CHEMICAL BONDING & MOLECULAR STRUCTURES

MULTIPLE CHOICE QUESTIONS

1. The bond angle is minimum in

(a) NH_4^+ (b) NOCl

(c) H_2Se (d) SO_3

Sol. (c)

$NH_4^+ \longrightarrow sp^3$ hybridisation – 109°28′.

$NOCl \longrightarrow sp^2$ hybridisation – 120°

$H_2Se \longrightarrow sp^3$ hybridisation because of lone pair bond angle gets minimized.

$SO_3 \longrightarrow sp^2$ hybridisation 120°.

2. The observed dipole moment of HCl molecule is 1.03 D. If H–Cl bond distance is 1.275 Å and electronic charge is 4.8×10^{-10} e.s.u. The % polarity in HCl will be

(a) 1.275×1.03 % (b) $\frac{4.8\times1.275\times10^{-8}}{1.03}$ %

(c) $\frac{1.03\times100}{4.8\times1.275}$ % (d) $\frac{4.8\times10^{-10}}{1.03} \times 100\%$

Sol. (c)

$$\text{Percentage polarity} = \frac{\text{observed dipole moment of molecules} \times 100}{\text{calculated dipole moment}} \%$$

Here observed dipole moment of HCl = 1.03 D

Calculated dipole moment of HCl = $4.8\times10^{-10} \times 1.275\times10^{-8}$

$= 4.8 \times 1.275$ D

Therefore, % polarity = $\frac{1.03}{4.8\times1.275}\times100\%$.

3. Which of the following has same bond order as NO^+ has?

(a) CN^- (b) O_2^-

(c) CN^+ (d) none of them

Sol. (a)

NO^+ and CN^- both have 14 electrons and also both will have the following configuration.

$\sigma1s^2\sigma^*\ 1s^2\sigma2s^2\sigma^*2s^2\begin{pmatrix}\pi_{2p_y}^{\ 2}\\ \pi_{2p_z}^{\ 2}\end{pmatrix}\sigma2p_x^{\ 2}$

$\therefore$ Bond order of NO^+ = Bond order of CN^- = 3.

4. The correct order of increasing bond angles is

(a) $PF_3< PCl_3< PBr_3< PI_3$ (b) $PI_3< PCl_3< PBr_3< PF_3$

(c) $PI_3< PBr_3< PCl_3< PF_3$ (d) $PCl_3< PBr_3< PI_3< PF_3$

Sol. (a)

As the size of surrounding atom increases the electronic repulsion increases bond angle increases.

5. Which of the following is planar?

(a) XeO_4 (b) XeO_2F_2

(c) XeO_3F_2 (d) XeF_4

Sol. (d)

XeO_4– tetrahedral

XeO_3F_2– trigonal bipyramidal

XeO_2F_2– trigonal bipyramidal

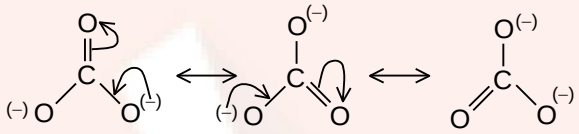
XeF_4– square planar.

6. Which of the following does not contain coordinate bond?

(a) BH_4^- (b) NH_4^+

(c) CO_3^{2-} (d) H_3O^+

Sol. (c)

CO_3^{2-} is 

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

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

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

Sol. (a)

H–O–O–H, O ← O=O, O=O

Due to resonance in O_3, O–O bond length will be in between O=O and O–O.

8. Which species has the maximum number of lone pair of electrons on the central atom?

(a) ClO_3^- (b) XeF_4

(c) SF_4 (d) I_3^-

Sol. (d)

In I_3^-, central atom has 3 lone pair and two bond pair.

9. Which of the following compound has highest covalent character?

(a) NaCl (b) KCl

(c) $MgCl_2$ (d) LiCl

Sol. (c)

More is the charge on cation, more is the polarisation of anion by cation. Hence, more is the covalent character.

