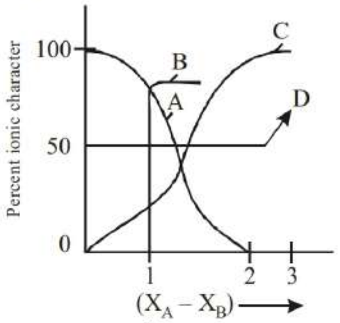
4

CHEMICAL BONDING AND MOLECULAR STRUCTURE

MCQs with One Correct Answer

1. For AB bond if percent ionic character is plotted against electronegativity difference ($X_A - X_B$), the shape of the curve would look like



The correct curve is

(a) (A) (b) (B)

(c) (C) (d) (D)

2. 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 (0.2D). This is because

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

(b) in NH_3 as well as NF_3 the atomic dipole and bond dipole are in opposite directions

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

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

3. Among the following, the species with identical bond order are

(a) CO and O_2^{2-}

(b) O_2^- and CO

(c) O_2^{2-} and B_2

(d) CO and N_2^+

4. Which of the following statements is/are true

1. PH_5 and $BiCl_5$ do not exist
2. $p\pi - d\pi$ bond is present in SO_2
3. I_3^+ has bent geometry
4. SeF_4 and CH_4 have same shape

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

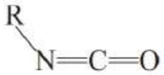
(c) 1, 3, 4 (d) 1, 2, 4

5. The number of sigma (σ) and pi (π) bonds present in 1,3,5,7 octatetraene respectively are

(a) 14 and 3 (b) 17 and 4

(c) 16 and 5 (d) 15 and 4

6. The hybridizations of N, C and O shown in the following compound



respectively, are

(a) sp^2, sp, sp^2 (b) sp^2, sp^2, sp^2

(c) sp^2, sp, sp (d) sp, sp, sp^2

7. The bond dissociation energy of B – F in BF_3 is 646 kJ mol^{-1} whereas that of C – F in CF_4 is 515 kJ mol^{-1}. The correct reason for higher B – F bond dissociation energy as compared to that of C – F is

(a) stronger σ bond between B and F in BF_3 as compared to that between C and F in CF_4.

(b) significant $p\pi - p\pi$ interaction between B and F in BF_3 whereas there is no possibility of such interaction between C and F in CF_4.

(c) lower degree of $p\pi - p\pi$ interaction between B and F in BF_3 than that between C and F in CF_4.

(d) smaller size of B– atom as compared to that of C– atom.

8. The most polarizable ion among the following is

(a) F^- (b) I^-

(c) Na^+ (d) Cl^-

9. Minimum $F-S-F$ bond angle present in :

(a) SSF_2 (b) SF_6

(c) SF_2 (d) F_3SSF

10. Which of the following statement is correct about I_3^+ and I_3^- molecular ions?

(a) Number of lone pairs at central atoms are same in both molecular ions

(b) Hybridization of central atoms in both ions are same

(c) Both are polar species

(d) Both are planar species

11. In which of the following species, *d*-orbitals having *xz* and *yz* two nodal planes involved in hybridization of central atom?

(a) $IO_2F^-_2$

(b) ClF^-_4

(c) IF_7

(d) None of these

12. The type of bonds present in sulphuric anhydride is,

(a) 3σ and three $p\pi - d\pi$

(b) 3σ, one $p\pi - p\pi$ and two $p\pi - d\pi$

(c) 2σ and three $p\pi - d\pi$

(d) 2σ and two $p\pi - d\pi$

13. The correct statement with regard to H_2^+ and H_2^- is

(a) Both H_2^+ and H_2^- do not exist

(b) H_2^- is more stable than H_2^+

(c) H_2^+ is more stable than H_2^-

(d) Both H_2^+ and H_2^- are equally stable

14. The correct order of bond energies in NO, NO^+ and NO^- is:

(a) $NO^- > NO > NO^+$

(b) $NO > NO^- > NO^+$

(c) $NO^+ > NO > NO^-$

(d) $NO^+ > NO^- > NO$

15. Which of the following represents the correct order of Cl–O bond lengths in $ClO^-, ClO_2^-, ClO_3^-, ClO_4^-$?

(a) $ClO_4^- = ClO_3^- = ClO_2^- = ClO^-$

(b) $ClO^- < ClO_2^- < ClO_3^- < ClO_4^-$

(c) $ClO_4^- < ClO_3^- < ClO_2^- < ClO^-$

(d) $ClO_3^- < ClO_4^- < ClO_2^- < ClO^-$

16. Which one of the following molecule will have all equal X—F bond length? (where X = Central atom)

(a) $SOCl_2F_2$ (b) SeF_4

(c) PBr_2F_3 (d) IF_7

17. Select the incorrect statement about N_2F_4 and N_2H_4 :

(I) In N_2F_4, *d*-orbitals are contracted by electronegative fluorine atoms, but *d*-orbital contraction is not possible by H-atom in N_2H_4

