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Chemical Bonding and Molecular Structure

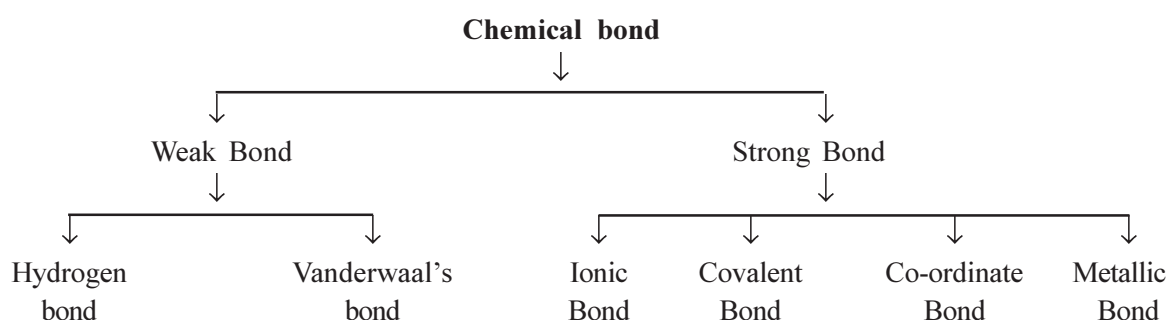
The group of atoms combine and exist as species having characteristic properties which are known as molecules.

The attraction force that keeps the different components (atom/ions) combined together is called chemical bond.

When two components join to each other, more stronger the force of attraction (chemical bond) between them lower will be their energy.

Stability of a molecule is more than its joining components (atom/ions)

Formation of a chemical bond is normally an exothermic reaction. In this process only the valence electrons of atom take part in bond formation.



• Kossel-Lewis Approach

• Approach of Kossel for chemical bond

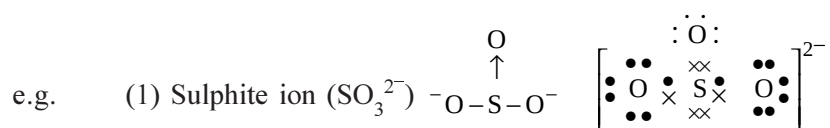
- Strongly electronegative elements (Halogen elements) and strongly electropositive elements join with each other by transfer of electron and achieve inert gas configuration (ns^2np^6).
- Ionic bond is formed by joining atoms with low ionization enthalpy to atoms with high electron gain enthalpy.
- Such type of attraction between cation and anion is called electrostatic attraction and the bond between them is called electrovalent bond.

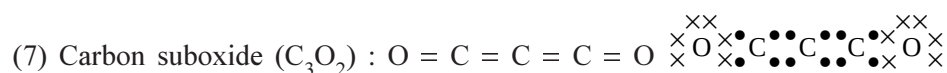
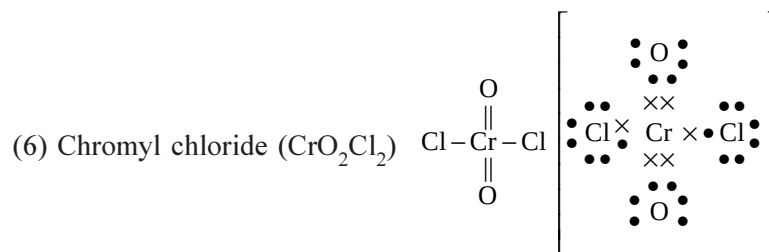
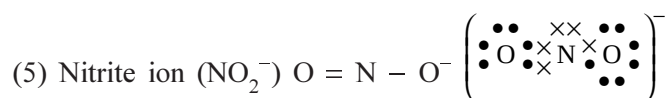
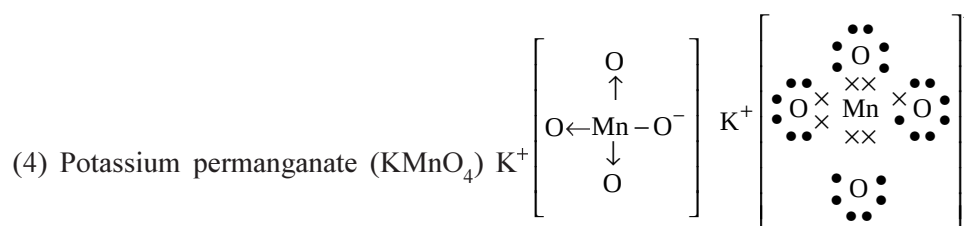
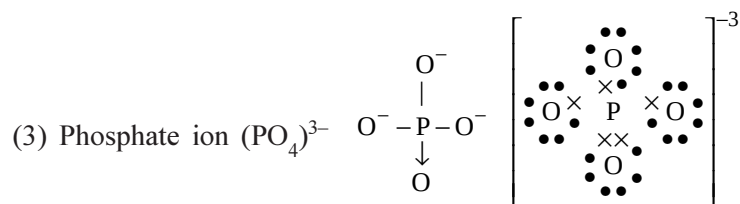
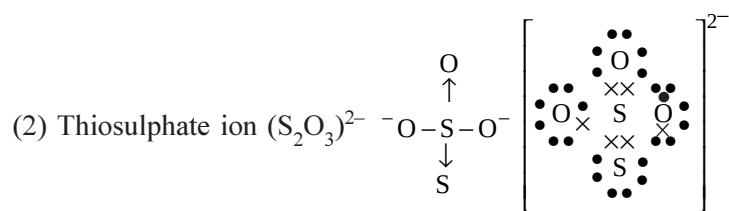
• Approach of Lewis for chemical bond

According to Lewis, formation of chemical bond is due to transfer or sharing of valence electron in atoms forming molecule electrons present in the inner orbit of atom are not involved in bonding.

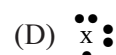
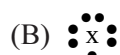
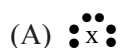
• Lewis dot representation

Valence electrons of elements are represented as dots around the symbol of elements. Such a method is known as Lewis dot representation





- Chemical bond is an example of
 (A) attraction (B) repulsion
 (C) (A) and (B) (D) no attraction or repulsion
- When two atoms join and form molecule
 (A) energy is released. (B) energy is adsorbed
 (C) energy is neither created nor absorbed (D) energy is absorbed or released
- Formation of which of the following ionic compound is against Kossel approach ?
 (A) CaF_2 (B) KBr (C) FeCl_3 (D) LiCl
- In covalent bond electron dot representation is known as
 (A) Lewis structure (B) Bohr's structure (C) Muliken structure (D) Kossel structure
- Show the correct dot representation of an atom having atomic no. seven ?



6. Which of the following is a dot representation for group two elements ?

- (A) $\ddot{x}$ (B) $\ddot{x}.$ (C) $\ddot{x}:$ (D) $:\ddot{x}:$

7. In which of the following central atom has incomplete octet ?

- (A) NH_4^+ (B) BCl_3 (C) CCl_4 (D) PCl_3

8. In which of the following expanded octet can be seen ?

- (A) BF_3 (B) NF_3 (C) SF_6 (D) CCl_4

9. How many non bonding electron pairs are present in Hydrazine (N_2H_4).

- (A) 3 (B) 2 (C) 1 (D) 4

10. Mention total number of valence electron in acetate ion ?

- (A) 32 (B) 24 (C) 23 (D) 36

11. How many electrons are there in peroxide ion ?

- (A) 18 (B) 20 (C) 16 (D) 34

Answers : 1. (C), 2. (A), 3. (C), 4. (A), 5. (D), 6. (A), 7. (B), 8. (C), 9. (B), 10. (B), 11. (A)

● Ionic Bond (electrovalent bond)

Ionic bond is formed when one or more electron of metal atom transfer into non-metal atom.

e.g, $\left\{ \begin{array}{l} \text{Na} \rightarrow \text{Na}^+ + \text{e}^- \\ \text{Cl} + \text{e}^- \rightarrow \text{Cl}^- \end{array} \right\}$ This way cation is formed from metal atom and anion is formed from non metal atom

e.g.,

Metal grp		Non metal grp	→	common formula	→	ions	→	example
1A	+	7A	→	MX	→	M^+, X^-	→	NaCl
2A	+	7A	→	MX_2	→	$\text{M}^{+2}, 2\text{X}^-$	→	MgCl_2
3A	+	7A	→	MX_3	→	$\text{M}^{+3}, 3\text{X}^-$	→	AlCl_3
1A	+	6A	→	M_2X	→	$2\text{M}^+, \text{X}^{2-}$	→	Li_2O
2A	+	6A	→	MX	→	$(\text{M}^{+2}, \text{X}^{2-})$	→	CaO
3A	+	6A	→	M_2X_3	→	$2\text{M}^{3+}, 3\text{X}^{2-}$	→	Al_2O_3
1A	+	5A	→	M_3X	→	$3\text{M}^+, \text{X}^{3-}$	→	Li_3N
2A	+	5A	→	M_3X_2	→	$3\text{M}^{+2}, 2\text{X}^{3-}$	→	Ca_3P_2
3A	+	5A	→	MX	→	$(\text{M}^{+3}, 3\text{X}^-)$	→	AlP

● Factors affecting ionic bond

- There should be large difference in electronegativity of atoms forming bond.
- Cation forming atom should have less ionization enthalpy and anion forming atom should have high electron gain enthalpy.
- It should have high lattice enthalpy.

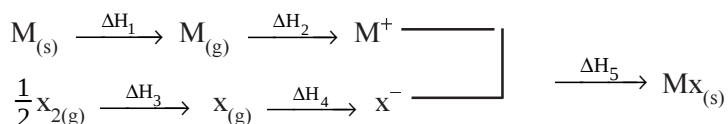
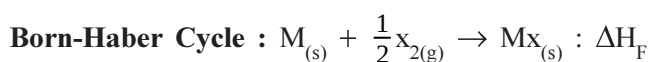
- **Characteristics of Ionic compound**

- (i) definite geometric and crystalline structure. (ii) High melting point and boiling point
- (iii) High density (iv) less volatility
- (v) less vapour pressure (vi) poor conductor/insulator for electricity in solid state
- (vii) good conductor of electricity in molten state (viii) soluble in polar solvent
- (ix) good conductor of electricity in solution (x) indicates ionic reaction

- **Born-Haber Cycle-Lattice enthalpy**

The energy required to remove ions to infinite distance from ionic compound in one mole solid state is called crystal lattice enthalpy.

e.g. Crystal lattice enthalpy of NaCl is 787 KJ/mole



ΔH_1 = sublimation enthalpy, ΔH_2 = ionization enthalpy, ΔH_3 = dissociation enthalpy

ΔH_4 = electron gain enthalpy, ΔH_5 = lattice enthalpy

According to Hess's law of heat summation, $\Delta H_f = \Delta H_1 + \Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5$

- **Solubility of Ionic solid**

Information on solubility of ionic compound is based on coulombic force of attraction between cation and anion in an ionic solid compound.

eg, $F = \frac{Z_1 Z_2 e^2}{Dr^2}$ where, F = coulombic force of attraction, Z_1, Z_2 = charge of ions

e = charge of electron, D = Dielectric constant of the medium

r = interionic distance (bond length)

- As attraction between ions increases, solubility of ionic solid decreases
- In a given solution if value of dielectric constant is high then attraction between cation and anion is less and solubility increases.

