PH_3 (b) KCl, H_2SO_4 (c) KCl (d) KCl, B_2H_6 (2018)
- 3. Total number of lone pairs of electrons in I_3^- ion is (a) 3 (b) 6 (c) 9 (d) 12

(2018)

9.

4. In the molecular orbital diagram for the molecular ion, N_2^+ , the number of electrons in the σ_{2p} molecular orbital is (a) 3 (b) 1 (c) 0 (d) 2

(b) 1 (c) 0 (d) 2 (Online 2018)

- 5. The decreasing order of bond angles in BF₃, NH₃, PF₃ and I_3^- is
 - (a) $I_3 > BF_3 > NH_3 > PF_3$ (b) $BF_3 > NH_3 > PF_3 > I_3^-$ (c) $I_3 > NH_3 > PF_3 > BF_3$ (d) $BF_3 > I_3 > PF_3 > NH_3$ *(Online 2018)*
- 6. H—N $\stackrel{(I)}{\cdots}$ N $\stackrel{(II)}{\cdots}$ N

In hydrogen azide (above) the bond orders of bonds (I) and (II) are

(I) (II) (a) > 2 < 2(b) < 2 < 2(c) < 2 > 2

- (d) > 2 > 2 (Online 2018)
- 7. Identify the pair in which the geometry of the species is T-shape and square-pyramidal, respectively.

(a)
$$IO_3^-$$
 and $IO_2F_2^-$ (b) $XeOF_2$ and $XeOF_4$
(c) ICl_2^- and ICl_5 (d) ClF_3 and IO_4^-

(Online 2018)

(Online 2018)

- 8. Which of the following best describes the diagram below of a molecular orbital?
 - (a) An antibonding π -orbital
 - (b) An antibonding σ -orbital
 - (c) A non-bonding orbital
 - (d) A bonding π -orbital

The most polar compound among the following is



(Online 2018)

- 10. The incorrect geometry is represented by
 - (a) BF_3 trigonal planar
 - (b) NF_3 trigonal planar
 - (c) AsF₅ trigonal bipyramidal
 (d) H₂O bent.

- 11. Which of the following conversions involves change in both shape and hybridisation?
 - (a) $BF_3 \rightarrow BF_4^-$ (b) $H_2O \rightarrow H_3O^+$
 - (c) $CH_4 \rightarrow C_2H_6$ (d) $NH_3 \rightarrow NH_4^+$

(Online 2018)

- 12. Which of the following species is not paramagnetic?
 (a) O₂
 (b) B₂
 (c) NO
 (d) CO (2017)
- 13. The group having isoelectronic species is

 (a) O²⁻, F⁻, Na, Mg²⁺
 (b) O⁻, F⁻, Na⁺, Mg²⁺
 (c) O²⁻, F⁻, Na⁺, Mg²⁺
 (d) O⁻, F⁻, Na, Mg²⁺
- 14. sp^3d^2 hybridization is not displayed by (a) SF₆ (b) PF₅ (c) $[CrF_6]^{3-}$ (d) BrF₅ (Online 2017)
- 15. Which of the following is paramagnetic? (a) CO (b) O_2^{2-} (c) NO⁺ (d) B₂ (Online 2017)
- 16. The group having triangular planar structures is

 (a) NCl₃, BCl₃, SO₃
 (b) CO₃²⁻, NO₃⁻, SO₃
 (c) NH₃, SO₃, CO₃²⁻
 (d) BF₃, NF₃, CO₃²⁻

 (Online 2017)
- 17. The species in which the N atom is in a state of sp hybridisation is
 - (a) NO_2^+ (b) NO_2^- (c) NO_3^- (d) NO_2 (2016)

