Chapter 4 Chemical Bonding

Multiple Choice Questions (M.C.Qs)

Choose the correct answer for each from the given options:

01 **The bond formed in fluorine molecule is due to the overlap of these orbitals:**
(a) s-s (b) s-p (c) p-p (d) none of these

02 **Bond energy of C = C as compared to that of C = C is:**
(a) greater (b) lesser (c) same (d) none of these

03 **The angle between sp^3 orbitals is:**
(a) 127° (b) 109.28° (c) 180° (d) 90°

04 **The strength of sigma bond is higher for:**
(a) s-s overlap (b) s-p overlap (c) p-p overlap (d) sp^3- s overlap

05 **The dipole moment of Cl_2 molecule is:**
(a) 0.00 debye (b) 1.03 debye (c) 1.85 debye (d) 1.67 debye

06 **The single bond in a covalent molecules is called:**
(a) pi-bond (b) sigma bond (c) coordinate covalent (d) none

07 **The sp^2 hybrid orbitals are:**
(a) non-planer (b) co-planer (c) linear (d) none of these

08 **Which bond is non-polar?**
(a) Cl-Cl (b) N-Cl (c) C-Cl (d) H-Cl

09 **Which atomic orbital is always involved in sigma bonding?**
(a) s-orbital (b) p-orbital (c) d-orbital (d) none of these

10 **In ethene (C_2H_4) molecule, there are:**
(a) 5 sigma and 1 pi bonds (b) 6 sigma bonds
(c) 4 sigma bonds and 2 pi bonds (d) none of these

11 **Which of the compounds has sp^2 hybridization?**
(a) NH_3 (b) C_2H_2 (c) C_2H_4 (d) H_2O

12 **The bond distance between C-C single bond is:**
(a) 1.54 Å (b) 1.35 Å (c) 1.39 Å (d) 1.20 Å

13 **The largest ionic character is possessed by:**
(a) HF (b) IICl (c) HBr (d) HI

14 **The geometrical shape of SO_2 molecules is:**
(a) linear (b) planer trigonal (c) tetrahedral (d) none of these

15 **The hybridization of nitrogen atom in NH_3 molecules is:**
(a) sp^3 (b) sp^2 (c) sp (d) none of these

16 ***The compound are formed by the elements and get stability by:***
(a) *mutual repulsion* (b) *decreasing the energy*
(c) *increasing the energy* (d) *becoming inert*

17 ***Which of the following molecule has zero dipole?***
(a) NH_3 (b) $CHCl_3$ (c) H_2O (d) BF_3

18 ***'Debye' is the unit for the measurement of :***
(a) *dipole moment* (b) *electrostatic force*
(c) *Londen force* (d) *none of these*

19 ***Presence of ionic character in covalent bond make the bond length:***
(a) *larger* (b) *smaller* (c) *no change* (d) *none of these*

20 ***Bond energy depends upon:***
(a) *bond length* (b) *size of bonded atoms*
(c) *multiple bonds* (d) *all of them*

21 ***Which type of bond is present i. CH_4 and NaH:***
(a) *covalent in both* (b) *covalent in CH_4 and ionic in NaH*
(c) *ionic in both* (d) *ionic in CH_4 and covalent in NaH*

22 ***The charge on a cation M is +2 an[illegible]nion A is -3, The formula of the compound is :***
(a) M_2A (b) MA_2 [illegible] (d) M_2A_3

23 ***An atom or group of atoms which are e[illegible]ly charged are called:***
(a) *free ions* (b) *anions* [illegible]*ions* (d) *cations*

24 ***The shell of an atom with highest value of 'n' is called:***
(a) *valence shell* (b) *inner shell* (c) *empty shell* (d) *filled shell*

25 ***The interaction of valence electrons of combining atom forms:***
(a) *chemical bond* (b) *ionic bond* (c) *covalent bond* (d) *hydrogen bond*

26 ***The most polar bond is:***
(a) *N-F* (b) *F-F* (c) *C-F* (d) *O-F*

27 ***In a crystal, cations and anions are held together by:***
(a) *sharing of electrons* (b) *nuclear forces*
(c) *electrostatic forces* (d) *electrons*

28 ***Ionic compounds are most commonly formed by the combination of groups:***
(a) *3 and 5* (b) *2 and 5* (c) *4 and 8* (d) *1 and 7*

29 ***The nature of bond in diamond is:***
(a) *electrovalent* (b) *metallic*
(c) *co-ordinate covalent* (d) *covalent*

30 ***Tetrahedral shape of molecules is formed because of :***
(a) *sp-hybridization* (b) *sp^2-hybridization*
(c) *sp^3-hybridization* (d) *None of them*