eg., $D(H_2O) > D(C_2H_5OH) > D(CH_3OCH_3)$

$\therefore \xrightarrow[\text{solubility decreases}]{H_2O > C_2H_5OH > CH_3OCH_3}$

As interionic distance between ion is more, attraction is less and solubility of ionic solid is more.

eg., $\xrightarrow{\text{solubility increases}} LiF < LiCl < LiBr < LiI$

eg., $\xrightarrow{\text{solubility increases}} LiF < NaF < KF < RbF < CsF$

- If the size of one of the two ions is very large, then with the decrease in size of the other ion solubility of ionic solid increases

eg., $\text{CsI} < \text{CsBr} < \text{CsCl} < \text{CsF} \rightarrow$ solubility increases

eg., $\text{CsI} < \text{KI} < \text{NaI} < \text{LiI} \rightarrow$ solubility increases

eg., $\text{CsNO}_3 < \text{KNO}_3 < \text{NaNO}_3 < \text{LiNO}_3 \rightarrow$ solubility increases

- More the electric charge of ions, higher is the attraction and solubility decreases.

eg., $\text{NaCl} > \text{Na}_2\text{SO}_4 > \text{Na}_3\text{PO}_4$

$(\text{Cl}^-) \quad (\text{SO}_4)^{2-} \quad (\text{PO}_4)^{3-} \rightarrow$ solubility decreases

12. Which of the following has higher melting point ?

(A) NaCl (B) NaF (C) NaBr (D) NaI

13. In KF ionic radius of F^- is more than F, then ionic radius of K^+ is

(A) less than K (B) more than F^- (C) equal to F^- (D) None

14. Which of the following pairs shows the highest and lowest ionic characteristics ?

(A) LiCl, RbCl (B) RbCl, BeCl_2 (C) RbCl, MgCl_2 (D) MgCl_2 , BeCl_2

15. In which of the following electrovalent bond is present ?

(A) NaCl (B) Br_2 (C) PF_5 (D) XeF_4

16. Which of the following compound is possible if element X with $1s^2 2s^2 2p^6 3s^2$ configuration combine with chlorine atom ?

(A) XCl_3 (B) XCl_2 (C) XCl (D) X_3Cl

17. $x = 1s^2$, $y = 1s^2 2s^2 2p^2$, $z = 1s^2 2s^2 2p^5$, $w = 1s^2 2s^2 2p^6$

out of the elements x, y, z and w which of them has maximum possibility of forming ionic bond ?

(A) x (B) y (C) z (D) w

18. If formula of a metal phosphate is MPO_4 , then the metal nitrate compound formula is

(A) MNO_3 (B) $\text{M}_2(\text{NO}_3)_2$ (C) $\text{M}(\text{NO}_3)_2$ (D) $\text{M}(\text{NO}_3)_3$

19. If formula of a metal oxide is MO , then what can be possible formula of metal phosphate ?

(A) $\text{M}_2(\text{PO}_4)_2$ (B) $\text{M}(\text{PO}_4)$ (C) M_2PO_4 (D) $\text{M}_3(\text{PO}_4)_2$

20. If atomic number of an atom is 20, then which atomic number atom can chemically combine with this atom ?

(A) 11 (B) 16 (C) 14 (D) 10

21. Which of the following is the strongest ionic bond ?

(A) Cs – Cl (B) Al – Cl (C) C – Cl (D) H – Cl

22. What does lattice enthalpy of a compound depend on ?
 (A) only ionic charge (B) only size of ion
 (C) size and charge of ion (D) None
23. Ionic compound $A^+ \cdot B^-$ is only possible when
 (A) Ionization enthalpy of A is less and e^- gain enthalpy of B is less
 (B) Ionization enthalpy of A is less and e^- gain enthalpy of B is more
 (C) Ionization enthalpy of A is more and e^- gain enthalpy of B is less
 (D) None
24. If ion is then lattice enthalpy is high.
 (A) small size (B) less electric charge (C) zero electric charge (D) None
25. Due to what reason electrical conductivity in molten NaCl is possible ?
 (A) free electron (B) free ion (C) free molecules (D) Na and Cl atom
26. If electronic configuration of four elements L, Q, P and R are respectively
 $L = 1s^2 2s^2 2p^4$, $Q = 1s^2 2s^2 2p^6 3s^2 3p^5$
 $P = 1s^2 2s^2 2p^6 3s^1$, $R = 1s^2 2s^2 2p^6 3s^2$ then the ionic compound produced by them are respectively
 (A) L_2P , RL , PQ , R_2Q (B) LP , RL , PQ , RQ (C) P_2L , RL , PQ , RQ_2 (D) LP , R_2L , P_2Q , RQ
27. Statement 1 : Born Haber cycle is based on Hess's law.
 Statement 2 : Lattice enthalpy can be calculated using Born Haber cycle.
 (A) Statement 1 and 2 are correct and statement 2 is the explanation of statement 1
 (B) Statement 1 and 2 are correct, but statement 2 is not the explanation of statement 1
 (C) Statement 1 is correct and statement 2 is incorrect.
 (D) Statement 1 is incorrect and statement 2 is correct.
28. Which of the following ionic compound has least solubility ?
 (A) LiCl (B) LiI (C) LiF (D) LiBr
29. Which of the following ionic compound has highest solubility ?
 (A) NaF (B) CsF (C) KF (D) RbF
30. Which of the following ionic compound has least solubility ?
 (A) $CsNO_3$ (B) $NaNO_3$ (C) $LiNO_3$ (D) KNO_3

Answers : 12. (B), 13. (A), 14. (B), 15. (A), 16. (B), 17. (C), 18. (D), 19. (D), 20. (B),
 21. (A), 22. (C), 23. (B), 24. (A), 25. (B), 26. (C), 27. (B), 28. (C), 29. (B),
 30. (A)

● **Fajan's Rule (Covalent characteristic in ionic bond)**

When cation and anion are very strongly bonded to each other the positive charge of cation attracts the electron cloud of anion towards itself at the same time positive charge of cation and electropositive charge nucleus of anion experience repulsion due to this combined effect, anion cloud spreads towards the cation and increases size. Such type of distortion is known as polarization.

(1) Smaller the size of cation, more is its capacity to attract the electron cloud of anions. Due to which distortion (anionic polarity) of anion electron cloud increases due to which covalent characteristics increases and its melting point / boiling point decreases.

∴ covalent characteristics $\propto$ anionic polarity

∴ covalent characteristic $\propto \frac{1}{\text{size of cation}}$

∴ covalent characteristics $\propto$ size of anion

eg., $\text{CaF}_2 < \text{CaCl}_2 < \text{CaBr}_2 < \text{CaI}_2 \rightarrow$

- size of anion increases
- covalent characteristic increases
- Melting point/Boiling point decreases

eg., $\text{BaCl}_2 < \text{SrCl}_2 < \text{CaCl}_2 < \text{MgCl}_2 \rightarrow$

- size of cation decreases
- covalent character increases
- Melting point / Boiling point decreases

(2) As electric charge on cation or anion increases the anionic polarity increases (size increases) and covalent character of such compound increases and melting point and boiling point decreases.

eg., In KCl, CaCl_2 ionic charge of Ca^{+2} is greater than that of K^+ due to which CaCl_2 shows more covalent characteristics and melting point boiling point decreases.

eg., $\text{NaCl} < \text{MgCl}_2 < \text{AlCl}_3$

- +ve charge of cation increases
- covalent characteristic increases
- Melting point and Boiling point decreases

(3) Valence orbit eight electron (Inert)

eg., $(\text{Na}^+, \text{K}^+, \text{Ca}^{+2}, \text{Mg}^{+2})$

Valence orbit eighteen electron (Pseudo Inert)

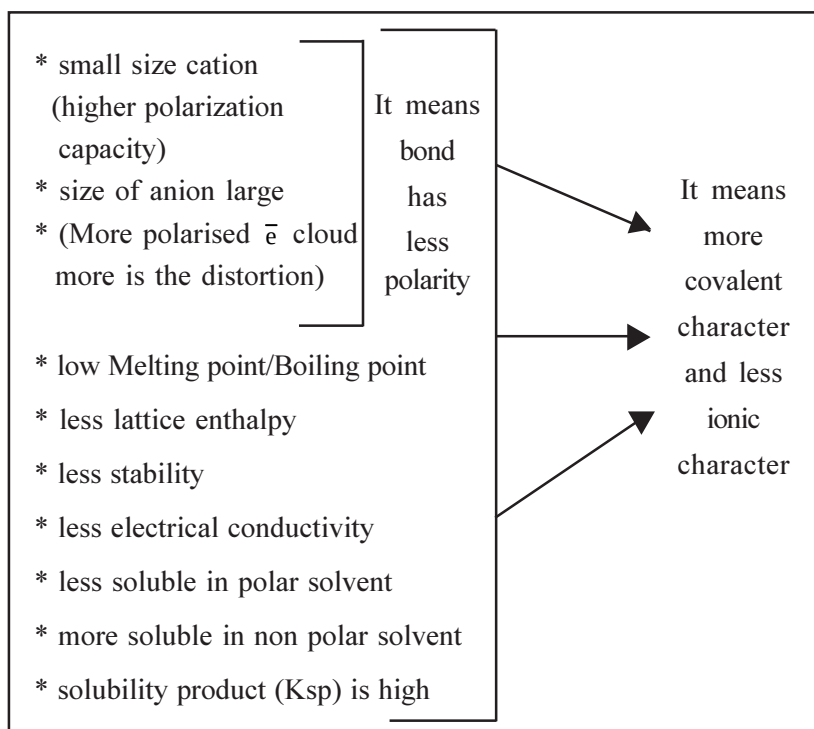
eg., $(\text{Cu}^+, \text{Ag}^+, \text{Zn}^{+2}, \text{Cd}^{+2}, \text{Sn}^{+4})$

If there are 18 electrons in valence orbit, then the polarity is more than 8 electrons, hence covalent characteristic increases and melting point/Boiling point decreases.

eg., In Cu_2Cl_2 , KCl $\text{K}^+ \rightarrow 2, 8, 8$

$\text{Cu}^+ \rightarrow 2, 8, 18$ so,

Cu_2Cl_2 shows more covalent characteristic and less Melting point/Boiling point than KCl.