(II) The N-N bond energy in N_2F_4 is more than N-N bond energy in N_2H_4

(III) The N-N bond length in N_2F_4 is more than that of in N_2H_4

(IV) The N-N bond length in N_2F_4 is less than that of in N_2H_4

(a) I, II and III

(b) I and III

(c) II and IV

(d) II and III

18. The correct order of 'S—O' bond length is

(a) $SO_3^{2-} > SO_4^{2-} > SO_3 > SO_2$

(b) $SO_3^{2-} > SO_4^{2-} > SO_2 > SO_3$

(c) $SO_4^{2-} > SO_4^{2-} > SO_2 > SO_3$

(d) $SO_4^{2-} > SO_4^{2-} > SO_3 > SO_2$

19. Among the following transformations, the hybridization of the central atom remains unchanged in

(a) $CO_2 \rightarrow HCOOH$

(b) $BF_3 \rightarrow BF_4^-$

(c) $NH_3 \rightarrow NH_4^+$

(d) $PCl_3 \rightarrow PCl_5$

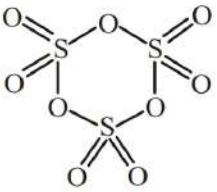
20. In which species, X—O bond order is 1.5 and contains $p\pi - d\pi$ bond(s).

(a) $IO_2F^{-}{}_{2}$ (b) $HCOO^-$

(c) $SO^{2-}{}_{3}$ (d) XeO_2F_2

Numeric Value Answer

21. Consider the following molecule



Calculate the value of $p \div q$, here p and q are total number of $d\pi$–$p\pi$ bonds and total number of sp^3 hybridised atoms respectively in given molecule.

22. Calculate the value of "$x + y - z$" here x, y and z are total number of non-bonded electron pair(s), pie(π) bond(s) and sigma (σ) bonds in hydrogen phosphite ion respectively.

23. Total number of species which used all three *p*-orbitals in hybridisation of central atoms and should be non-polar also are

XeO_2F_2, $SnCl_2$, IF_5, I_3^+, XeO_4, SO_2, XeF_7^+, SeF_4

24. Consider the following orbitals $3s$, $2p_x$, $4d_{xy}$, $4d_z^2$, $3d_{x^2-y^2}$, $3p_y$, $4s$, $4p_z$ and find total number of orbital(s) having even number of nodal plane.

25. For the following molecules :

PCl_5, BrF_3, ICl_2^-, XeF_5^-, NO_3^-, XeO_2F_2, PCl_4^+, CH_3^+

Calculate the value of $\dfrac{a+b}{c}$

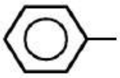
a = Number of species having sp^3d-hybridisation

b = Number of species which are planar

c = Number of species which are non-planar

26. Find total number of orbital which can overlap colaterally, (if inter nuclear axis is z) $s, p_x, p_y, p_z, d_{xy}, d_{yz}, d_{xz}, d_{z^2}, d_{x^2-y^2}$

27. In O_2^- , O_2 and O_2^{2-} molecular species, the sum of the total number of antibonding electrons is _________

28. Dipole moment of  X is 1.6 D. What is the dipole moment of following compound:

29. What is the % of *p*-character with central atom in SF_6 molecule?

30. Consider the following values for an ionic compound NaCl.

$\Delta H_f(NaCl) = -200$ KJ/mol

$\Delta H_{sub}(Na(s)) = 650$ KJ/mol

$\Delta H_{diss}(Cl_2(g)) = 400$ KJ/mol

$I.E._1(Na(g)) = 500$ KJ/mol

Electron gain enthalpy $(Cl(g)) = -350$ KJ/mol

Using Born Haber Cycle, find the value of lattic energy (U) in KJ/mol.