18. The group of molecules having identical shape is Its bond order is 2.5. (a) (a) PCl_5 , IF_5 , XeO_2F_2 (b) BF_3 , PCl_3 , XeO_3 (b) It is diamagnetic in gaseous state. (c) SF_4 , XeF_4 , CCl_4 (d) ClF₃, XeOF₂, XeF₃ (c) It is a neutral oxide. (Online 2016) (d) It combines with oxygen to form nitrogen dioxide. 19. Aqueous solution of which salt will not contain ions with (2014)the electronic configuration $1s^22s^22p^63s^23p^6$? 27. For which of the following molecules significant $\mu \neq 0$? (a) NaF (b) KBr (c) NaCl (d) CaI_2 SH (Online 2016) (3) **20.** The bond angle H - X - H is the greatest in the compound (a) PH_3 (b) CH₄ (c) NH_3 (d) H₂O (Online 2016) ÒН 21. The intermolecular interaction that is dependent on the (b) Only (1) (a) (3) and (4)inverse cube of distance between the molecules is (c) (1) and (2)(d) Only (3) (2014)(a) London force (b) hydrogen bond **28.** The correct statement for the molecule, CsI_3 , is (c) ion-ion interaction (d) ion-dipole interaction. (a) it contains Cs^+ , I^- and lattice I_2 molecule (2015)(b) it is a covalent molecule 22. The geometry of $XeOF_4$ by VSEPR theory is (c) it contains Cs^+ and I_3^- ions (d) it contains Cs^{3+} and I^{-} ions. (a) trigonal bipyramidal (b) square pyramidal (2014)(c) octahedral (d) pentagonal planar. **29.** Stability of the species Li_2 , Li_2^- and Li_2^+ increases in the (Online 2015) order of (a) $Li_2^- < Li_2 < Li_2^+$ (c) $Li_2^- < Li_2^+ < Li_2$ 23. After understanding the assertion and reason, choose the (b) $Li_2 < Li_2^+ < Li_2^-$ (d) $Li_2 < Li_2^- < Li_2^+$ correct option. (2013)Assertion : In the bonding molecular orbital (MO) of H₂, 30. In which of the following pairs of molecules/ions, both the electron density is increased between the nuclei. species are not likely to exist? **Reason :** The bonding MO is $\psi_A + \psi_B$, which shows destructive (b) H_2^+ , He_2^{2-} (a) H_2^- , He_2^{2+} interference of the combining electron waves. (d) H_2^{2+} , He_2 (c) H_2^{-}, He_2^{2-} (a) Assertion and reason are correct and reason is the (2013)correct explanation for the assertion. 31. Which one of the following molecules is expected to exhibit Assertion and reason are correct, but reason is not (b)diamagnetic behaviour? the correct explanation for the assertion. (d) O₂ (a) S₂ (b) C₂ (c) N_2 Assertion is correct, reason is incorrect. (c) (2013)(d) Assertion is incorrect, reason is correct. 32. The molecule having smallest bond angle is (Online 2015) (a) AsCl₃ (b) SbCl₃ (c) PCl_3 (d) NCl₃ 24. Molecule AB has a bond length of 1.617 Å and a dipole (2012)moment of 0.38 D. The fractional charge on each atom (absolute magnitude) is $(e_0 = 4.802 \times 10^{-10} \text{ esu})$ 33. In which of the following pairs the two species are not (b) 0.05 (c) 0.5 (d) 1.0 (a) 0 isostructural? (b) PF_5 and BrF_5 (d) CO_3^{2-} and NO_3^{-} (a) PCl_4^+ and $SiCl_4$ (c) AlF_6^{3-} and SF_6 (Online 2015) 25. Which compound exhibits maximum dipole moment among (2012)the following? **34.** The structure of IF_7 is NO_2 (a) square pyramid (b) trigonal bipyramid NO_2 (c) octahedral (d) pentagonal bipyramid. (2011)(a) **35.** The hybridisation of orbitals of N atom in NO_3^- , NO_2^+ and NH_4^+ are respectively (a) sp, sp^2 , sp^3 (c) sp, sp^3 , sp^2 (b) sp^2 , sp, sp^3 (d) sp^2 , sp^3 , spNH₂ (2011) $\sqrt{O_2}$ NO_2 36. Among the following the maximum covalent character is NH₂ shown by the compound (d)(c) (a) FeCl₂ (b) SnCl₂ (c) $AlCl_3$ (d) MgCl₂ (2011) NH_2 37. Using MO theory predict which of the following species (Online 2015) has the shortest bond length? 26. Which one of the following properties is not shown by (c) $\bar{O_2}$ (d) $O_2^{2^-}$ (a) O_2^{2} (b) O_2^+ NO? (2009)

- 38. Which one of the following constitutes a group of the isoelectronic species?
 - (b) C_2^{2-}, O_2^-, CO, NO (d) $CN^-, N_2, O_2^{2-}, C_2^{2-}$ (a) N_2, O_2^-, NO^+, CO (c) $NO^+, C_2^{2-}, CN^-, N_2$ (2008)
- **39.** Which one of the following pairs of species have the same bond order?
 - (a) NO^+ and CN^+ (b) CN^{-} and NO^{+} (c) CN^{-} and CN^{+} (d) O_2^- and CN^- (2008)
- 40. Which of the following hydrogen bonds is the strongest?
 - (a) O H - F (b) O — H - - - H (c) F — H - - - F (d) O — H - - - O (2007)
- 41. In which of the following ionization processes, the bond order has increased and the magnetic behaviour has changed?

(a)
$$N_2 \rightarrow N_2^+$$
 (b) $C_2 \rightarrow C_2^+$
(c) $NO \rightarrow NO^+$ (d) $O_2 \rightarrow O_2^+$ (2007)

- 42. The charge/size ratio of a cation determines its polarizing power. Which one of the following sequences represents the increasing order of the polarizing power of the cationic $\begin{array}{l} \text{species, } K^+, \ Ca^{2+}, \ Mg^{2+}, \ Be^{2+}?\\ \text{(a)} \quad Ca^{2+} < Mg^{2+} < Be^+ < K^+\\ \text{(b)} \quad Mg^{2+} < Be^{2+} < K^+ < Ca^{2+}\\ \text{(c)} \quad Be^{2+} < K^+ < Ca^{2+} < Mg^{2+}\\ \text{(d)} \quad K^+ < Ca^{2+} < Mg^{2+} < Be^{2+} \\ \end{array}$

 - (2007)
- 43. Which of the following species exhibits the diamagnetic behaviour?
 - (b) O_2^{2-} (a) NO (c) O_2^+ (d) O_2 (2007)
- 44. In which of the following molecules/ions are all the bonds not equal?