31 ***Maximum repulsion exists between:***
(a) *lone pair-lone pair* (b) *lone pair-bond pair*
(c) *bond pair-bond pair* (d) *none of them*

32 ***Which one of the following contains co-ordinate covalent-bond?***
(a) H_3O^+ (b) CH_4 (c) H_2O (d) CO_2

33 ***Which is the weakest-bond:***
(a) *covalent bond* (b) *ionic bond* (c) *metallic bond* (d) *hydrogen bond*

34 ***The distance between the nucleus of two atoms forming a covalent bond is known as:***
(a) atomic radius (b) bond energy (c) bond length (d) ionic radius

35 ***Which solid does not contain covalent bonds?***
(a) Diamond (b) Ice (c) Copper (d) Graphite

36 ***Which one the following molecules has a co-ordinate covalent bond?***
(a) NH_4Cl (b) HCl (c) $NaCl$ (d) $AlCl_3$

37 ***Which one of the following is non-directional orbital?***
(a) sp^2 (b) $4d$ (c) $4f$ (d) $3s$

38 ***sp^3 hybridization is present in:***
(a) CCl_4 (b) NH_3 (c) H_2O (d) all of them

39 ***Hybridization is due to:***
(a) separation of orbitals (b) removal of electron pair
(c) addition of electron pair (d) mixing up of atomic orbitals

40 ***A bonding orbital which is symmetrical about a line joining the two atomic nuclei is called:***
(a) pi bond (b) sigma bond (c) dative bond (d) hydrogen bond

41 ***Which of the following bond require the largest amount of energy to dissociate into atoms?***
(a) Cl-Cl (b) $N \equiv N$ (c) $O = O$ (d) HCl

42 ***The distance between two carbon atoms is largest in which of the following molecules?***
(a) C_2H_6 (b) C_2H_4 (c) C_2H_2 (d) C_6H_6

43 ***During the formation of bond, the energy of the system:***
(a) increases (b) decreases (c) remain unchanged (d) None

44 ***Total number of electrons that take part in forming O_2 molecule:***
(a) 2 electrons (b) 6 electrons (c) 4 electrons (d) 8 electrons

45 ***The degree of polarity of a molecule is called:***
(a) dipole moment (b) bond energy (c) moment arm (d) ionic character

46 ***In C_2H_4 molecule the C-H bond is:***
(a) single covalent bond (b) double covalent bond
(c) triple bond (d) none of these

47 ***The mixing of different energies & shapes of orbitals is called:***
(a) hybridization (b) orientation (c) bonding (d) none of them

48 ***Which of the sp^3 hybrid molecule contains two lone pair:***
(a) CH_4 (b) HCl (c) H_2O (d) NH_3

49 ***The bond angle of linear molecular structure is:***
(a) 180° (b) 120° (c) 109.28° (d) 107°

50 ***Covalent bond was first discovered by:***
(a) W. Kossel (b) G.N. Lewis (c) Pauling (d) Sigdwick

51 ***In sp^3 hybridization the ratio of s and p orbital is:***
(a) 1:1 (b) 1:2 (c) 1:3 (d) 1:4

52 ***HF exists in liquid state due to:***
(a) Vander Waal's forces (b) hydrogen bond
(c) covalent bond (d) ionic bond

53 ***Protonic bridge is another name of :***
(a) covalent bond (b) ionic bond (c) hydrogen bond (d) dative bond

Chemical Bonding

54 ***The bond angle in case of NH_3 is reduced from:***
(a) 109° to 107° (b) 120° to 104° (c) 109° to 104.5° (d) 120° to 107°

55 ***The p-orbital which is not involved in sp^2 hybridization:***
(a) p_x-orbital (b) p_y orbital (c) p_z orbital (d) all p orbitals

56 ***Coulomb meter is a S.I unit for the measurement of :***
(a) bond energy (b) energy of activation
(c) lattice energy (d) dipole moment

57 ***Na^+, Mg^{+2}, Al^{+3} ions are:***
(a) isotopes (b) isobars (c) isoelectronics (d) isomers

58 ***Electronegativity difference between atoms helps to determine the:***
(a) physical properties of compounds (b) chemical properties of compounds
(c) nature of the bond (d) structure of the molecule

59 ***Which of the following solids consists of atoms or molecules held together only by Vander Waal's forces?***
(a) $CO_{2(s)}$ (b) Cu (c) $H_2O_{(s)}$ (d) MgO

60 ***Which of the following has no tetrahedral shape?***
(a) CH_4 (b) H_2O (c) NH_3 (d) PCl_5