10. Which one of the following species is paramagnetic?

(a) O_2^- (b) CN^-

(c) CO (d) NO^+

Sol. (a)

Only O_2^- has unpaired electrons in molecular orbital.

11. The shape of XeO_3 is

(a) T–shaped (b) Tetrahedral

(c) Triangular planar (d) Pyramidal

Sol. (d)

The state of hybridisation of Xe in XeO_3 is sp^3. Three corners of tetrahedron are occupied by the three O–atoms and the fourth corner is occupied by lone pair. Therefore shape of XeO_3 is pyramidal.

12. The shape of XeO_3 is

(a) T–shaped (b) Tetrahedral

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Sol. (d)

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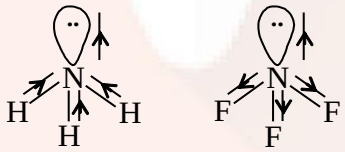
13. Which of the following is arranged in order of increasing dipole moment?

(a) $BCl_3 < NH_3 < H_2O < NF_3$ (b) $BCl_3 < NF_3 < NH_3 < H_2O$

(c) $NH_3 < NF_3 < H_2O < BCl_3$ (d) $H_2O < NF_3 < NH_3 < BCl_3$

Sol. (b)

BCl_3 is a planar species. Hence it has zero dipole moment. Out of NH_3 and NF_3, NH_3 has higher dipole moment because of orientation of bond moments as shown



$\therefore$ Correct order is $BCl_3 < NF_3 < NH_3 < H_2O$.

14. Predict the correct statement with regard to the bond orders of the species CN^+, CN and CN^-.

(a) The bond order of CN^+ is greater than the bond orders of CN and CN^-.

(b) The bond orders of CN^- and CN are greater than the bond order of CN^+.

(c) CN^+ and CN^- have the same bond orders, while that of CN is less than that of CN^+ or CN^-.

(d) The bond orders of CN^+, CN and CN^- are 2, 3 and 2.5 respectively.

Sol. (b)

The bond order of CN^+, CN and CN^- are 2, 2.5 and 3 respectively.

15. $N_0/2$ atoms of X(g) are converted into $X^+(g)$ by energy E_1. $N_0/2$ atoms of X(g) are converted into $X^-(g)$ by energy E_2. Hence, ionization potential and electron affinity of X(g) are: (N_0 is Avogadro Number)

(a) $\frac{2E_1}{N_0}, \frac{2(E_1 - E_2)}{N_0}$

(b) $\frac{2E_1}{N_0}, \frac{2E_2}{N_0}$

(c) $\frac{(E_1 - E_2)}{N_0}, \frac{2E_2}{N_0}$

(d) $2E_1, 2E_2$

Sol. (d)

$X(g) \longrightarrow X^+(g) + e$

If I is ionization energy then

$$\frac{1}{2}(I) = E_1$$

$$I = \mathbf{2E_1}$$

If E is electron affinity then

$$\frac{1}{2}(E) = E_2$$

$E = 2E_2$

16. In XeF_2, XeF_4 and XeF_6 the number of lone pair of electrons on Xe is respectively (Atomic numbers: F = 9, Xe = 54)

(a) 2, 3, 1 (b) 1, 2, 3

(c) 4, 1, 2 (d) 3, 2, 1

Sol. (d)

XeF_2:Xe has got2 bond pairs and 3 lone pairs.

XeF_4: Xe has got 4 bond pairs and 2 lone pairs.

XeF_6:Xe has got 6 bond pairs and 1 lone pair.

17. The resonating structures of isocyanate ion (NCO^-) are

$$\underset{(i)}{O=C=N^-} \longleftrightarrow \underset{(ii)}{{}^-O-C\equiv N} \longleftrightarrow \underset{(iii)}{{}^+O\equiv C-N^{2-}}$$

Choose the most stable resonating structure of NCO^- and give oxidation states of O, C and N is that order.