(d) BF₄ (a) SF_4 (b) SiF_4 (c) XeF_4 (2006)

- 45. Among the following mixtures, dipole-dipole as the major interaction, is present in
 - (a) benzene and ethanol
 - (b) acetonitrile and acetone
 - (c) KCl and water
 - (d) benzene and carbon tetrachloride. (2006)
- 46. Which of the following molecules/ions does not contain unpaired electrons?

(a)
$$O_2^{2-}$$
 (b) B_2 (c) N_2^{+} (d) O_2 (2006)

47. Of the following sets which one does NOT contain isoelectronic species?

(a)
$$PO_4^{-7}$$
, SO_4^{-7} , CIO_4^{-7}
(b) CN^{-7} , N_2 , C_2^{-7}
(c) SO_3^{2-7} , CO_3^{2-7} , NO_3^{-7}
(d) BO_3^{3-7} , CO_3^{2-7} , NO_3^{-7}
(2005)

48. Which one of the following species is diamagnetic in nature? (a) He_2^+ (b) H₂ (c) H_2^+ (d) H_2^- (2005)

- 49. The maximum number of 90° angles between bond pair-bond pair of electrons is observed in
 - (a) dsp^3 hybridisation (c) dsp^2 hybridisation (b) sp^3d hybridisation
 - (d) sp^3d^2 hybridisation. (2004)
- 50. Which one of the following has the regular tetrahedral structure? (b) SF_4 (c) BF_4 (a) XeF_4 (d) $[Ni(CN)_4]^2$ (Atomic nos.: B = 5, S = 16, Ni = 28, Xe = 54) (2004)
- **51.** The bond order in NO is 2.5 while that in NO^+ is 3. Which of the following statements is true for these two species?
 - Bond length in NO^+ is greater than in NO. (a)
 - (b) Bond length in NO is greater than in NO^+ .
 - Bond length in NO^+ is equal to that in NO. (c)
 - Bond length is unpredictable. (2004)(d)
- **52.** The correct order of bond angles (smallest first) in H₂S, NH₃, BF₃ and SiH₄ is

(a)
$$H_2S < SiH_4 < NH_3 < BF_3$$
 (b) $NH_3 < H_2S < SiH_4 < BF_3$
(c) $H_2S < NH_2 < SiH_4 < BF_2$ (d) $H_2S < NH_2 < BF_2 < SiH_4$

53. The pair of species having identical shapes for molecules of both species is

(a)
$$CF_4$$
, SF_4 (b) XeF_2 , CO_2
(c) BF_3 , PCl_3 (d) PF_5 , IF_5 (2003)

54. Which one of the following compounds has the smallest bond angle in its molecule?

(a)
$$SO_2$$
 (b) OH_2 (c) SH_2 (d) NH_3 (2003)

55. Which of the following are arranged in an increasing order of their bond strengths?

(a)
$$O_2^- < O_2 < O_2^+ < O_2^{2-}$$

(b) $O_2^{2-} < O_2^- < O_2 < O_2^+$
(c) $O_2^- < O_2^{2-} < O_2 < O_2^+$
(d) $O_2^+ < O_2 < O_2^{2-} < O_2^{2-}$
(2002)

56. A square planar complex is formed by hybridisation of which atomic orbitals?

(a)
$$s, p_x, p_y, d_{yz}$$

(b) $s, p_x, p_y, d_{x^2-y^2}$
(c) s, p_x, p_y, d_{z^2}
(d) s, p_y, p_z, d_{xy}
(2002)

- 57. Number of sigma bonds in P_4O_{10} is (a) 6 (b) 7 (d) 16 (2002) (c) 17
- 58. In which of the following species is the underlined carbon having sp³ hybridisation? (a) CH_3COOH $CH_3 \underline{C}H_2 OH$ (c) CH₃COCH₃

(d)
$$CH_2 = \underline{C}H - CH_3$$
 (2002)

59. In which of the following species the interatomic bond angle is 109°28'?

(a)
$$NH_3, (BF_4)^-$$
 (b) $(NH_4)^+, BF_3$
(c) NH_3, BF_3 (d) $(NH_2)^-, BF_3$ (2002)

ANSWER KEY												
1.	(d)	2. (c)	3. (c)	4. (b)	5. (a)	6. (c)	7. (b)	8. (a)	9. (a)	10. (b)	11. (a)	12. (d)
13.	(c)	14. (b)	15. (d)	16. (b)	17. (a)	18. (d)	19. (a)	20. (b)	21. (b)	22. (b)	23. (c)	24. (b)
25.	(b)	26. (b)	27. (a)	28. (c)	29. (c)	30. (d)	31. (b, c)	32. (b)	33. (b)	34. (d)	35. (b)	36. (c)
37.	(a)	38. (c)	39. (b)	40. (c)	41. (c)	42. (d)	43. (b)	44. (a)	45. (b)	46. (a)	47. (c)	48. (b)
49.	(d)	50. (c)	51. (b)	52. (c)	53. (b)	54. (c)	55. (b)	56. (b)	57. (d)	58. (b)	59. (a)	

1. (d) : $\text{He}_2^{2^+}(2 \text{ electrons}) \Rightarrow \sigma 1s^2$ B.O. $= \frac{2}{2} = 1$ He₂⁺ (3 electrons) $\Rightarrow \sigma 1s^2 \sigma^* 1s^1$ B.O. $= \frac{2-1}{2} = 0.5$ H₂⁻ (3 electrons) $\Rightarrow \sigma 1s^2 \sigma^* 1s^1$ B.O. $= \frac{2-1}{2} = 0.5$ H₂²⁻ (4 electrons) $\Rightarrow \sigma 1s^2 \sigma^* 1s^2$ B.O. $= \frac{2-2}{2} = 0$

Thus, H_2^{2-} cannot exist as it has zero bond order.