31. Which of the following shows correct order of melting point of compounds ?
 (A) $\text{Li}_2\text{CO}_3 < \text{Cs}_2\text{CO}_3 < \text{Rb}_2\text{CO}_3 < \text{K}_2\text{CO}_3$ (B) $\text{Cs}_2\text{CO}_3 < \text{Li}_2\text{CO}_3 < \text{Rb}_2\text{CO}_3 < \text{K}_2\text{CO}_3$
 (C) $\text{Cs}_2\text{CO}_3 < \text{Rb}_2\text{CO}_3 < \text{K}_2\text{CO}_3 < \text{Li}_2\text{CO}_3$ (D) $\text{Li}_2\text{CO}_3 < \text{K}_2\text{CO}_3 < \text{Rb}_2\text{CO}_3 < \text{Cs}_2\text{CO}_3$
32. Which of the following shows correct order of covalent characteristic in compounds ?
 (A) $\text{LiCl} > \text{BeCl}_2 > \text{BCl}_3$ (B) $\text{BCl}_3 > \text{BeCl}_2 > \text{LiCl}$
 (C) $\text{BCl}_3 > \text{LiCl} > \text{BeCl}_2$ (D) $\text{BCl}_3 > \text{BeCl}_2 = \text{LiCl}$
33. Which of the following shows correct order of covalent characteristic in compounds ?
 (A) $\text{SnI}_4 > \text{SnBr}_4 > \text{SnCl}_4 > \text{SnF}_4$ (B) $\text{SnBr}_4 > \text{SnI}_4 > \text{SnCl}_4 > \text{SnF}_4$
 (C) $\text{SnI}_4 > \text{SnCl}_4 > \text{SnF}_4 > \text{SnBr}_4$ (D) $\text{SnF}_4 > \text{SnCl}_4 > \text{SnBr}_4 > \text{SnI}_4$
34. Which of the following has the lowest melting point ?
 (A) PbCl_2 (B) NaCl (C) MgCl_2 (D) SnCl_4
35. Which of the following shows maximum covalent characteristic ?
 (A) PbCl_2 (B) NaCl (C) MgCl_2 (D) SnCl_4
36. Which of the following shows correct order of solubility in polar solvent ?
 (A) $\text{PbO}_2 < \text{RbI} < \text{CdI}_2$ (B) $\text{CdI}_2 < \text{RbI} < \text{PbO}_2$
 (C) $\text{PbO}_2 < \text{CdI}_2 < \text{RbI}$ (D) $\text{RbI} < \text{CdI}_2 < \text{PbO}_2$
37. Which of the following carbonate does not give oxide on heating ?
 (A) ZnCO_3 (B) CaCO_3 (C) Na_2CO_3 (D) MgCO_3
38. Which of the following compound has maximum ionic characteristics ?
 (A) BeCl_2 (B) LiCl (C) SnCl_2 (D) MgCl_2

39. Which of the following compound has minimum ionic characteristics ?
 (A) Cu_2Cl_2 (B) KCl (C) RbCl (D) NaCl
40. Which of the following has maximum polarity ?
 (A) Mg^{+2} (B) K^+ (C) Sc^{+3} (D) Ni^{+2}
41. Mention the correct order of solubility in water for the following compound ?
 (A) $\text{NaF} < \text{MgO} < \text{AlN}$ (B) $\text{AlN} < \text{NaF} < \text{MgO}$
 (C) $\text{AlN} < \text{MgO} < \text{NaF}$ (D) $\text{AlN} = \text{NaF} < \text{MgO}$
42. Which of the following has maximum solubility in water ?
 (A) AgI (B) AgF (C) AgCl (D) AgBr
43. Which of the following carbonate has maximum stability ?
 (A) MgCO_3 (B) CaCO_3 (C) SrCO_3 (D) BaCO_3
44. Which of the following has maximum solubility product ?
 (A) BeCl_2 (B) BaCl_2 (C) CaCl_2 (D) SrCl_2
45. Which of the following has minimum solubility product ?
 (A) SnBr_4 (B) SnF_4 (C) SnCl_4 (D) SnI_4

Answers : 31. (D), 32. (B), 33. (A), 34. (D), 35. (D), 36. (C), 37. (C), 38. (C), 39. (A),
 40. (D), 41. (C), 42. (B), 43. (D), 44. (A), 45. (B)

● Covalent Bond

Bond formed by sharing of one or more electrons of valence orbit of atoms resulting into completion of octet of the atoms is called covalent bond.



● Covalency

The total number of electrons of an atom of an element shared by other atoms for covalent bond formation is called the covalency of the element.

eg., Group 14 covalency of element = 4

Group 15 covalency of element = 3

Group 16 covalency of element = 2

Group 17 covalency of element = 1

Atoms of elements having d-orbital show more than one type of covalency

eg., element covalency

Phosphorous $\rightarrow$ 3, 5

Sulphur $\rightarrow$ 2, 4, 6

Iodine $\rightarrow$ 1, 3, 5, 7

● **Factors affecting covalent bond**

(i) Atoms taking part in bond formation should have same electronegativity or should have minimum difference in electronegativity.

(ii) On sharing electrons the atoms should complete octet

● **Characteristics of covalent bond**

- poor conductor/insulator of electricity
- less soluble in polar solvent
- They experience non ionic process, which are normally slow.
- They possess relatively low Melting point/Boiling point. (exception : SiC, Diamond)

46. How many electrons take part in bond formation of N_2 ?

- (A) 3 (B) 2 (C) 6 (D) 1

47. L : $1s^2 2s^2 2p^1$, M : $1s^2 2s^2 2p^5$,

Q : $1s^2 2s^2 2p^6 3s^1$, R : $1s^2 2s^2 2p^2$

which of the mentioned has maximum capacity to form diatomic molecule ?

- (A) Q (B) M (C) R (D) L

48. Which of the following shows pair of covalent Hydrides ?

- (A) NaH and CaH_2 (B) NH_3 and B_2H_6 (C) NaH and NH_3 (D) CaH_2 and B_2H_6

49. Which of the following has covalent bond ?

- (A) Na_2S (B) $AlCl_3$ (C) NaH (D) $MgCl_2$

50. Compared to ionic compounds covalent compounds have melting point and boiling point

- (A) Low, High (B) High, Low (C) High, High (D) Low, Low

51. How many electron pairs are present in valence orbit of oxygen atom in H_2O ?

- (A) 4 (B) 1 (C) 2 (D) 3

52. Which of the following compound has ionic and covalent bond both ?

- (A) CCl_4 (B) NH_4Cl (C) $CaCl_2$ (D) H_2O

53. **Mention True (T) or False (F) for the following statement.**

(i) There is sharing of electron between two atoms in a covalent compound

(ii) The bond formed in such compounds are polar or non polar.

(iii) In such compounds there is no transfer of electrons between two atoms.

(iv) In such compounds bonds do not possess directional properties.

- (A) FFTT (B) TTTF (C) TTFT (D) TFFT

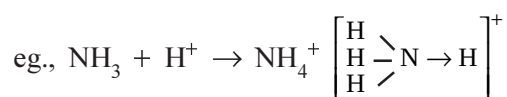
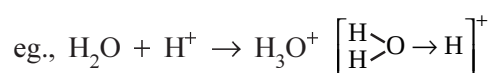
54. Due to what reason boron forms covalent bond ?
 (A) small size (B) high ionization enthalpy
 (C) low ionization enthalpy (D) (A) and (B) both
55. Bond energy of O-H covalent bond in water is
 (A) greater than bond energy of H-bond. (B) equal to bond energy of H-bond.
 (C) less than bond energy of H-bond. (D) None
56. In which of the following compound P-H bond shows least covalent character ?
 (A) PH_3 (B) P_2H_6 (C) PH_6^+ (D) P_2H_5
57. Which of the following compound has strongest bond and highest bond energy ?
 (A) F_2 (B) Cl_2 (C) Br_2 (D) I_2
58. Which of the following shows strongest covalent bond ?
 (A) H-Cl (B) Cl-Cl (C) C-Cl (D) B-Cl
59. In which of the following are covalent bond soluble ?
 (A) Polar solvent (B) Non polar solvent (C) Strong acid (D) all solvents
60. What will be the electronic configuration of x if x_2 molecule is trivalent ?
 (A) $1s^2 2s^2 2p^5$ (B) $1s^2 2s^2 2p^3$ (C) $1s^2 2s^1$ (D) $1s^2 2s^2 2p^1$

Answers : 46. (C), 47. (B), 48. (B), 49. (B), 50. (C), 51. (A), 52. (B), 53. (B), 54. (D), 55. (A), 56. (C), 57. (B), 58. (A), 59. (B), 60. (B)

● **Co-ordinate covalent bond :**

Sharing of electron between two atoms/ions where any one atom/ion donate electron pair for sharing, such a bond is called co-ordinate covalent bond.

This bond is denoted by ' $\rightarrow$ ' and the direction of arrow is from the atom donating the electron pair towards the atom receiving electron pair.



61. What kind of bonding takes place between NH_3 and BF_3 ?
 (A) covalent bond (B) co-ordinate covalent bond
 (C) ionic bond (D) H bond
62. Due to what reason co-ordinate covalent bond is formed ?
 (A) Migration of electron (B) sharing of electron
 (C) donating electron for sharing (D) None
63. Which of the following does not have co-ordinate covalent bond ?
 (A) NO_2 (B) O_3 (C) NH_4^+ (D) CCl_4
64. Which of the following has co-ordinate covalent bond ?
 (A) N_2O_5 (B) BeCl_2 (C) HCl (D) H_2O
65. Which of the following has co-ordinate covalent bond ?
 (A) CH_3NC (B) CH_3OH (C) CH_3Cl (D) NH_3
66. Which of the following has co-ordinate covalent bond ?
 (A) O_3 (B) SO_3 (C) H_2SO_4 (D) mentional all
67. In which of the following co-ordinate covalent bond is not present ?
 (A) BH_4^- (B) CO_3^{2-} (C) H_3O^+ (D) NH_4^+
68. Which of the following does not have co-ordinate covalent bond ?
 (A) SO_2 (B) HNO_3 (C) H_2SO_3 (D) HNO_2
69. Which of the following has co-ordinate covalent bond ?
 (A) CH_3NO_2 (B) AlCl_3 (C) NaCl (D) CH_2Cl_2

Answers : 61. (B), 62. (C), 63. (D), 64. (A), 65. (A), 66. (D), 67. (B), 68. (D), 69. (A)
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● Valence Shell Electron Pair Repulsion principle (VSEPR principle)

According to detailed presentation of principle by Nyhlom and Gillespie, the shape of the molecule depends upon the number of electron pairs bonding and nonbonding electron pairs in valence shells around the central atom. Based on repulsion between such electron pair shape of molecule is decided lone pair electron and bond pair electron.

The magnitude of the repulsion produced between such electron pair is as follows :

$$L_p - L_p > L_p - B_p > B_p - B_p$$

These electron pairs possess the tendency of obtaining such an arrangement in the space that the repulsion between them is minimum and as a result there is maximum distance between them.