ANSWER KEY																			
1	(c)	**4**	(a)	**7**	(b)	**10**	(d)	**13**	(c)	**16**	(a)	**19**	(c)	**22**	(3)	**25**	(3)	**28**	(1.6)
2	(a)	**5**	(b)	**8**	(b)	**11**	(c)	**14**	(c)	**17**	(b)	**20**	(a)	**23**	(2)	**26**	(6)	**29**	(50)
3	(c)	**6**	(a)	**9**	(d)	**12**	(b)	**15**	(c)	**18**	(b)	**21**	(1)	**24**	(5)	**27**	(21)	**30**	(1200)

Hints & Solutions

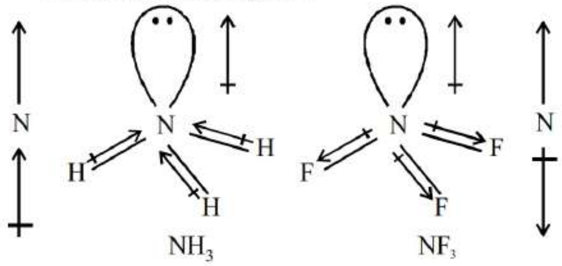
CHAPTER

4

Chemical Bonding and Molecular Structure

1. **(c)** Percent ionic character is given by following equation.
% of ionic character = $16(X_A - X_B) + 3.5(X_A - X_B)^2$
From the above relation, it is clear that as soon as $(X_A - X_B)$ increases, % ionic character will also increase. Therefore, curve C show a correct path.

2. **(a)** In NH_3 the atomic dipole (orbital dipole due to lone pair) and bond dipole are in the same direction whereas in NF_3 these are in opposite direction so in the former case they are added up whereas in the latter case net result is reduction of dipole moment. It has been shown in the following figure :



3. **(c)** $\text{B.O.} = \frac{1}{2}(N_b - N_a)$
where, N_b = electrons in bonding orbitals N_a = electrons in antibonding orbitals.
The electronic configuration of CO (14) is

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

$$\therefore \quad \text{B.O} = \frac{1}{2}(10-4) = \frac{6}{2} = 3$$

The electronic configuration of O_2^{2-} (18) is

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

$$\pi^*2p_x^2 = \pi^*2p_y^2$$

$$\text{B.O} = \frac{1}{2}(10-8) = 1$$

The electronic configuration of O_2^- (17) is

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

$$\pi^*2p_x^2 = \pi^*2p_y^1$$

$$\text{B.O} = \frac{1}{2}(10-7) = \frac{3}{2} = 1.5$$

The electronic configuration of B_2 (10) is

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

$$\text{B.O} = \frac{1}{2}[6-4] = \frac{2}{2} = 1$$

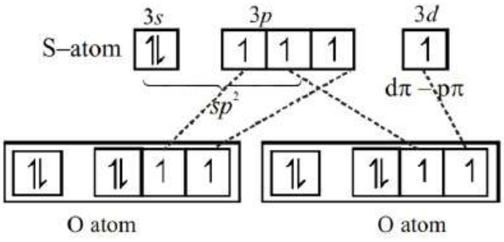
Electronic configuration of N_2^+ (13) is

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

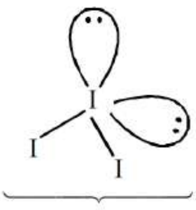
$$\text{B.O} = \frac{1}{2}[9-4] = \frac{5}{2} = 2.5$$

Thus, option (c) is correct.

4. **(a)** 1. PH_5 doesn't exist because *d*–orbital of P interact with *s*–orbital of H. Bond formed is not stable and not energetically favorable and in case of $BiCl_5$ + 5 oxidation state is not stable due to inert pair effect.
2.



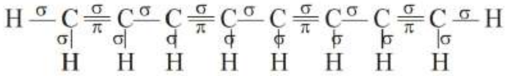
3. I_3^+ $I-\overset{+}{\underset{\bullet\bullet}{\overset{\bullet\bullet}{I}}}-I$ sp^3 hybridisation