2. (c) : KCl is an ionic compound. While all other compounds contain covalent bond.

 $\begin{array}{c} : \vec{I}: \quad \neg^{-} \\ \vdots \vec{I}: \quad \neg^{-} \\ \mathbf{3.} \quad (\mathbf{c}): \quad \bigcirc \mid I \\ : \vec{I}: \\ : \vec{I}: \end{array}$

Total lone pairs = 9

4. (b) : Molecular orbital electronic configuration of N_2^+ : $\sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \pi 2p_x^2 = \pi 2p_y^2 \sigma 2p_z^1$ Therefore, the number of electrons in $\sigma 2p_z$ M.O. = 1 5. (a) : Species Bond angle

 $\begin{array}{cccc} BF_{3} & 120^{\circ} \\ NH_{3} & 107^{\circ} \\ PF_{3} & 100^{\circ} \\ I_{3}^{-} & 180^{\circ} \end{array}$

BF₃ is trigonal planar (sp^2 hybridised). NH₃ is pyramidal (sp^3 hybridised) with one lone pair. PF₃ is also pyramidal but its bond angle is lesser than NH₃ due to lesser bond pair repulsions than NH₃ as fluorine is more electronegative than hydrogen, the electron pairs are attracted more towards F, giving lesser repulsion between bond pairs in PF₃. I₃ has linear shape.

6. (c) : The structure of hydrogen azide is (I)

$$H - N \stackrel{(I)}{=} N \stackrel{(II)}{=} N$$

Bond order of bond I is less than 2. Bond order of bond II is greater than 2.

7. (b) : Geometries of the species are given as :







This compound has greater magnitude of resultant dipole moment.



10. (b) : NF₃ has a trigonal pyramidal molecular geometry.



12. (d): (a) $O_2(16): \sigma 1s^2 \sigma * 1s^2 \sigma 2s^2 \sigma * 2s^2 \sigma 2p_z^2 \pi 2p_x^2 = \pi 2p_y^2 \pi * 2p_x^1$ = $\pi * 2p_y^1$

Number of unpaired electrons = 2 (paramagnetic) (b) $B_2(10): \sigma_1s^2 \sigma_1s^2 \sigma_2s^2 \sigma_2s^2 \sigma_2p_x^2 = \pi_2p_y^1$ Number of unpaired electrons = 2 (paramagnetic) (c) NO(15): $\sigma_1s^2 \sigma_1s^2 \sigma_2s^2 \sigma_2s^2 \sigma_2p_z^2 = \pi_2p_y^2 \sigma_2p_x^2$ Number of unpaired electron = 1 (paramagnetic) (d) CO(14): $\sigma_1s^2 \sigma_1s^2 \sigma_2s^2 \sigma_2s^2 \sigma_2s^2 \sigma_2p_x^2 = \pi_2p_y^2 \sigma_2p_z^2$ Number of unpaired electron = 0 (diamagnetic)

13. (c) : The species having same number of electrons are called isoelectronic species.

Number of e^- s in O²⁻ = 8 + 2 = 10 Number of e^- s in F⁻ = 9 + 1 = 10 Number of e^- s in Na⁺ = 11 - 1 = 10 Number of e^- s in Mg²⁺ = 12 - 2 = 10 Therefore, the ions, given in option (c) are isoelectronic.

14. (b) : Hybridization
$$(X) = \frac{1}{2} [VE + MA - c + a]$$

where, VE = No. of valence electrons,

MA = No. of monovalent atoms/groups surrounding the central atom, c = Charge on the cation, a = Charge on the anion

(a)
$$SF_6 \Rightarrow X = \frac{1}{2} [6 + 6 - 0 + 0] = 6 \Rightarrow sp^3d^2$$

(b)
$$PF_5 \Rightarrow X = \frac{1}{2} [5 + 5 - 0 + 0] = 5 = sp^3d$$

(c) $[CrF_6]^{3-} = sp^3d^2$ hybridisation

(d)
$$[BrF_5] \Rightarrow X = \frac{1}{2}[7+5+0+0] = 6 = sp^3d^2$$

Hence, PF₅ exhibits sp^3d hybridization, not sp^3d^2 .

15. (d) : According to MOT,

CO(14) : $KK \sigma 2s^2$, $\sigma^2 2s^2$, $\sigma 2p_z^2$, $\pi 2p_x^2 = \pi 2p_y^2$ No unpaired electron, hence diamagnetic. NO⁺(14) : $KK \sigma 2s^2$, $\sigma^2 2s^2$, $\sigma 2p_z^2$, $\pi 2p_x^2 = \pi 2p_y^2$ No unpaired electron, hence diamagnetic $O_2^{2-}(18) : KK \sigma 2s^2$, $\sigma^2 2s^2$, $\pi 2p_x^2 = \pi 2p_y^2$, $\sigma 2p_z^2$, $\pi^2 2p_x^2 = \pi^2 2p_y^2$ No unpaired electron, hence diamagnetic $B_2(10) : KK \sigma 2s^2$, $\sigma^2 2s^2$, $\pi 2p_x^1$, $\pi 2p_y^1$ Two unpaired electrons, hence paramagnetic.