Serial No.	Molecule			Shape
(1)	AB_2	2	0	linear
(2)	AB_3	3	0	planar triangle
(3)	AB_2E	2	1	V-shape, angular
(4)	AB_4	4	0	Tetrahedral
(5)	AB_3E	3	1	Pyramidal
(6)	AB_2E_2	2	2	V-shape, angular
(7)	AB_5	5	0	Triagonal bipyramidal
(8)	AB_4E	4	1	See-Saw
(9)	AB_3E_2	3	2	T-shape
(10)	AB_2E_3	2	3	linear
(11)	AB_6	6	0	octahedral
(12)	AB_5E	5	1	square pyramidal
(13)	AB_4E_2	4	2	squareplanar
(14)	AB_7	7	0	Pentagonal bipyramidal
(15)	AB_6E	6	1	distorted octahedral

70. Which of the following has least bond angle ?
 (A) H_2O (B) NH_3 (C) CH_4 (D) PCl_5
71. According to VSEPR principle, what will be the shape of the molecule in which central atom have 4 bonded pair of electron in valence shell ?
 (A) Linear (B) Tetrahedral (C) Octahedral (D) Trigonal bipyramidal
72. In which molecules all atoms are planar ?
 (A) CH_4 (B) BF_3 (C) PF_3 (D) NH_3
73. Water is
 (A) linear (B) Angular (C) Both (A) and (B) (D) None
74. Which of the following shows decreasing order of bond angle ?
 (A) $NH_3 > PH_3 > AsH_3 > SbH_3$ (B) $NH_3 > AsH_3 > PH_3 > SbH_3$
 (C) $SbH_3 > AsH_3 > PH_3 > NH_3$ (D) $PH_3 > NH_3 > AsH_3 > SbH_3$
75. According to VSEPR theory, which of the molecule can be explained inspite of central atom not possessing lone pair ?
 (A) PCl_5 (B) PCl_3 (C) NH_3 (D) SF_4

76. Which of the following pair of molecule has same shape ?
 (A) CF_4 , SF_4 (B) XeF_2 , CO_2 (C) BF_3 , PCl_3 (D) PF_5 , IF_5
77. In XeF_6 , what is the oxidation number of Xe, type of hybridisation and shape of molecule respectively ?
 (A) +6, sp^3d^3 , distorted octahedral (B) +4, sp^3d^2 , square planar
 (C) +6, sp^3 , pyramidal (D) +6, sp^3d^3 , square pyramidal
78. In which of the following do we see maximum bond angles of 90° between bonded-bonded electron pair ?
 (A) dsp^2 hybridisation (B) sp^3d hybridisation (C) dsp^3 hybridisation (D) sp^3d^2 hybridisation
79. According to VSEPR what is the shape of ClO_3^- ion ?
 (A) planar triangle (B) pyramidal (C) tetrahedral (D) square planar
80. Which of the following is not a linear molecule ?
 (A) C_2H_2 (B) H_2S (C) BeCl_2 (D) CS_2
81. Which of the following component is not linear ?
 (A) ICl_2^- (B) I_3^- (C) N_3^- (D) ClO_3^-
82. Which of the following has maximum bond angle between two covalent bond ?
 (A) CO_2 (B) CH_4 (C) NH_3 (D) H_2O
83. According to VSEPR, what is the shape of XeOF_2 ?
 (A) like seesaw (B) V shape (C) T shape (D) planar triangle
84. BCl_3 is a planar molecule while NCl_3 molecule is pyramidal because
 (A) NCl_3 has lone pair while BCl_3 does not have lone pair
 (B) B-Cl bond is more coplanar than N-Cl bond.
 (C) size of N atom is smaller than B-atom.
 (D) N-Cl bond is more covalent than B-Cl.

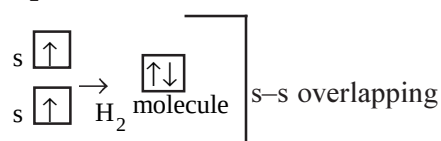
Answers : 70. (B), 71. (B), 72. (B), 73. (B), 74. (A), 75. (A), 76. (B), 77. (A), 78. (D), 79. (A), 80. (B), 81. (D), 82. (A), 83. (C), 84. (D)

● Valence Bond Theory

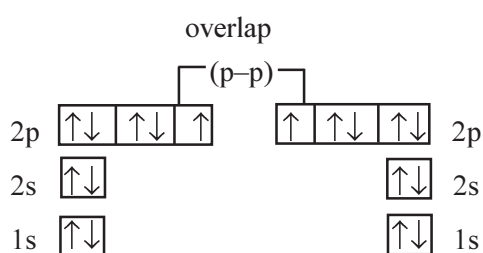
- It was presented by Heitler and London and developed by Pauling and Slater.
- The bond is formed by overlapping of valence orbitals of atoms.
- Each orbital shares one electron in overlapping.
- Strength of the bond depends on extent of overlapping.
- Strength of overlapping of p-orbitals is less than s-orbital.
- due to axial overlapping of orbitals σ bond is formed and due to parallel overlapping of orbitals π bond is formed.

σ -bond	π -bond
axial overlapping of orbital	parallel overlapping of orbital
It is an independent bond formation.	π bond is formed only after formation of σ bond
more strong	compared to σ bond it is weak
maximum overlapping	minimum overlapping
free rotation of bond is possible	free rotation of bond is not possible

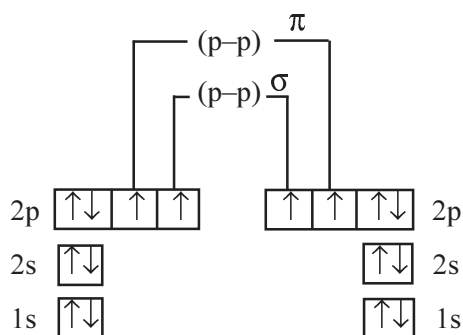
eg., H_2 molecule



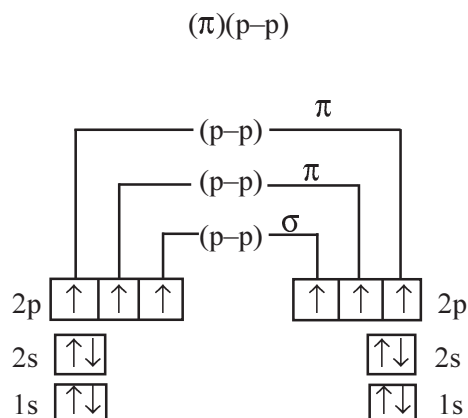
eg., F_2 molecule



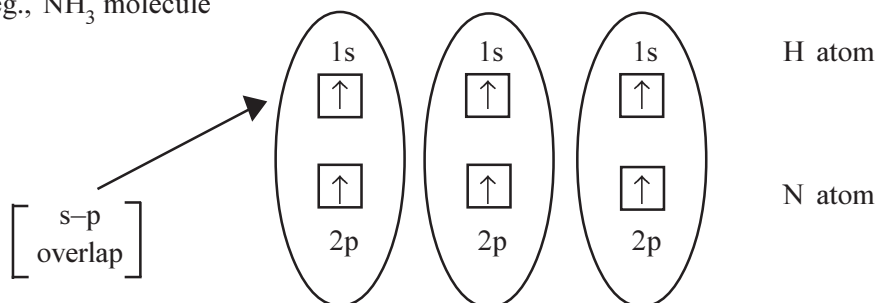
eg., O_2 molecule



eg., N_2 molecule



eg., NH_3 molecule



● Limitations of valence bond theory

- (1) It cannot explain magnetism of O_2 molecule.
- (2) It cannot explain what is the effect of bond formation of valence orbit on inner orbits.
- (3) This principle cannot explain molecules having odd number of e^- .

85. Which of the following overlapping is possible in F_2 molecule formation ?
 (A) axial overlapping of s-s orbitals (B) parallel overlapping of p-p orbitals
 (C) axial overlapping of p-p orbitals (D) axial overlapping of s-p orbitals
86. A double bond is formed by sharing of how many electrons between two atoms ?
 (A) 2 electrons (B) 4 electrons (C) 1 electron (D) all electrons
87. Angular shaped ozone molecule contains
 (A) 1 sigma and 1 π bond (B) 2 sigma and 1 π bond
 (C) 1 sigma and 2 π bond (D) 2 sigma and 2 π bond
88. Which of the following has shortest C-C bond ?
 (A) $sp-sp$ (B) sp^2-sp (C) sp^2-sp^2 (D) sp^3-sp
89. In which of the following $d\pi - p\pi$ bond is formed ?
 (A) NO_3^- (B) CO_3^{2-} (C) BO_3^{3-} (D) SO_3^{2-}
90. What is the number and type of bond between 2 carbon atom in calcium carbide ?
 (A) 1σ and 1π (B) 1σ and 2π (C) 2σ and 1π (D) 2σ and 2π
91. Order of strength of bond produced by $2s-2s$, $2p-2p$ and $2p-2s$ overlapping is ?
 (A) $s-s > p-p > p-s$ (B) $p-p > p-s > s-s$ (C) $s-s > p-s > p-p$ (D) $p-p > s-s > p-s$
92. Xylene possesses σ bonds.
 (A) 6 (B) 9 (C) 12 (D) 18
93. Which of the following does not possess π bond ?
 (A) C_2H_2 (B) C_2H_4 (C) C_6H_6 (D) C_6H_{12}
94. In P_4O_{10} the number of sigma bonds is
 (A) 6 (B) 7 (C) 17 (D) 16
95. The number of σ and $d\pi - p\pi$ bond in pyrophosphoric acid $[H_4P_2O_7]$ is respectively ?
 (A) 8, 2 (B) 6, 2 (C) 12, 0 (D) 12, 2
96. Acetate ion contains
 (A) one C - O single bond and one C = O double bond
 (B) two C - O single bond
 (C) two C = O double bond
 (D) None
97. bond is always formed by s-orbital.
 (A) sigma (B) π (C) sigma and π (D) None
98. Which of the following molecule possess more than one sigma bond ?
 (A) F_2 (B) N_2 (C) CH_4 (D) H_2
99. Which of the following is the strongest bond ?
 (A) C - C (B) C = C
 (C) C $\equiv$ C (D) They are of equal strength
100. The number of π bonds in XeO_3 and XeO_4 are respectively.
 (A) 3, 4 (B) 4, 2 (C) 2, 3 (D) 3, 2

Answers : 85. (B), 86. (B), 87. (B), 88. (A), 89. (D), 90. (B), 91. (B), 92. (D), 93. (D), 94. (D), 95. (D), 96. (A), 97. (A), 98. (C), 99. (C), 100. (A)

● Hybridisation

In a given atom, atomic orbitals with negligible difference in energy when overlapped with each other, they produce same number of new equienergetic orbitals, such orbitals are called hybrid orbitals and the phenomena is known as Hybridisation.

● characteristics of hybridisation

- orbitals with equal/less energy difference overlap with each other.
- The number of hybrid orbitals produced is equal to the number of overlapped atomic orbitals.
- Shape, size and energy of hybrid orbitals is same.
- There are two types of geometry created due to hybridisation.

Regular Geometry	Irregular Geometry
↓	↓
In each orbital there are bonded pairs	In each orbital there are bonded or lone pair

Type of hybridisation

- (1) $sp \rightarrow s + p$
- (2) $sp^2 \rightarrow s + p + p$
- (3) $sp^3 \rightarrow s + p + p + p$
- (4) $sp^3d \rightarrow s + p + p + p + d$
- (5) $sp^3d^2 \rightarrow s + p + p + p + d + d$
- (6) $sp^3d^3 \rightarrow s + p + p + p + d + d + d$
- (7) $dsp^2 \rightarrow d + s + p + p$
- (8) $dsp^3 \rightarrow d + s + p + p + p$

Hybridisation involving d-orbitals

- (1) $sp^3d \rightarrow dz^2$
- (2) $sp^3d^2 \rightarrow dz^2, dx^2 - y^2$
- (3) $sp^3d^3 \rightarrow dxy, dyz, dzx$
- (4) $dsp^2 \rightarrow dx^2 - y^2$
- (5) $dsp^3 \rightarrow dx^2 - y^2$

● Hybridisation and shape

Hybridisation	Shape	bond angle	example
sp	Linear	180°	BeCl ₂
sp ²	Planar triangle	120°	BF ₃
sp ³	Tetrahedral	109°28'	CH ₄
sp ³ d	Trigonal Bipyramidal	90° and 120°	PCl ₅
sp ³ d ²	Octahedral	90°	SF ₆
sp ³ d ³	Pentagonal Bipyramidal	90° and 72°	IF ₇
dsp ²	Square planar	90°	[Ni(CN) ₄] ²⁻

● **Hybridisation and shape of important ions.**

Ions	Hybridisation	Shape	Number of non bonded electron pair
SO_4^{2-}	sp^3	Tetrahedral	0
PO_4^{3-}	sp^3	Tetrahedral	0
ClO_4^-	sp^3	Tetrahedral	0
NH_4^+	sp^3	Tetrahedral	0
CO_3^{2-}	sp^2	Planar triangle	0
NO_3^-	sp^2	Planar triangle	0
ClO_3^-	sp^3	pyramidal	1
ClO_2^-	sp^3	V-shape	2
I_3^-	sp^3d	linear	3
ICl_2^-	sp^3d	linear	3
ICl_2^+	sp^3	V-shape	2

● **Method to determine hybridisation**

● Sum up the total number of electrons in valence orbit of each atom/ion.