Bent geometry

4. SeF_4 sp^3d see–saw
CH_4 sp^3 tetrahedral
Thus, option **(a)** is correct

5. **(b)**

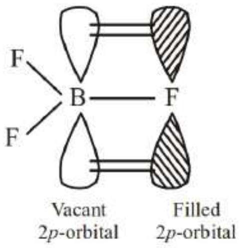


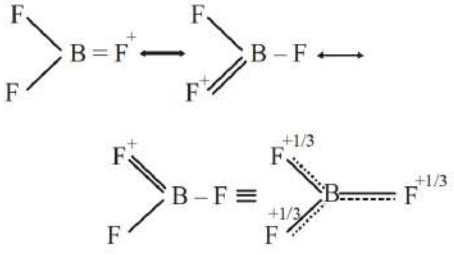
$$H \overset{\sigma}{-} \underset{H}{\overset{|\sigma}{C}} \underset{\pi}{\overset{\sigma}{=}} \underset{H}{\overset{|\sigma}{C}} \overset{\sigma}{-} \underset{H}{\overset{|\sigma}{C}} \underset{\pi}{\overset{\sigma}{=}} \underset{H}{\overset{|\sigma}{C}} \overset{\sigma}{-} \underset{H}{\overset{|\sigma}{C}} \underset{\pi}{\overset{\sigma}{=}} \underset{H}{\overset{|\sigma}{C}} \overset{\sigma}{-} \underset{H}{\overset{|\sigma}{C}} \underset{\pi}{\overset{\sigma}{=}} \underset{H}{\overset{|\sigma}{C}} \overset{\sigma}{-} H$$

1, 3, 5, 7 - octatetraene
17 σ and 4π

6. **(a)** $R-N=C=O$
Nitrogen has 2 sigma bond and a lone pair of electron
∴ hybridisation is sp^2. Carbon has 2 sigma bond ∴ hybridisation is sp. Oxygen has 1 sigma bond and two lone pair of electron ∴ hybridisation is sp^2.
NOTE: π-bonding electron does not take part in hybridisation.

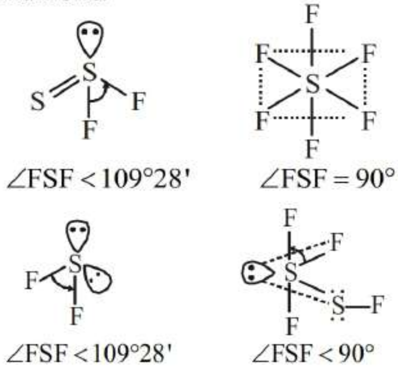
7. **(b)** The delocalised $p\pi - p\pi$ bonding between filled p-orbital of F and vacant p-orbital of B leads to shortening of B–F bond length which results in higher bond dissociation energy of the B–F bond.





8. **(b)** As the size of anion increases polarizibility of anion increase. Among given anions I^- has maximum size.

9. **(d)**



10. **(d)**

Hyb. : sp^3	Hyb. : sp^3d
$\mu \neq 0$	$\mu = 0$
Planar	Planar

11. **(c)** $IO_2F_2^-$: Hyb. sp^3d, $[\equiv sp_xp_yp_zd_{z^2}]$

ClF_4^- : Hyb. sp^3d^2 $[\equiv sp_xp_yp_zd_{x^2-y^2}d_{z^2}]$

IF_7 : Hyb. sp^3d^3.$[sp_xp_yp_zd_{x^2-y^2}d_{xy}d_{z^2}]$

d_{xy} : orbital has two nodal planes xz and yz.

12. **(b)** SO_3

$$\left.\begin{array}{l}\sigma \text{ bond} = 3 \\ \pi \text{ bond} = 3\end{array}\right\} \text{number of covalent bond} = 6$$

Lone pair = $\frac{1}{2} = (6-6\ )= 0$
Hybridization = 3 + 0 = 3 (sp^2)
Unhybridized p–orbitals left = 1 so $p\pi$–$p\pi$ = 1
π bond = 3
$p\pi - d\pi = 3 - 1 = 2$
Thus, SO_3 has 3σ, one $p\pi$–$p\pi$ and two $p\pi - d\pi$ bonds.

13. **(c)** $H_2^+ : (\sigma 1s^1)$

$\therefore$ B.O. $= \frac{1}{2}(1-0) = \frac{1}{2}$

$H_2^- : (\sigma 1s^2)(\sigma^* 1s^1)$

$\therefore$ B.O. $= \frac{1}{2}(2-1) = \frac{1}{2}$

Even though the bond order of H_2^+ and H_2^- are equal but H_2^+ is more stable than H_2^- as in the latter, an electron is present in the antibonding (σ^*1s) orbital of higher energy, which results in repulsion and decrease the stability.

14. **(c)** Bond energy $\propto$ Bond order

Bond order can be determined by MO configuration.