16. (b) : CO_3^{2-} , NO_3^{-} , $SO_3 : sp^2$ hybridised

16. (**b**) : CO₃ , NO₃ , SO₃ : *sp* hybridised **17.** (**a**) : $\begin{bmatrix} O = N = O \end{bmatrix}^{+}$ *sp* hybridisation $\begin{bmatrix} O \\ | i \\ O \end{bmatrix}^{-}$ *sp*² hybridisation $\begin{bmatrix} O \\ | i \\ O \end{bmatrix}^{-}$ *sp*² hybridisation *sp*² hybridisation

18. (d) : Evaluate the hybridisation of all the molecules to predict their shape.

$$H = \frac{1}{2} [VE + MA - c + a]$$

CIF₃, $H = \frac{1}{2} (7 + 3 - 0 + 0) = 5 (sp^3d)$
XeOF₂, $H = \frac{1}{2} (8 + 2 - 0 + 0) = 5 (sp^3d)$
XeF₃⁺, $H = \frac{1}{2} (8 + 3 - 1 + 0) = 5 (sp^3d)$

All molecules have 3 bond pairs and 2 lone pairs, thus, they have T-shape.

19. (a) : Na⁺ :
$$1s^22s^22p^6$$

F⁻ : $1s^22s^22p^6$

20. (b):

Molecule	Hybridisation	Bond angle
PH_3	sp^3	93.6°
CH ₄	sp^3	109°28′
NH ₃	sp^3	107.8°
H ₂ O	sp^3	104.5°

21. (b) : Dipole-dipole interaction (hydrogen bonding) is proportional to $1/r^3$, where r is the distance between the polar molecules.

22. (b) : In XeOF₄, Xe is sp^3d^2 hybridised and has square pyramidal geometry.

$$M$$
 dq N M W N

23. (c) : Bonding molecular orbital involves constructive interference.

24. (b) : Dipole moment (μ) = $q \times d$ d(distance) = 1.617 Å = 1.617 × 10⁻⁸ cm μ = 0.38 D = 0.38 × 10⁻¹⁸ esu cm

$$= \frac{\mu}{63} = \frac{538 = \times 65^{-6=}}{636 \times 65^{-6}}$$

$$] \{ 1r - mo\mu \{ z \mod ms q D \frac{Xm\mu oxq ot \max q}{^{\wedge} \{ \mu mx ot \max q = \frac{n}{n} \}} = \frac{538 = \times 65^{-6=}}{636 \times 65^{-6} \times 93 = 57 \times 65^{-65}} = 5359 => \approx 535$$
25. (b) :

26. (b) : The electronic configuration of NO molecule is NO(15):
$$\sigma_{1s^2}, \sigma_{1s^2}, \sigma_{2s^2}, \sigma_{2s^2}, \sigma_{2p^2}, (\pi_{2p^2_x} = \pi_{2p^2_y}), (\pi_{2p^2_x} = \pi_{2p^2_y})$$
 This indicates that it has one unpaired electron in its outermost shell. So, NO molecule is paramagnetic in the gaseous state.

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

NO combines with O₂ to give NO₂.
2NO + O₂ \longrightarrow 2NO₂

It is neutral to litmus *i.e.* neutral in nature.



28. (c) : Cs cannot show +3 oxidation state. So, CsI₃ is formulated as Cs⁺ and I_3^- ions. It is a typical ionic compound.

29. (c) : Species Bond order Li_{2} 1 Li_{2} 0.5 Li_{2}^{+} 0.5

The bond order of Li_2^- and Li_2^+ is same but Li_2^+ is more stable than Li_2^- because it has less number of antibonding electrons. Hence, $Li_2^- < Li_2^+ < Li_2$.

30. (d) : Species with zero bond order does not exist. $H_2^{2+}: \sigma(1s)^0$

 \therefore Bond order = 0

 $\operatorname{He}_2: \sigma(1s)^2 \sigma^*(1s)^2$

Bond order = $\frac{2-2}{2} = 0$

31. (b, c) : The electronic configuration of the given molecules are :

$$\begin{split} & C_{2}: KK(\sigma 2s)^{2} (\sigma^{*}2s)^{2} (\pi 2p_{x})^{2} (\pi 2p_{y})^{2} \\ & N_{2}: KK(\sigma 2s)^{2} (\sigma^{*}2s)^{2} (\pi 2p_{x})^{2} (\pi 2p_{y})^{2} (\sigma^{*}2p_{z})^{2} \\ & O_{2}: KK(\sigma 2s)^{2} (\sigma^{*}2s)^{2} (\sigma 2p_{z})^{2} (\pi 2p_{x})^{2} (\sigma 2p_{y})^{2} (\pi^{*}2p_{x})^{1} (\pi^{*}2p_{y})^{1} \\ & S_{2}: KK(\sigma 3s)^{2} (\sigma^{*}3s)^{2} (\pi 3p_{x})^{2} (\pi 3p_{y})^{2} (\sigma^{*}3p_{z})^{2} (\pi^{*}3p_{x})^{1} (\pi^{*}3p_{y})^{1} \end{split}$$

The molecules C_2 and N_2 do not possess unpaired electrons. Hence, these are expected to exhibit diamagnetic behaviour.