● If the total is greater than 8 then divide by 8 and if the total is 8 or less than 8, then divide by 2 and if the answer is 2, 3, 4, 5, 6, 7 then the hybridisation is as follows :

eg.,	Total	→	Hybridisation
	2	→	sp
	3	→	sp^2
	4	→	sp^3
	5	→	sp^3d
	6	→	sp^3d^2
	7	→	sp^3d^3

eg., CO_3^{2-} : $1(4) + 3(6) + 2 = 24 \text{ e}^-$

$$\therefore \frac{24}{8} = 3[\text{sp}^2 \text{ hybridisation}]$$

eg., NH_4^+ = $1(5) + 4(1) - 1 = 8 \text{ e}^-$

$$\therefore \frac{8}{2} = 4[\text{sp}^3 \text{ Hybridisation}]$$

eg., PCl_5 = $1(5) + 5(7) = 40$

$$\therefore \frac{40}{8} = 5[\text{sp}^3\text{d Hybridisation}]$$

eg., $\text{SF}_6 = 1(6) + 6(7) = 48$

$$\therefore \frac{48}{8} = 6[\text{sp}^3\text{d}^2 \text{ Hybridisation}]$$

eg., $\text{XeF}_6 = 1(8) + 6(7) = 50$

$$\therefore \frac{50}{8} + (2) \text{ remainder (less than 8 value)} \therefore 6 + \frac{2}{2} = 6 + 1 = 7[\text{sp}^3\text{d}^3 \text{ Hybridisation}]$$

- 101.** Show hybridisation in SF_6 and percentage of d character.
 (A) sp^3d^2 , 33.33 % (B) sp^3d , 20 % (C) sp^2d , 25 % (D) sp^3d , 75 %
- 102.** In which of the compounds there are carbon with sp^2 and sp^3 hybridisation ?
 (A) $\text{CH}_3 - \text{CH} = \text{CH}_2$ (B) $\text{CH}_2 = \text{CH}_2$
 (C) $\text{CH} \equiv \text{CH}$ (D) $\text{CH}_2 = \text{CH} - \text{CH} = \text{CH}_2$
- 103.** Show hybridisation of C in $\text{C}_2[\text{CN}]_4$
 (A) sp^2 (B) sp and sp^2 (C) sp and sp^3 (D) sp
- 104.** Hybridisation of SO_2 and SO_3 molecule is respectively.
 (A) sp , sp^2 (B) sp^2 , sp^2 (C) sp^2 , sp^3 (D) sp , sp^3
- 105.** Show the increasing order of size of hybrid orbitals.
 (A) $\text{sp} < \text{sp}^3 < \text{sp}^2$ (B) $\text{sp} < \text{sp}^2 < \text{sp}^3$ (C) $\text{sp}^3 < \text{sp} < \text{sp}^2$ (D) $\text{sp}^3 < \text{sp}^2 < \text{sp}$
- 106.** Show the s character in methane, ethene and ethyne.
 (A) 25 %, 33 %, 50 % (B) 25 %, 50 %, 75 % (C) 50 %, 75 %, 100 % (D) 10 %, 20 %, 40 %
- 107.** Hybridisation of C in diamond, graphite and Acetylene is
 (A) sp^3 , sp^2 , sp^2 (B) sp , sp^2 , sp^3 (C) sp^2 , sp^3 , sp^3 (D) sp^3 , sp^2 , sp
- 108.** In which of the following central atom has sp^2 hybridisation ?
 (A) NO_2^- , NH_2^- (B) NH_2^- , H_2O (C) NO_2^- , H_2O (D) BF_3 , NO_2^-
- 109.** If the central atom has sp^2 hybridisation in a molecule what will be the shape of the molecule ?
 (A) pyramidal (B) Tetrahedran (C) Octahedran (D) planar triangle
- 110.** What is the Hybridisation of S atom in SF_2 , SF_4 and SF_6
 (A) sp^2 , sp^3 , sp^3d^2 (B) sp^3 , sp^3 , sp^3d (C) sp^3 , sp^3d , sp^3d^2 (D) sp^3 , sp^2 , d^2sp^3
- 111.** Which of the following hybridisation has maximum bond angle ?
 (A) sp^2 (B) sp (C) sp^3 (D) dsp^2
- 112.** In Buta-1, 2diene there is
 (A) Only sp hybridised carbon (B) Only sp^2 hybridised carbon
 (C) sp and sp^2 hybridised carbon
 (D) sp , sp^2 and sp^3 all three type hybridised carbon
- 113.** What will be the hybridisation of central atom in NH_3 , $[\text{PtCl}_4]^{2-}$, PCl_5 and BCl_3 respectively ?
 (A) dsp^2 , dsp^3 , sp^2 , sp^3 (B) sp^3 , dsp^2 , dsp^3 , sp^2
 (C) dsp^2 , sp^2 , sp^3 , dsp^3 (D) dsp^2 , sp^3 , sp^2 , dsp^3
-

114. What is the shape of NH_3 molecule and hybridisation of N ?
 (A) Tetrahedral, sp^3 (B) Triagonal pyramid, sp^3 (C) Triangular, sp^2 (D) None
115. Which of the following has inter atomic bond angle $109^\circ 28'$?
 (A) NH_4^+ , BF_3 (B) NH_2^- , BF_3 (C) NH_3 , BF_4^- (D) NH_3 , BF_4
116. Which of the following pair is correct based on hybridisation and shape ?
 (A) BeCl_2 , sp^2 linear (B) BeCl_2 , sp^2 angular
 (C) BCl_3 , sp^2 triangular pyramid (D) BCl_3 , sp^3 tetrahedron

Answers : 101. (A), 102. (A), 103. (B), 104. (B), 105. (B), 106. (A), 107. (D), 108. (D), 109. (D), 110. (C), 111. (B), 112. (D), 113. (B), 114. (B), 115. (C), 116. (C)

● Dipole moment

- Covalent bond formed between two atoms having difference in electronegativity is called a polar covalent bond.

eg., $(\text{H} \times \overset{+\delta}{\underset{\cdot\cdot}{\text{Cl}}} \overset{-\delta}{\cdot\cdot}) = \text{H} - \text{Cl}$ polarity of such molecule is measured by dipole moment

- Dipole moment (μ) = $\delta \times d$.

Where, δ = charge developed due to difference in electronegativity

d = distance between nucleus of two atoms

- Unit of Dipole moment is Debye

1 Debye = 10^{-18} esu cm

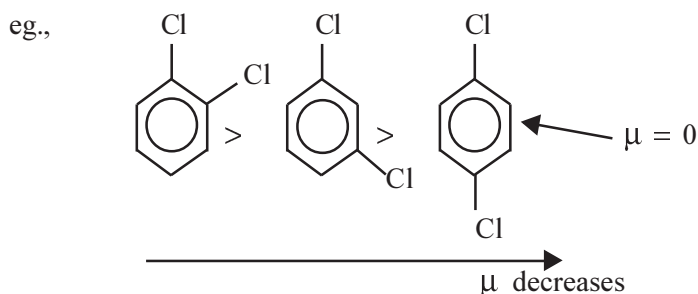
= 1.6×10^{-29} coulomb meter

- Direction of Dipole moment is always from electropositive to electronegative as well as denoted by ' $\rightarrow$ ' from central atom to atom containing non bonded electron pair.
- Take $\mu = 0$ for all molecules having regular geometry like PCl_5 , SF_6 .
- Take $\mu = 0$ for all molecules having planar structure like benzene and naphthalene etc.
- Take $\mu = 0$ for all non polar molecules like CO_2 , BF_3 , CCl_4 , BeCl_2 , CH_4 etc.
- % ionic character of a compound based on dipole moment can be determined as follows :

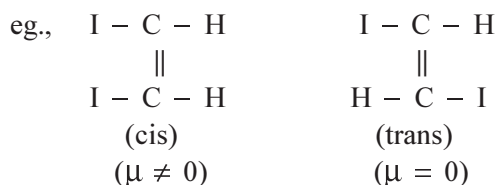
eg., % ionic character = $\frac{\text{Experimental value of dipole moment}}{\text{Theoretical value of dipole moment}} \times 100$

- Normally in symmetric compound as bond angle increases dipole moment decreases.

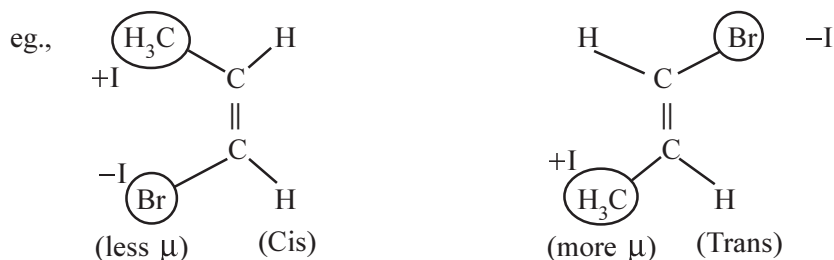
$$\mu \propto \frac{1}{\text{bond angle}}$$



- Out of cis and trans isomers dipole moment of cis isomers is more than trans isomers.



- In C = C If two groups having opposite inductive effect are attached on both sides, then dipole moment of trans isomer is more.