(a) (i) O(– 3), C(+4), N(–2)

(b) (ii) O(–2), C(+4), N(–3)

(c) (iii) O(–1), C(+4), N(–3)

(d) (i) O(0), C(+4), N(–5)

Sol. (b)

18. Molecular shapes of SF_4, CF_4 and XeF_4 are

(a) same with 2, 0 and 1 lone pairs of electrons respectively.

(b) same with 1, 1 and 1 lone pairs of electrons respectively.

(c) different with 1, 0 and 2 lone pairs of electrons respectively.

(d) different with 1, 1 and 1 lone pairs of electrons respectively.

Sol. (c)

In SF_4, BP = 4, LP = 1, see-saw shaped.

In CF_4, BP = 4, LP = 0, tetrahedral shape.

In XeF_4, BP = 4, LP = 2, square planar shape.

19. Match List I with List II and select the correct answer:

List I (Ion)	**List II (Shapes)**
A. ICl_2^-	1. Linear
B. BrF_2^+	2. Pyramidal
C. ClF_4^-	3. Tetrahedral
D. $AlCl_4^-$	4. Square planar
	5. Angular

	A	B	C	D
(a)	1	2	4	5
(b)	4	5	2	3
(c)	1	5	4	3
(d)	5	1	3	4

Sol. (c)

ICl_2^-; BP = 2 LP = 3; Linear

BrF_2^+; BP = 2 LP = 2; Angular

ClF_4^-; BP = 4 LP = 2; Square planar

$AlCl_4^-$; BP = 4 LP = 0; Tetrahedral

20. In which of the following process, the least energy is released?

(a) $N(g) + e^- \rightarrow N^-(g)$ (b) $O(g) + e^- \rightarrow O^-(g)$

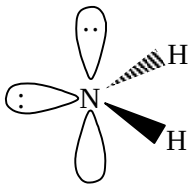
(c) $F(g) + e^- \rightarrow F^-(g)$ (d) $S(g) + e^- \rightarrow S^-(g)$

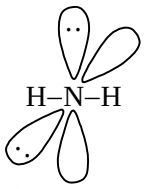
Sol. (a)

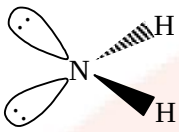
$2p^3$ of N has symmetrical electronic configuration.

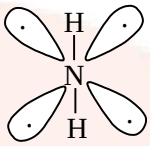
$3p^4$ of s has unsymmetrical electronic configuration.

21. The three–dimensional representation of H_2N^- is

(a) 

(b) 

(c) 

(d) 

Sol. (c)

22. In the formation of N_2^+ from N_2, the electron is lost from a

(a) σ–orbital (b) π–orbital

(c) σ*–orbital (d) π*–orbital

Sol. (a)

M.O. configuration of N_2 is:

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

M.O. configuration of N_2^+ is:

$1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \pi_{2p_y}^2 = \pi_{2p_z}^2 \, \sigma_{2p_x}^1$.

INTEGER TYPE QUESTIONS

23. If MX_3 is T shaped, then the number of lone pair around M is

Sol. (2)

For T–shape 2 lps appear at same side of axial line at plane of paper.

24. The lattice energy of solid NaCl is 180 kcal/mol. The dissolution of the solid in water in the form of ions is endothermic to the extent of 1 kcal/mol. If the solution energies of Na^+ and Cl^- are in the ratio 6:5, what is the enthalpy of hydration of Na^+ ion?