32. (b): As we move down the group the size of atom increases and as size of central atom increases, lone pair-bond pair repulsion also increases. Thus bond angle decreases.

Increasing order of atomic radius : N < P < As < SbDecreasing order of bond angle : $NCl_3 > PCl_3 > AsCl_3 > SbCl_3$

33. (b) : PCl_4^+ and $SiCl_4 \Rightarrow$ both tetrahedral

 $PF_5 \implies$ trigonal bipyramidal

 $BrF_5 \Rightarrow square pyramidal$

 AlF_6^{3-} and SF_6 both are octahedral, CO_3^{2-} and NO_3^{-} both are trigonal planar.

34. (d) : The structure is pentagonal bipyramidal having sp^3d^3 hybridisation as given below:



35. (b) : The structures of NO_3^- , NO_2^+ and NH_4^+ is

$$\begin{array}{c} O - \overset{+}{N} \leqslant \overset{O^{-}}{O} & sp^{2} \text{ hybridisation} \\ O = \overset{+}{N} = O & sp \text{ hybridisation} \\ \begin{bmatrix} H \\ I \\ N \\ H & H \end{bmatrix}^{+} & sp^{3} \text{ hybridisation} \end{array}$$

36. (c) : We know that, extent of polarisation ∞ covalent character in ionic bond.

Fajan's rule states that

(i) the polarising power of cation increases, with increase in magnitude of positive charge on the cation

 \therefore Polarising power \propto charge of cation

(ii) the polarising power of cation increases with the decrease in the size of a cation.

$$\therefore$$
 Polarising power $\propto \frac{1}{\text{size of cation}}$

Here the AlCl₃ is satisfying the above two conditions *i.e.*, Al is in +3 oxidation state and also has small size. So it has more covalent character.

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

$$O_{2}^{2^{+}} : (\sigma 1s)^{2} (\sigma^{*} 1s)^{2} (\sigma 2s)^{2} (\sigma^{*} 2s)^{2} (\sigma 2p_{z})^{2} (\pi 2p_{x})^{2} = (\pi 2p_{y})^{2}$$

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

$$O_{2}^{+} : (\sigma 1s)^{2} (\sigma^{*} 1s)^{2} (\sigma 2s)^{2} (\sigma^{*} 2s)^{2} (\sigma 2p_{z})^{2} (\pi 2p_{x})^{2} = (\pi 2p_{y})^{2} (\pi^{*} 2p_{x})^{1}$$

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

$$O_{2}^{-} : (\sigma 1s)^{2} (\sigma^{*} 1s)^{2} (\sigma 2s)^{2} (\sigma^{*} 2s)^{2} (\sigma 2p_{z})^{2} (\pi 2p_{x})^{2} = (\pi 2p_{y})^{2} (\pi^{*} 2p_{x})^{2}$$

$$= (\pi^{*} 2p_{y})^{1}$$

$$\therefore B.O. = \frac{10-7}{2} = 1.5$$

$$O_{2}^{2^{-}} : (\sigma 1s)^{2} (\sigma^{*} 1s)^{2} (\sigma 2s)^{2} (\sigma^{*} 2s)^{2} (\sigma 2p_{z})^{2} (\pi 2p_{x})^{2} = (\pi 2p_{y})^{2} (\pi^{*} 2p_{x})^{2}$$

$$= (\pi^{*} 2p_{y})^{2}$$

$$\therefore B.O. = \frac{10-8}{2} = 1.0$$

$$\therefore B.O. \approx \frac{1}{\text{Bond length}}$$

$$\therefore O_2^{2^+} \text{ has the shortest bond length.}$$

38. (c) : Number of electrons in each species are given below $N_2 = 14$ $O_2^- = 17$ $NO^+ = 14$ CO = 14 $CN^- = 14$ $C_2^{2-} = 14$ $O_2^{2-} = 18$ NO = 15It is quite evident from the above that NO^+ , C_2^{2-} , CN^- , N_2 and COare isoelectronic in nature. Hence option (c) is correct.

39. (b) : In the given pair of species, number of electron in NO^+ = number of electron in CN^- = 14 electrons. So they are isoelectronic in nature.

Hence bond order of these two species will be also similar which is shown below.

 $\begin{array}{l} \mathrm{NO}^+ \to \sigma 1 s^2 \ \sigma^* 1 s^2 \ \sigma 2 s^2 \ \sigma^* 2 s^2 \ \sigma 2 p_z^2 \ \pi 2 p_x^2 \ \pi 2 p_y^2 \\ \mathrm{B.O} = 1/2 \ [N_b - N_a] = 1/2 \ [10 - 4] = 3 \\ \mathrm{CN}^- \to \sigma 1 s^2 \ \sigma^* 1 s^2 \ \sigma 2 s^2 \ \sigma^* 2 s^2 \ \pi 2 p_x^2 \ \pi 2 p_y^2 \ \sigma 2 p_z^2 \end{array}$ B.O =1/2 [10 - 4] 40. (c) : Because of highest electronegativity of F,

hydrogen bonding in F — H - - - F is strongest.