- Shape of molecule based on dipole moment

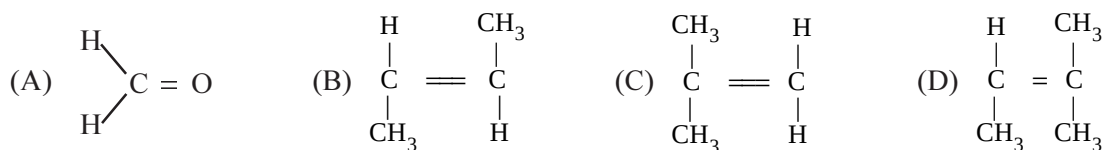
Common formula	Shape	Dipole moment	Example
AX	linear	cannot be zero	HF, HCl
AX ₂	linear bent (V-shape)	zero Not zero	CO ₂ , CS ₂ H ₂ O, NO ₂
AX ₃	planar triangle pyramidal T-shape	zero Not zero Not zero	BF ₃ NH ₃ , PCl ₃ ClF ₃
AX ₄	tetrahedral square planar see-saw	zero zero Not zero	CH ₄ , CCl ₄ XeF ₄ SF ₄ , TeCl ₄
AX ₅	triagonal bipyramidal square pyramidal	zero Not zero	PCl ₅ BrCl ₅
AX ₆	octahedral distorted octahedral	zero Not zero	SF ₆ XeF ₆
AX ₇	pentagonal bipyramidal	zero	IF ₇

Dipole moment in polar molecule = ionic charge $\times$ ionic distance

(charge in esu unit and ionic distance in cm unit)

$$1 \text{ \AA} = 1 \times 10^{-8} \frac{\text{esu}}{\text{cm}} = 1 \times 10^{-10} \frac{\text{esu}}{\text{m}}$$

117. Which of the following compound has maximum dipole moment ?
 (A) CH_3Cl (B) CH_2Cl_2 (C) CHCl_3 (D) CCl_4
118. Which of the following has property of lowest polarity ?
 (A) water (B) ethanol (C) ethane (D) ether
119. CCl_4 does not show dipole moment because
 (A) it has planar structure.
 (B) it has definite tetrahedral structure.
 (C) size of carbon and chlorine is same.
 (D) carbon and chlorine have same electronegativity.
120. Which of the following pair has permanent dipole moment ?
 (A) SiF_4 , NO_2 (B) NO_2 , CO_3 (C) NO_2 , O_3 (D) SiF_4 , CO_2
121. Which of the following has maximum dipole moment ?
 (A) CO_2 (B) BF_3 (C) SO_2 (D) trans-but-2-ene
122. Calculate dipole moment of a polar molecule having ionic charge 4.8×10^{-10} esu and interionic distance is $\overset{\circ}{\text{A}}$.
 (A) 48.1D (B) 4.18D (C) 4.8D (D) 0.48D
123. HCl is a completely polar molecule with a dipole moment of 6.12D. If its experimental value of dipole moment is 1.03D, then calculate percentage of ionic character ?
 (A) 17 % (B) 83 % (C) 50 % (D) 90 %
124. Show the correct order of dipole moment ?
 (A) $\text{CH}_4 < \text{NF}_3 < \text{NH}_3 < \text{H}_2\text{O}$ (B) $\text{NH}_3 < \text{CH}_4 < \text{NF}_3 < \text{H}_2\text{O}$
 (C) $\text{NH}_3 < \text{NF}_3 < \text{CH}_4 < \text{H}_2\text{O}$ (D) $\text{H}_2\text{O} < \text{NH}_3 < \text{NF}_3 < \text{CH}_4$
125. Why is bonded electron pair arranged unequally between two atoms in a molecule ?
 (A) Dipolar (B) covalent bond (C) disintegration of molecule (D) None
126. Which of the following has maximum dipole moment ?



127. Which of the following has maximum dipole moment ?
 (A) AsH_3 (B) SbH_3 (C) PH_3 (D) NH_3
128. If dipole moment of chlorobenzene is 1.73D, then what will be the dipole moment of p-dichlorobenzene ?
 (A) 3.46D (B) 0.00D (C) 1.73D (D) 1.00D
129. Which of the following molecule shows dipole moment ?
 (A) 1, 4-dichlorobenzene (B) Cis-1, 2-dichloro ethene
 (C) Trans-1, 2-dichloro ethene (D) Trans-2, 3-dichloro But-2-ene

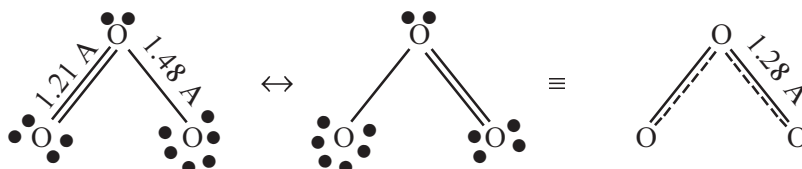
130. Which of the following has maximum dipole moment ?
 (A) CH_4 (B) CHCl_3 (C) CCl_4 (D) CH_2Cl_2
131. Mention the correct order of polarity for the given molecule ?
 (A) $\text{NH}_3 < \text{H}_2\text{O} < \text{HF} > \text{H}_2\text{S}$ (B) $\text{H}_2\text{S} < \text{NH}_3 < \text{H}_2\text{O} < \text{HF}$
 (C) $\text{H}_2\text{O} < \text{NH}_3 < \text{H}_2\text{S} < \text{HF}$ (D) $\text{HF} < \text{H}_2\text{O} < \text{NH}_3 < \text{H}_2\text{S}$
132. Arrange the molecules in increasing order of dipole moment ?
 (I) Toluene (II) m-dichlorobenzene (III) o-dichlorobenzene (IV) p-dichlorobenzene
 (A) I, IV, II, III (B) IV, I, II, III (C) IV, I, III, II (D) IV, II, I, III
133. Which of the following molecule has both polar and non polar bond ?
 (A) NH_4Cl (B) HCN (C) H_2O_2 (D) CH_4

Answers : 117. (A), 118. (C), 119. (B), 120. (C), 121. (C), 122. (C), 123. (A), 124. (A), 125. (A), 126. (A), 127. (D), 128. (B), 129. (B), 130. (D), 131. (B), 132. (B), 133. (A)

● Resonance

● When any substance/molecule/ion can be described by more than one electronic structure, where any one electronic structure can describe all the characteristic property of the molecule then all the possible electronic structures are called resonating structure and the phenomena is known as resonance.

- eg., Resonance in O_3



- Resonating structures have identical arrangement of components.
- Resonating structures have same bond angle between components.
- Resonating structures have different electronic arrangement.
- Resonating structures have same number of bonds
- Resonating structures are more stable than normal structure of substance.
- Minimum energy required for interconversion between resonating structures is called resonance energy.
- Resonating structures have same number of paired and unpaired electron.

134. Which of the following molecule shows resonance ?
 (A) O_3 (B) NH_3 (C) CH_4 (D) H_2O
135. How many resonating structures are possible in carbonate ion ?
 (A) 2 (B) 3 (C) 6 (D) 9

136. Which of the following does not show resonating structure ?
 (A) C_6H_6 (B) CO_2 (C) CO_3^{2-} (D) SiO_2
137. How many non bonded electron pair are present in the central atom of O_3 molecule ?
 (A) 1 (B) 0 (C) 2 (D) 3
138. Which of the following statement is not correct for resonating structures ?
 (A) Resonating structures have equal energy
 (B) Resonating structures do not have same number of electron pair.
 (C) Arrangement of electron is different in resonating structures.
 (D) Resonating structures have identical arrangement of atoms.
139. What is different in resonating structures ?
 (A) Atomic arrangement (B) Electronic arrangement (C) Reactive group (D) Alkali group
140. Because of resonance
 (A) bond length decreases. (B) energy of molecule decreases.
 (C) stability of molecule increases. (D) all given are true.

Answers : 134. (A), 135. (B), 136. (D), 137. (A), 138. (B) 139. (B) 140. (D)

● Molecular Orbital Theory (MOT)

● Atomic orbitals of equal energy undergo complimentary and opposing overlapping with each other producing Molecular orbital.

● electrons are arranged in atomic orbital and molecular orbitals on the basis of Aaf-bau, Pauli and Hund's rule.

● The number of atomic orbitals that combine with each other is the same number of molecular orbitals. Half the number of these molecular orbitals are called Bonding Molecular Orbital (BMO) and remaining half number are called Antibonding Molecular Orbitals (ABMO).

● Energy of BMO is less than the energy of ABMO.

● Conditions for Linear Combination of Atomic Orbitals (LCAO)

(1) The atomic orbitals of the combining atoms must possess similar energies.

(2) The combining atoms must be as near as possible so that the overlapping can be maximum on the axis of atomic orbitals.

(3) The symmetry of the atomic orbitals of combining atoms must be same.

● Order of energy of molecular orbitals for 14 or less than 14 electron containing system (atom/ion)

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

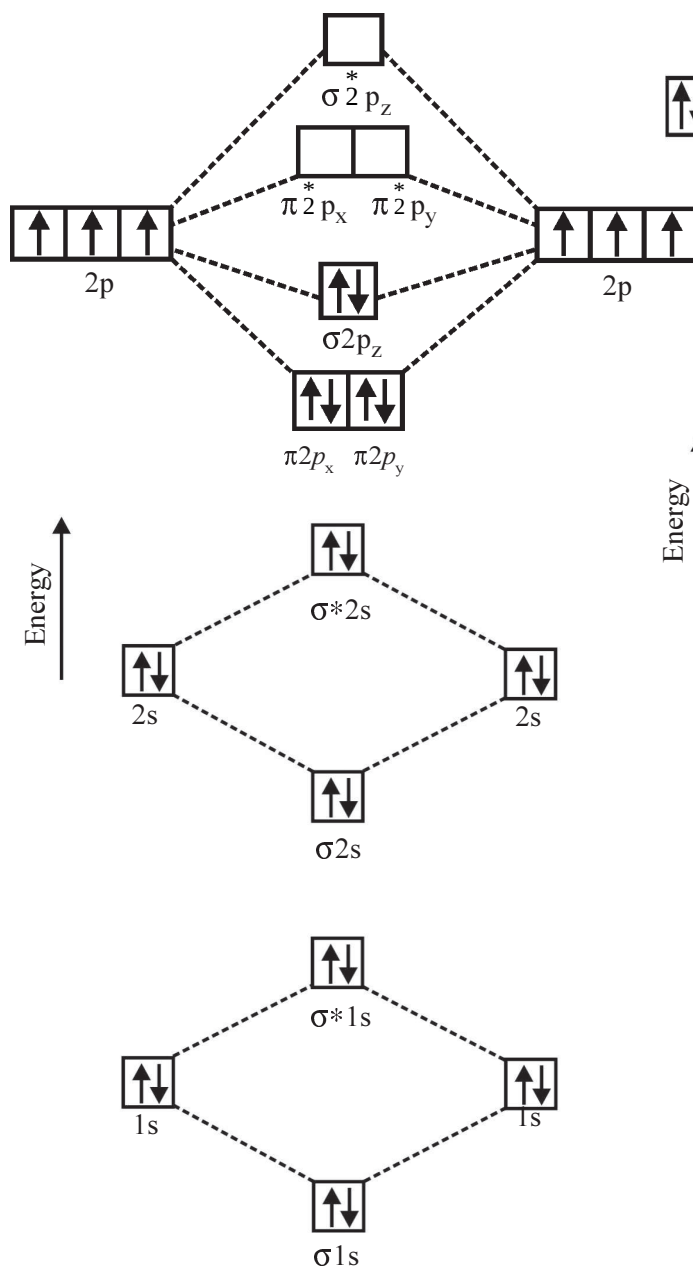
● Order of energy of molecular orbitals more than 14 electron containing system (atom/ion)