NO **:** No. of electrons $= 7 + 8 = 15$

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

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

NO^+ **:** No. of electrons $= 15 - 1 = 14$

Delete $\pi^* 2p_x^1$ from NO configuration

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

NO^- **:** No. of electrons $= 15 + 1 = 16$

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

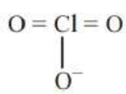
$$\pi^* 2p_x^1 = \pi^* 2p_y^1$$

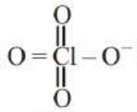
$\therefore$ Bond order $= \dfrac{10-6}{2} = 2$

$\therefore$ Bond order; hence bond strength
$NO^+ > NO > NO^-$

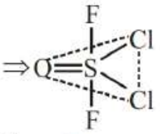
15. **(c)** The B.O in $Cl-O^-$ is 1

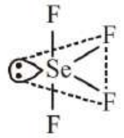
The B.O in $O=Cl-O^-$ is 1.5

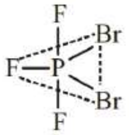
The B.O. in  $O=\underset{\underset{O^-}{|}}{Cl}=O$ is $\dfrac{5}{3} = 1.66$

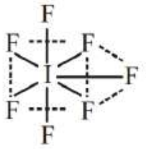
The B.O. in  $O=\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{Cl}}-O^-$ is $\dfrac{7}{4} = 1.75$

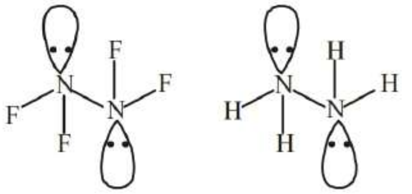
The bond length increases as B.O. decreases.

16. **(a)** $\Rightarrow$  $\Rightarrow$ both S—F bonds are of equal length.

$\Rightarrow$  $\Rightarrow$ Equatorial Se—F bond is shorter than axial Se—F bond.

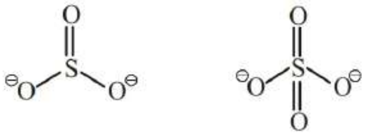
$\Rightarrow$  $\Rightarrow$ Equatorial P—F bond is shorter than axial P—F bond.

$\Rightarrow$  $\Rightarrow$ Equatorial I—F bond is longer than axial I—F bond.

17. **(b)** 

It can be explained on the basis of Bent's rule. In N_2F_4, N—N bond has more *s*-character hence bond length decreases.

While in N_2H_4, N—N bond has less *s*-character (i.e., more *p*-character), hence bond lengths increases.

18. **(b)** 

B.O. $= \dfrac{4}{3} = 1.33$ B.O. $= \dfrac{6}{4} = 1.5$

$$\left[\text{B.L.} \propto \frac{1}{\text{B.O.}} \right]$$

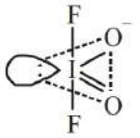
$$\therefore SO_3^{2-} > SO_4^{2-} > \underbrace{SO_2 > SO_3}_{\text{Bent's Rule}}$$

19. **(c)**

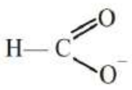
Compounds	**Hybridization of central atom**
CO_2	*sp*
HCOOH	sp^2
BF_3	sp^2
BF_4^-	sp^3
NH_3	sp^3
NH_4^+	sp^3
PCl_3	sp^3
PCl_5	sp^3d

Hybridization of NH_3 and NH_4^+ remains unchanged after transformation i.e. sp^3.

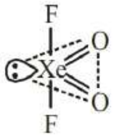
20. **(a)**



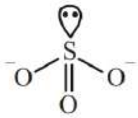
p_π-p_π bond(s) = 0
p_π-d_π bond(s) = 1
Bond order of (I—O) = 1.5



p_π-p_π bond(s) = 1
p_π-d_π bond(s) = 0
Bond order of (C—O) = 1.5

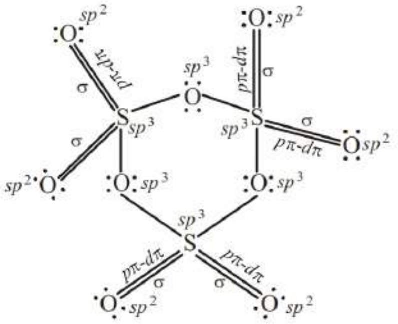


p_π-p_π bond(s) = 0
p_π-d_π bond(s) = 1
Bond order of (S–O) = 1.33



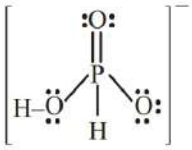
p_π-p_π bond(s) = 0
p_π-d_π bond(s) = 2
Bond order of (Xe—O) = 2.0