41. (c) : Molecular orbital configuration of

 $N_2 \Rightarrow \sigma 1 s^2 \sigma^* 1 s^2 \sigma 2 s^2 \sigma^* 2 s^2 \pi 2 p_x^2 \pi 2 p_y^2 \sigma 2 p_z^2 \Rightarrow paramagnetic$

Bond order = $\frac{10-4}{2} = 3$ $N_2^+ \Rightarrow \sigma 1s^2 \sigma s 1s^2 \sigma 2s^2 \sigma s 2s^2 \pi 2p_x^2 \pi 2p_y^2 \sigma 2p_z^1 \Rightarrow \text{ paramagnetic}$ Bond order = $\frac{9-4}{2}$ = 2.5

 $C_{2} \Rightarrow \sigma 1s^{2} \sigma^{*} 1s^{2} \sigma 2s^{2} \sigma^{*} 2s^{2} \pi 2p_{x}^{2} \pi 2p_{y}^{2} \Rightarrow \text{diamagnetic}$ Bond order = $\frac{8-4}{2} = 2$ $C_{2}^{+} \Rightarrow \sigma 1s^{2} \sigma^{*} 1s^{2} \sigma 2s^{2} \sigma^{*} 2s^{2} \pi 2p_{x}^{2} \pi 2p_{y}^{1} \Rightarrow \text{paramagnetic}$ Bond order = $\frac{7-4}{2} = 1.5$ NO $\Rightarrow \sigma 1s^{2} \sigma^{*} 1s^{2} \sigma 2s^{2} \sigma^{*} 2s^{2} \sigma 2p_{z}^{2} \pi 2p_{x}^{2} \pi 2p_{y}^{2} \pi^{*} 2p_{x}^{1}$

 \Rightarrow paramagnetic

Bond order = $\frac{10-5}{2}$ = 2.5 NO⁺ $\Rightarrow \sigma 1s^2 \sigma * 1s^2 \sigma 2s^2 \sigma * 2s^2 \sigma 2p_z^2 \pi 2p_x^2 \pi 2p_y^2 \Rightarrow$ diamagnetic Bond order = $\frac{10-4}{2}$ = 3 $O_2 \Rightarrow \sigma 1s^2 \sigma r 1s^2 \sigma 2s^2 \sigma r 2s^2 \sigma 2p_z^2 \pi 2p_x^2 \pi 2p_y^2 \pi r 2p_x^1 \pi r 2p_y^1$

 \Rightarrow paramagnetic

Bond order = $\frac{10-6}{2}$ = 2 $O_2^+ \Rightarrow \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z^2 \pi 2p_x^2 \pi 2p_y^2 \pi^* 2p_x^1$

 \Rightarrow paramagnetic

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

42. (d) : High charge and small size of the cations increases polarisation.

As the size of the given cations decreases as $K^+ > Ca^{2+} > Mg^{2+} > Be^{2+}$ Hence, polarising power decreases as $K^+ < Ca^{2+} < Mg^{2+} < Be^{2+}$

43. (b) : Molecular orbital configuration is NO $\Rightarrow \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z^2 \pi 2p_y^2 \pi 2p_y^2 \pi^* 2p_y^2$ \Rightarrow paramagnetic $O_2 \implies \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z^2 \pi 2p_z^2 \pi 2p_y^2 \pi^* 2p_y^1 \pi^* 2p_y^1$ \Rightarrow paramagnetic

 $O_2^{2-} \Rightarrow \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z^2 \pi 2p_x^2 \pi 2p_y^2 \pi^* 2p_x^2 \pi^* 2p_y^2$ $\stackrel{\sim}{\Rightarrow} \begin{array}{l} \text{diamagnetic} \\ \text{O}_2^+ \Rightarrow \sigma 1 s^2 \, \sigma^* 1 s^2 \, \sigma 2 s^2 \, \sigma^* 2 s^2 \, \sigma 2 p_z^2 \, \pi 2 p_x^2 \, \pi 2 p_y^2 \, \pi^* 2 p_x^1 \end{array}$ \Rightarrow paramagnetic 44. (a):



 SiF_4 : sp^3 hybridisation and tetrahedral geometry.



 $XeF_4: sp^3d^2$ hybridisation, shape is square planar instead of octahedral due to presence of two lone pair of electrons on Xe atom.



 BF_{4}^{-} : sp^{3} hybridisation and tetrahedral geometry.

45. (b) : Dipole-dipole interactions occur among the polar molecules. Polar molecules have permanent dipoles. The positive pole of one molecule is thus attracted by the negative pole of the other molecule. The magnitude of dipole-dipole forces in different polar molecules is predicted on the basis of the polarity of the molecules, which in turn depends upon the electronegativities of the atoms present in the molecule and the geometry of the molecule (in case of polyatomic molecules, containing more than two atoms in a molecule).