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

$$\text{Bond order} = \text{B.O.} = \frac{1}{2}(\text{Number of } e^- \text{ in BMO} - \text{number of } e^- \text{ in ABMO})$$

$$= \frac{1}{2}[\text{Nb} - \text{Na}]$$

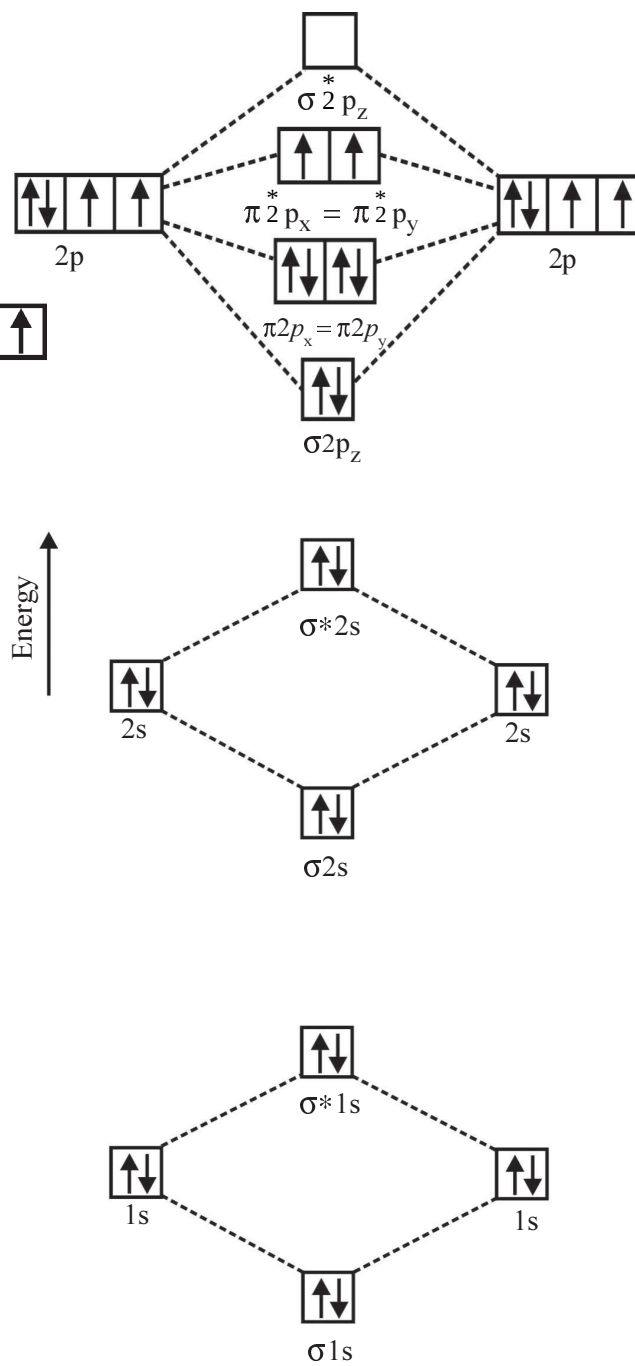
M.O. diagram for 14 or less than 14 e⁻ system



M.O. diagram for N₂ molecule

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

M.O. diagram for more than 14 e⁻ system



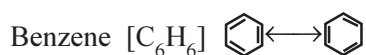
M.O. diagram for O₂ molecule

$$\text{B.O.} = \frac{1}{2}[\text{Nb} - \text{Na}] = \frac{1}{2}(10 - 6) = 2$$

● Method to calculate bond order

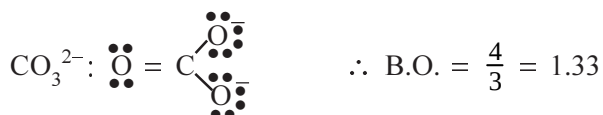
Electron	Bond order	Example
08	0.0	Be ₂
09	0.5	B ₂ ⁺ , Be ₂ ⁻
10	1.0	B ₂ , Be ₂ ²⁻
11	1.5	C ₂ ⁺ , B ₂ ⁻
12	2.0	C ₂ , N ₂ ⁺²
13	2.5	N ₂ ⁺ , C ₂ ⁻
14	03	N ₂ , O ₂ ⁺²
15	2.5	O ₂ ⁺ , N ₂ ⁻
16	2.0	O ₂ , N ₂ ²⁻
17	1.5	O ₂ ⁻ , F ₂ ⁺
18	1.0	O ₂ ²⁻ , F ₂
19	0.5	F ₂ ⁻
20	00	F ₂ ⁻² , Ne ₂

● Method to calculate bond order of multiatomic ion or molecule



$$\text{B.O.} = \frac{\text{Total no. of bonds between two atoms in a molecule}}{\text{number of resonating structure of molecule}}$$

$$= \frac{2+1}{2} = 1.5$$



$$\text{Bond order} \propto \text{stability} \propto \text{dissociation enthalpy} \propto \text{lattice enthalpy} \propto \frac{1}{\text{Bond length}} \propto \frac{1}{\text{activity}} \propto \frac{1}{\text{reactivity}}$$

141. Which of the following shows correct order of stability of component ?
 (A) $\text{Li}_2 < \text{Li}_2^+ < \text{Li}_2^-$ (B) $\text{Li}_2^- < \text{Li}_2^+ < \text{Li}_2$ (C) $\text{Li}_2 < \text{Li}_2^- < \text{Li}_2^+$ (D) $\text{Li}_2^- < \text{Li}_2 < \text{Li}_2^+$
142. Which of the following components does not exist ?
 (A) H_2^+ , He_2^{2-} (B) H_2^- , He_2^{2-} (C) H_2^{2+} , He (D) H_2^- , He_2^{2+}
143. Which of the following has same bond order ?
 (A) N_2^+ , O_2 (B) N_2^+ , O_2^{2+} (C) N_2^- , O_2 (D) N_2 , O_2
144. What is correct for peroxide ion according molecular orbital principle ?
 (A) It has bond order 2 and is diamagnetic (B) It has bond order 1 and is paramagnetic
 (C) It has bond order 1 and is diamagnetic (D) It has bond order 2 and is paramagnetic
145. Which of the following component has bond order different from that of CO ?
 (A) NO^- (B) NO^+ (C) CN^- (D) N_2
146. Based on MO theory how many nonbonded electron pair are present in O_2^{-2} ?
 (A) 4 (B) 3 (C) 2 (D) 5
147. Which of the following has the least bond length ?
 (A) O_2^{+2} (B) O_2^+ (C) O_2^- (D) O_2^{2-}
148. Show decreasing order of bond length.
 (A) $\text{N}_2^{2-} > \text{N}_2 > \text{N}_2^-$ (B) $\text{N}_2^{2-} > \text{N}_2^- > \text{N}_2$ (C) $\text{N}_2 > \text{N}_2^{2-} > \text{N}_2^-$ (D) $\text{N}_2^- > \text{N}_2^{2-} > \text{N}_2$
149. For the following molecules show the correct order of bond length in O-O bond.
 (A) $\text{H}_2\text{O} < \text{O}_2 < \text{O}_3$ (B) $\text{O}_2 < \text{H}_2\text{O}_2 < \text{O}_3$ (C) $\text{O}_2 < \text{O}_3 < \text{H}_2\text{O}_2$ (D) $\text{O}_3 < \text{H}_2\text{O} < \text{O}_2$
150. Show the correct order of bond length in C-O bond.
 (A) $\text{CO} < \text{CO}_3^{2-} < \text{CO}_2$ (B) $\text{CO} < \text{CO}_2 < \text{CO}_3^{2-}$
 (C) $\text{CO}_2 < \text{CO}_3^{2-} < \text{CO}$ (D) $\text{CO}_3^{2-} < \text{CO} < \text{CO}_2$
151. In which of the following ionization process, bond order increases and there is change in magnetic property ?
 (A) $\text{C}_2 \rightarrow \text{C}_2^+$ (B) $\text{NO} \rightarrow \text{NO}^+$ (C) $\text{O}_2 \rightarrow \text{O}_2^+$ (D) $\text{N}_2 \rightarrow \text{N}_2^+$
152. Based on MO theory, which of the following statement is true with respect to magnetic property and bond order for O_2^+ .
 (A) paramagnetic and bond order $< \text{O}_2$ (B) paramagnetic and bond order $> \text{O}_2$
 (C) diamagnetic and bond order $< \text{O}_2$ (D) diamagnetic and bond order $> \text{O}_2$
153. Based on MO theory what is diamagnetism of O_2 dependent on ?
 (A) unpaired electron in bonding sigma molecular orbital.
 (B) unpaired electron in non bonding sigma molecular orbital.
 (C) unpaired electron in bonding π molecular orbital.
 (D) unpaired electron in non bonding π molecular orbital.

154. When $N_2 \rightarrow N_2^+$ and $O_2 \rightarrow O_2^+$ where is electron removed from respectively ?
 (A) (π^*2p_y or π^*2p_x) and (π^*2p_y or π^*2p_x)
 (B) ($\pi 2p_x$ or $\pi 2p_y$) and ($\pi 2p_x$ or $\pi 2p_y$)
 (C) ($\sigma 2p_z$) and (π^*2p_y or π^*2p_x)
 (D) (π^*2p_y or π^*2p_x) and ($\pi 2p_y$ or $\pi 2p_x$)
155. Which of the following is the correct order for bond energy of given component ?
 (A) $NO^- > NO > NO^+$ (B) $NO > NO^- > NO^+$ (C) $NO^+ > NO > NO^-$ (D) $NO^+ > NO^- > NO$
156. Which of the following components is not paramagnetic ?
 (A) ClO_2 (B) ClO_2^- (C) NO_2 (D) NO
157. Which of the following components is paramagnetic ?
 (A) CO (B) O_2^- (C) CN^- (D) NO^+
158. Which of the following components is/are diamagnetic ?
 (A) C_2 (B) N_2 (C) O_2 (D) S_2
159. Which of the following component is diamagnetic ?
 (A) O_2^{2-} (B) O_2^+ (C) O_2 (D) NO
160. Which of the following component is diamagnetic ?
 (A) H_2^- (B) H_2^+ (C) H_2 (D) He_2^+
161. Which of the following molecule is paramagnetic ?
 (A) Na_2O_2 (B) O_3 (C) N_2O (D) KO_2
162. Which one has same bond order ?
 (A) CN^- , CN^+ (B) O_2^- , CN^- (C) NO^+ , CN^+ (D) CN^- , NO^+
163. Which of the following does not have bond order ?
 (A) N_2^+ (B) O_2^{2+} (C) N_2 (D) NO^+
164. Show the correct order of strength of bond for dioxygen molecule, peroxide ion, superoxide ion as well as mono positive di oxygen ion ?
 (A) $O_2^+ > O_2^- > O_2^{2-} > O_2$ (B) $O_2^+ > O_2 > O_2^- > O_2^{2-}$
 (C) $O_2^{2-} > O_2^- > O_2 > O_2^+$ (D) $O_2^{2-} > O_2^- > O_2^+ > O_2$
165. In a N_2 molecule having bond order 3, if there are four electrons in ABMO, then how many electrons are there in BMO ?
 (A) 6 (B) 2 (C) 10 (D) 8
166. Bond order of PO_4^{3-} ion is
 (A) 1.33 (B) 2.5 (C) 1.25 (D) 3.0
167. Bond order of perchlorate (ClO_4^-) ion is
 (A) 1.35 (B) 2.35 (C) 1.5 (D) 1.75

168. In which of the following components there are maximum electrons in ABMO ?

- (A) O_2 (B) O_2^{2-} (C) O_2^- (D) O_2^+

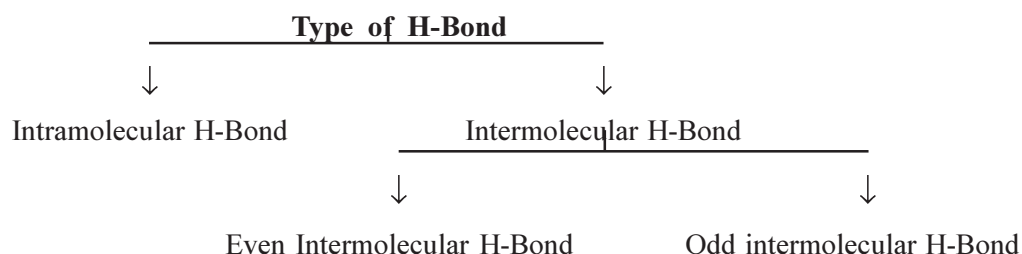
169. Based on MO theory, how many electron pairs are present in M.O. diagram of Ne_2 molecule ?