Sol. (b)

$Na^+(g) + Cl^-(g) \longrightarrow NaCl(s)$; $\Delta H = 180$ kcal

$NaCl(s) + aq \longrightarrow Na^+(aq) + Cl^-(aq)$; $\Delta H = 1$ kcal

$Na^+(g) + Cl^-(g) + aq. \longrightarrow Na^+(aq.) + Cl^-(aq.)$; $\Delta H = A$ kcal

$\Delta H_{solution} = \Delta H_{lattice} + \Delta H_{hydration}$

$\therefore \quad 1 = 180 + \Delta H_{hydration}$

$\therefore \quad \Delta H_{hydration} = -179$ kcal $= A$

ΔH_{Na^+} (hydration) + ΔH_{Cl^-} (hydration) = a

ΔH_{Na^+} (hydration) $= \frac{6A}{11} = \frac{6\times(-179)}{11} =$ **– 97.5 kcal**.

25. The lattice energy of solid NaCl is 180 kcal/mol. The dissolution of the solid in water in the form of ions is endothermic to the extent of 1 kcal/mol. If the solution energies of Na^+ and Cl^- are in the ratio 6:5, what is the enthalpy of hydration of Cl^- ion?

Sol. $Na^+(g) + Cl^-(g) \longrightarrow NaCl(s)$; $\Delta H = 180$ kcal

$NaCl(s) + aq \longrightarrow Na^+(aq) + Cl^-(aq)$; $\Delta H = 1$ kcal

$Na^+(g) + Cl^-(g) + aq. \longrightarrow Na^+(aq.) + Cl^-(aq.)$;

$\Delta H = A$ kcal

$\Delta H_{solution} = \Delta H_{lattice} + \Delta H_{hydration}$

$\therefore 1 = 180 + \Delta H_{hydration}$

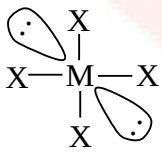
$\therefore \quad \Delta H_{hydration} = -179$ kcal $= A$

ΔH_{Na^+} (hydration) + ΔH_{Cl^-} (hydration) $= A$

ΔH_{Cl^-} (hydration) $= \frac{5A}{11} = \frac{5\times(-179)}{11} =$ **– 81.4 kcal**.

26. A molecule MX_4 has a square planar shape. The number of non-bonding pair of electrons is

Sol. (2)



$\Rightarrow sp^3d^2 \Rightarrow$ Octahedral structure $\Rightarrow$ square planar (geo).

27. The maximum number of H-bonds in which water molecule can participate is

Sol. (4)

28. The dipole moment (in Debye units) of m–dichlorobenzene is 1.72. What is the value of dipole moment for o–dichlorobenzene?

Sol. (2.98)

$$\mu_R = \sqrt{\mu_1^2 + \mu_2^2 + 2\mu_1\mu_2 \cos 120^o} = \sqrt{\mu^2} \qquad (\mu_1 = \mu_2 = \mu)$$

$$\mu = \mu_R = 1.72$$

$$\mu_R = \sqrt{\mu_1^2 + \mu_2^2 + 2\mu_1\mu_2 \cos 60^o} = \sqrt{2\mu^2 + 2\mu^2 \frac{1}{2}} \qquad (\mu_1 = \mu_2 = \mu)$$

$$= \sqrt{3} \times \mu = \sqrt{3} \times 1.72 = \mathbf{2.98\ D}.$$

29. A diatomic molecule has a dipole moment of 1.92 D and a bond length of 2.0Å. What is the percentage ionic character in the molecule if e = 4.8×10^{-10} esu?

Sol. % ionic characters = $\dfrac{\text{observed dipole moment}}{\text{calculated dipole moment assuming 100\% ionic character}} \times 100$

$$= \left[\frac{1.92\ \text{D}}{(4.80 \times 10^{-10}) \times (2 \times 10^{-8}\ \text{cm})}\right] \times 100 = \frac{1.92\ \text{D}}{(4.8 \times 2)\text{D}} \times 100 = \mathbf{20\%}.$$

30. If the electronegativity difference between two atoms A and B is 2.0, then the percentage ionic character in the molecule is

Sol. % ionic character= $16(\Delta E.N) + 3.5(\Delta E.N)^2$

$= 16\ (2) + 3.5\ (2)^2$

$= 46$