21. **(1)**



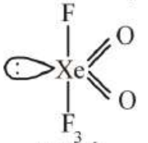
$p = 6, q = 6; \frac{p}{q} = 1$

22. **(3)**

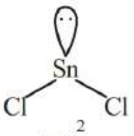


$x = 7, y = 1, z = 5$
$7 + 1 - 5 = 3.$

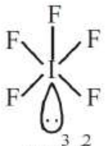
23. **(2)** XeO_4, XeF_7^+



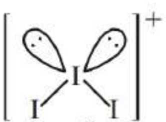
→ sp^3d
→ polar



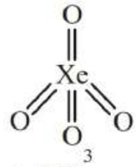
→ sp^2
→ polar



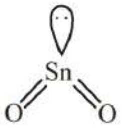
→ sp^3d^2
→ polar



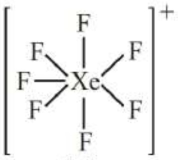
→ sp^3
→ polar



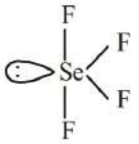
→ sp^3
→ non-polar



→ sp^2
→ polar



→ sp^3d^3
→ non-polar



→ sp^3d
→ polar

24. **(5)**

Species	Nodal Plane
$3s$	0
$4d_{z^2}$	0
$4s$	0
$2p_x$	1
$3d_{x^2-y^2}$	2
$4p_z$	1
$4d_{xy}$	2
$3p_y$	1

∴ Total no. of orbitals
$= 3s, 4d_{xy}\ 4d_{z^2}, 3d_{x^2-y^2}, 4s$ (Five)

25. **(3)** $PCl_5 \longrightarrow sp^3d$, non-planar

$BrF_3 \longrightarrow sp^3d$, bent, T-shape, planar

$ICl_2^- \longrightarrow sp^3d$, linear, planar

$XeF_5^- \longrightarrow sp^3d^3$, pentagonal planar

$NO_3^- \longrightarrow sp^2$, planar

$XeO_2F_2 \longrightarrow sp^3d$, see-saw, non-planar

$PCl_4^+ \longrightarrow sp^3$, tetrahedral, non-planar

$CH_3^+ \longrightarrow sp^2$, Trigonal planar
$a = 4, b = 5, c = 3$

so, $\frac{a+b}{c} = 3$

26. **(6)** $(p_x, p_y, d_{xy}, d_{yz}, d_{xz}, d_{x^2-y^2})$

27. **(21)** Molecular orbital electronic configuration of these species are :

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

$\pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^2 = \pi^* 2p_y^1$

$O_2(16e^-) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2,$

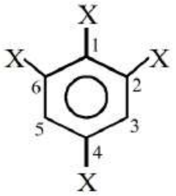
$\pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^1 = \pi^* 2p_y^1$

$O_2^{2-}(18e^-) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2,$

$\pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^2 = \pi^* 2p_y^2$

Therefore number of antibonding electrons are 7, 6 and 8 respectively and the sum is 21.

28. **(1.6)** The substituent in *o*– and *p*– position, will cancel each others dipole moment.



The angle between 2 and 6 positions is 120°. The resultant dipole moment generated by these two is:

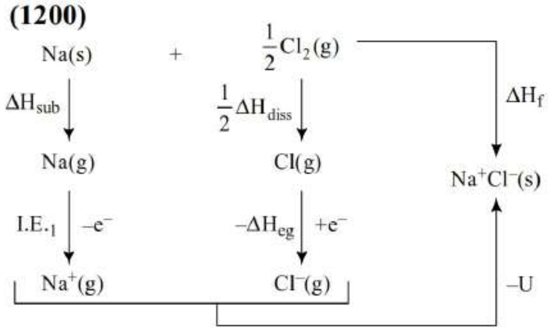
$$\mu = \sqrt{\mu_1^2 + \mu_2^2 + 2\mu_1\mu_2 \cos\theta}$$

$$= \sqrt{1.6^2 + 1.6^2 + 2 \times 1.6 \times 1.6 \times \cos(120)} = 1.6\text{ D}$$

29. **(50)** The hybridization of S in SF_6 is sp^3d^2.

$$\%\,p\text{ character} = \frac{3}{6} \times 100 = 50$$

30. **(1200)**



$$\Delta H_f = \Delta H_{sub} + \frac{1}{2}\Delta H_{diss} + I.E._1 - \Delta H_{eg} - U$$

$$\Rightarrow \quad -200 = 650 + \frac{1}{2} \times 400 + 500 - 350 - U$$

$$\Rightarrow \quad U = 1200\text{ kJ/mol}$$