- (A) 7 (B) 10 (C) 5 (D) 3

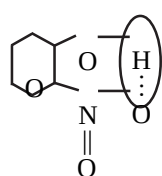
Answers : 141. (B), 142. (C), 143. (B), 144. (C), 145. (A), 146. (A), 147. (A), 148. (B), 149. (C), 150. (B), 151. (B), 152. (B), 153. (D), 154. (C), 155. (C), 156. (B), 157. (B), 158. (A), (B) 159. (A), 160. (C), 161. (D), 162. (D), 163. (A), 164. (B), 165. (C), 166. (C), 167. (D), 168. (B), 169. (B)

• Hydrogen bond (H-bond)

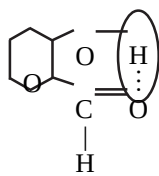
- The attraction produced between N, O, F elements having high electronegativity with negative charge and less electronegativity (electropositive) possessing H-atom is called Hydrogen bond.



- Intra molecular H bond :** In one molecule itself one component with high electronegativity forms a bond with less electronegative component.

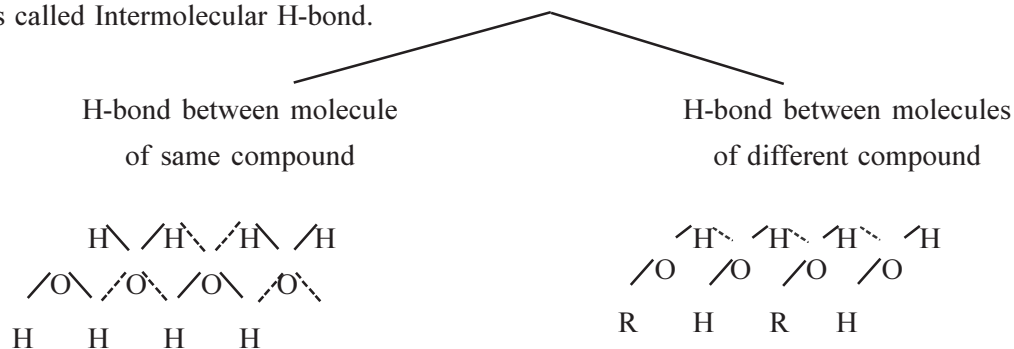


o-nitrophenol



salicylaldehyde

- Intermolecular H Bond :** Formation of H bond in two or more same or different type of compounds is called Intermolecular H-bond.



• effect of H-bond

- Those organic compounds which form H-bond with water are water soluble and those which do not form H-bond will remain water insoluble.

- (2) With increase in strength of H-bond in compounds (liquid) viscosity increases.
- (3) Dielectric constant increases as polarity increases due to H-bond.
- (4) There is increase in melting point / boiling point of compound due to H-bond.
- (5) Due to H-bond experimental molecular mass increases eg. CH_3COOH exist as a dimer due to H-bond.
- (6) Physical state of a substance changes due to H-bond. eg. H_2O is liquid, while H_2S is gas.

● **Van der waal force of attraction**

- **Deviation in behaviour of ideal gas :** On studying this phenomena Van der Waal mentioned weak attractive force exist between any two gaseous molecules which cannot be explained by any principle or any other chemical reaction. Such force of attraction is known as Van der Waal force of attraction.
- It is a weak force of attraction which prevails upto $4.5 \text{ \AA}$ distance.
- As its magnitude is less as 10 Kcal, it is mostly hidden under by other attractive forces.
- **Factors affecting Van der Waals force of attraction are**
 - shape of molecule
 - contact surface of molecule
 - number of electrons in molecule
 - average intermolecular distance
- **Type of Van der Waal's force of attraction**
 - dispersion / london force
 - dipole-dipole force
 - dipole induced dipole force

170. Why is density of water maximum at 277 K temperature ?

- | | |
|-----------------------------|--------------------------|
| (A) due to H-bond | (B) due to Ionic bond |
| (C) due to Co-ordinate bond | (D) due to metallic bond |

171. Which of the following has maximum number of H-bond ?

- | | | | |
|-------------|------------------|-------------------|-------------------|
| (A) Ethanol | (B) Diethylether | (C) ethylchloride | (D) Triethylamine |
|-------------|------------------|-------------------|-------------------|

172. Which of the following is the strongest bond ?

- | | |
|--|--|
| (A) $\text{F} - - - - \text{H} - - - - \text{F}$ | (B) $\text{F} - - - - \text{H} - - - - \text{O}$ |
| (C) $\text{O} - - - - \text{H} - - - - \text{S}$ | (D) $\text{O} - - - - \text{H} - - - - \text{N}$ |

173. Compared to other Hydrogen Halides, Hydrogen flouride is liquid, because

- | | |
|--|--------------------------------|
| (A) small size of F atom | (B) HF is a weak acid |
| (C) H-F molecules are joined by H-bond | (D) Flourine is strong reagent |

174. In which of the following there is no H-bond ?
 (A) phenol (B) liquid NH_3 (C) water (D) liquid HCl
175. Boiling point of H_2S is less than that of H_2O because
 (A) H-bond (B) high specific density
 (C) less ionization (D) high dielectric constant
176. Hydrogen bond is formed in those substances which possess H bond and
 (A) more electronegative atom (B) more electro positive atom
 (C) metal atom with completely filled d-orbital (D) metalloid
177. Show the pair having strongest H-bond.
 (A) SiH_4 , SiF_6 (B) $\text{CH}_3 - \text{C} - \text{CH}_3$, CHCl_3
 $\parallel$
 O
 (C) $\text{H} - \text{C} - \text{OH}$, $\text{CH}_3 - \text{C} - \text{OH}$ (D) H_2O , H_2O_2
 $\parallel \quad \parallel$
 $\text{O} \quad \text{O}$
178. Which of the following has strongest H-bond ?
 (A) Methanol (B) Dimethylamine
 (C) Acetic acid (D) Methyl thio alcohol
179. Which of the following has H-bond ?
 (A) SiH_4 (B) LiH (C) HI (D) NH_3
180. Which of the following has maximum strongest H-bond ?
 (A) H_2O (B) H_2Se (C) H_2Te (D) HF
181. Boiling point of p-nitrophenol is more than o-nitrophenol because
 (A) behaviour of NO_2 group is different in at o and p-positions
 (B) p-nitrophenol has intramolecular H-bond.
 (C) p-nitrophenol has intermolecular H-bond.
 (D) molecular mass of p-nitrophenol is more than o-nitrophenol
182. Which of the following does not have H-bond ?
 (A) Acetic Acid (B) Ammonia (C) Ethanol (D) Diethyl ether
183. Which of the following has maximum possibility of H-bond formation ?
 (A) NH_3 (B) NH_2OH (C) HF (D) CH_3F

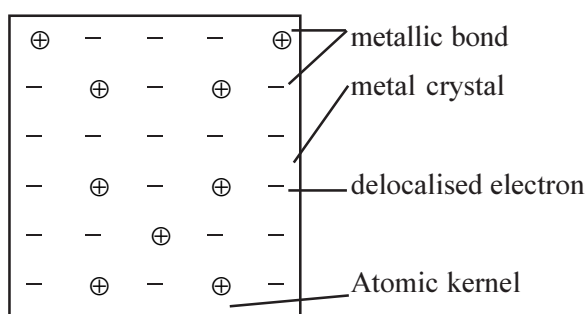
184. Methanol and ethanol are water soluble because
 (A) covalent bond (B) H-bond (C) O-bond (D) None
185. Nature of H-bond is
 (A) ionic (B) covalent (C) co-ordinate covalent (D) None
186. Which factor increases Van der Waal's force of attraction ?
 (A) Number of electron (B) Inter molecular distance
 (C) Number of proton (D) Number of neutron
187. Why is Van der Waal's force of attraction created ?
 (A) Nucleus of molecules attract each other.
 (B) Electrons on the surface of the molecule attract other molecule's electron on the surface
 (C) Electrons on the surface of the molecule are attracted by the nucleus of other molecules
 (D) Electrons on the surface of the molecule are repelled by the nucleus of other molecules.
188. Which of the following is not a factor affecting Van der Waal's force of attraction ?
 (A) Shape of molecules (B) Number of electrons in molecule
 (C) Bond formed between atoms in a molecule (D) Contact surface of molecule
189. Show the correct order of strength of Van der Waal's force of attraction.
 (A) $I_2 < Br_2 < Cl_2 < F_2$ (B) $F_2 < Cl_2 < Br_2 < I_2$ (C) $Br_2 < Cl_2 < F_2 < I_2$ (D) $Cl_2 < F_2 < Br_2 < I_2$
190. On what basis the less stability of liquid organic compound can be explained ?
 (A) H-bond (B) Metallic bond
 (C) Van der Waal's force of attraction (D) None

Answers : 170. (A), 171. (A), 172. (A), 173. (C), 174. (D), 175. (A), 176. (A), 177. (C), 178. (C), 179. (D), 180. (D), 181. (C), 182. (D), 183. (D), 184. (B), 185. (A), 186. (A), 187. (C), 188. (C), 189. (B), 190. (C)

● Metallic Bond :

- Bonds present in solid metallic crystals are called Metallic Bond.
- Metallic Bond is formed between positively charged atomic kernel and negatively charged delocalised electron.

● Electron sea model :



- Metallic bond does not have directional properties and it is weaker than covalent bond.

- Due to metallic bond, properties like electrical conductivity, ductileability, malleability, heat conductor etc. are seen in metal.

- 191.** Which of the following is not possible in metallic bond ?
 (A) overlapping (B) free electron
 (C) delocalised electron (D) None
- 192.** Which oxide indicates metal like conductivity ?
 (A) ReO_3 (B) VO (C) CrO_2 (D) given all
- 193.** Which of the following has no contribution of metallic Bond ?
 (A) Brass (B) Copper (C) Germanium (D) Zinc
- 194.** Which of the following is the example of solid metallic crystal ?
 (A) C (B) Si (C) W (D) AgCl
- 195.** Iron is more stronger than sodium because
 (A) size of Iron atom is small (B) Iron atoms are more closely arranged
 (C) Metallic bond in Iron is more (D) None
- 196.** Which of the following shows strongest bond formation ?
 (A) Van der Waals (B) Metallic bond (C) Dipole-Dipole (D) H-bond
- 197.** crystals are known as good conductors of Heat and electricity.
 (A) Ionic crystal (B) Covalent crystal (C) Metallic crystal (D) Molecular crystal
- 198.** If there is increase in charge of the metal ion in the crystal then it strength of metallic bond.
 (A) increases (B) decreases
 (C) no increase or decrease (D) increases or decreases
- 199.** Which of the following has highest melting point ?
 (A) Pb (B) Diamond (C) Fe (D) Na
- 200.** Which properties can be explained using metallic Bond ?
 (A) Heat conductivity (B) Malleability (C) Ductileability (D) given all

Answers : 191. (A), 192. (B), 193. (A), 194. (C), 195. (C), 196. (B), 197. (C), 198. (A), 199. (B), 200. (D)

•