46. (a) : The molecular orbital configuration of O_2^{2-} ion is *KK* $\sigma(2s)^2 \sigma^*(2s)^2 \sigma(2p_z)^2 \pi(2p_x)^2 \pi(2p_y)^2 \pi^*(2p_x)^2 \pi^*(2p_y)^2$ Here KK represents non-bonding molecular orbital of 1s orbital. O_2^{2-} contains no unpaired electrons. The molecular orbital configuration of B₂ molecule is $KK \sigma(2s)^2 \sigma^*(2s)^2 \pi(2p_x)^1 \pi(2p_y)^1$ It contains 2 unpaired electrons. The molecular orbital configuration of N_2^+ ion is $KK \sigma(2s)^2 \sigma^*(2s)^2 \sigma(2p_z)^2 \pi(2p_y)^2 \pi(2p_y)^2 \sigma(2p_z)^1$ It contains one unpaired electron. The molecular orbital configuration of O₂ molecule is $KK \sigma(2s)^2 \sigma^*(2s)^2 \pi(2p_x)^2 \pi(2p_y)^2 \sigma(2p_z)^2 \pi^*(2p_x)^1 \pi^*(2p_y)^1$ It contains 2 unpaired electrons.

47. (c) : Number of electrons in $SO_3^{2-} = 16 + 8 \times 3 + 2 = 42$ Number of electrons in $CO_3^{2-} = 6 + 8 \times 3 + 2 = 32$ Number of electrons in $NO_3^- = 7 + 8 \times 3 + 1 = 32$ These are not isoelectronic species as number of electrons are not same.

48. (b) : $\text{He}_2^+ \rightarrow \sigma(1s)^2 \sigma^*(1s)^1$, one unpaired electron $\text{H}_2 \rightarrow \sigma(1s)^2 \sigma^*(1s)^0$, no unpaired electron

 $H_2^+ \rightarrow \sigma(1s)^1 \sigma^*(1s)^0$, one unpaired electron

 $H_2^- \rightarrow \sigma(1s)^2 \sigma^*(1s)^1$, one unpaired electron $H_2^- \rightarrow \sigma(1s)^2 \sigma^*(1s)^1$, one unpaired electron.

Due to absence of unpaired electrons, H_2 will be diamagnetic.





51. (b): Higher the bond order, shorter will be the bond length. Thus NO^+ is having higher bond order than that of NO so NO^+ has shorter bond length.

52. (c) : The correct order of bond angle (smallest first) is

$$H_2S < NH_3 < SiH_4 < BF_3$$

92.6° < 107° < 109°28' < 120°



53. (b) : Central atom in each being *sp* hybridised shows linear shape.

F - Xe - F O = C = O

54. (c) : SO₂ OH₂ SH₂ NH₃ Bond angle : 119.5° 104.5° 92.5° 106.5°

55. (b) : Molecular orbital configuration of

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

$$\pi^{*}(2p_{y})^{1}; B.O. = \frac{10-6}{2} = 2$$

$$O_{2}^{+} \Rightarrow \sigma(1s)^{2} \sigma^{*}(1s)^{2} \sigma(2s)^{2} \sigma^{*}(2s)^{2} \sigma(2p_{z})^{2} \pi(2p_{x})^{2} \pi(2p_{y})^{2}$$

$$\pi^{*}(2p_{x})^{1}; B.O. = \frac{10-5}{2} = 2.5$$

$$O_{2}^{-} \Rightarrow \sigma(1s)^{2} \sigma^{*}(1s)^{2} \sigma(2s)^{2} \sigma^{*}(2s)^{2} \sigma(2p_{z})^{2} \pi(2p_{x})^{2} \pi(2p_{y})^{2} \pi^{*}(2p_{x})^{2}$$

$$\pi^{*}(2p_{y})^{1}; B.O. = \frac{10-7}{2} = 1.5$$

$$O_{2}^{2-} \Rightarrow \sigma(1s)^{2} \sigma^{*}(1s)^{2} \sigma(2s)^{2} \sigma^{*}(2s)^{2} \sigma(2p_{z})^{2} \pi(2p_{x})^{2} \pi(2p_{y})^{2} \pi^{*}(2p_{x})^{2}$$

$$\pi^{*}(2p_{y})^{2}; B.O. = \frac{10-8}{2} = 1$$

Hence increasing order of bond order is :

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

56. (b) : dsp^2 hybridisation gives square planar structure with s , p_x , p_y and $d_{x^2-y^2}$ orbitals with bond angles of 90°.

57. (d):
$$\bigcirc = P - \bigcirc P - \bigcirc P = \square P = [P = P =] P = [P =]$$

No. of σ bonds = 16 No. of π bonds = 4

58. (b): In molecules (a)
$$\begin{pmatrix} 0 \\ || \\ CH_3 - C - OH \end{pmatrix}$$
, (c) $\begin{pmatrix} 0 \\ || \\ CH_3 - C - CH_3 \end{pmatrix}$

and (d) ($CH_2 = CH - CH_3$), the carbon atom has a multiple bond, only (b) has sp^3 hybridization.

59. (a) : Both undergoes sp^3 hybridization. The expected bond angle should be 109°28' but actual bond angle is less than 109°28' because of the repulsion between lone pair and bonded pairs due to which contraction occurs.