61 ***In which of the following type of hybridization the bond angle is of 120° ?***
(a) sp^3 (b) sp^2 (c) sp (d) none of them

62 ***The number of unpaired electrons in the geometrical structure of water molecule is:***
(a) 1 (b) 2 (c) 3 (d) 4

63 ***The geometrical shape of PCl_5 is:***
(a) tetrahedral (b) trigonal
(c) linear (d) trigonal bi-pyramidal

64 ***Ionic compounds are soluble in:***
(a) benzene (b) water (c) chloroform (d) hexane

65 ***A covalent bond in which both the electrons are donated by one of the atom is called:***
(a) polar covalent (b) covalent
(c) co-ordinate covalent (d) double covalent

66 ***The crystal of covalent compounds are made up of :***
(a) atoms (b) ions (c) molecules (d) dipoles

67 ***Which bond is non-directional in character?***
(a) covalent (b) ionic (c) co-ordinate (d) none of these

68 ***The double bonds are present between the atoms of the molecule:***
(a) CO_2 (b) H_2O (c) NH_3 (d) CH_4

69 ***The bond formed due to parallel overlap of p-orbitals of two already bonded atoms is known as:***
(a) pi-bond (b) sigma bond (c) metallic bond (d) hydrogen bond

70 ***Which of the following molecule possesses hydrogen bonding?***
(a) HF (b) HI (c) HCl (d) HBr

71 ***Which of the following is a polar molecules?***
(a) NH_3 (b) CCl_4 (c) C_6H_6 (d) C_2H_4

72 ***The chemical bond which is formed by mutual sharing of electrons is called:***
(a) H-bond (b) ionic bond (c) metallic bond (d) covalent bond

73 ***Which compounds have fast reaction?***
(a) covalent (b) ionic (c) metallic (d) coordinate

74 ***Bond formed by complete transference of one or more electrons from one atom to another is called:***
(a) ionic bond (b) covalent bond (c) coordinate bond (d) metallic bond

75 ***An ion with a single positive charge becomes an atom by:***
(a) losing an electron (b) gaining an electron
(c) gaining a proton (d) sharing of electrons

76 ***Velency of carbon is:***
(a) two (b) three (c) four (d) zero

77 ***Unpaired electrons in the valence shell which involve in bonding are known as:***
(a) valence electron (b) bonding electron (c) free electrons (d) excited electron

78 ***Which molecule has covalent bond?***
(a) MgO (b) $NaCl$ (c) HCl (d) $CaCO_3$

79 ***Solid CH_4 is:***
(a) molecular solid (b) ionic solid (c) covalent solid (d) does not exist

80 ***Covalent compounds are generally soluble in:***
(a) non-polar solvent (b) polar solvent
(c) ionic solvent (d) none

81 ***Which of the following is least ionic?***
(a) $AgCl$ (b) KCl (c) $BaCl_2$ (d) $CaCl_2$

82 ***Mathematically dipole moment is defined as:***
(a) $\mu = e \times d$ (b) $\mu = \frac{e}{d}$ (c) $\mu = e \times m$ (d) $\mu = \frac{d}{e}$

83 ***The dipole moment of water molecules is:***
(a) 0 debye (b) 1.0 debye (c) 1.84 debye (d) 2.84 debye

84 ***Orbital with one nucleus at its center is called:***
(a) atomic orbital (b) molecular orbital (c) hybrid orbital (d) bonding orbital

85 ***This molecules has the maximum bond angle:***
(a) NH_3 (b) CO_2 (c) SO_2 (d) H_2O

86 ***The number of bonds in C_2H_2 molecules is:***
(a) one σ and two π (b) three σ and one π
(c) three σ and two π (d) two σ and two π

Answer Key

1. (c)	12. (a)	23. (c)	34. (c)	45. (d)	56. (d)	67. (b)	78. (c)
2. (a)	13. (a)	24. (a)	35. (c)	46. (a)	57. (c)	68. (a)	79. (a)
3. (b)	14. (b)	25. (a)	36. (a)	47. (c)	58. (c)	69. (a)	80. (a)
4. (c)	15. (a)	26. (c)	37. (d)	48. (c)	59. (a)	70. (a)	81. (a)
5. (a)	16. (b)	27. (c)	38. (d)	49. (a)	60. (d)	71. (a)	82. (a)
6. (b)	17. (d)	28. (d)	39. (d)	50. (b)	61. (b)	72. (d)	83. (c)
7. (b)	18. (a)	29. (d)	40. (b)	51. (c)	62. (b)	73. (b)	84. (a)
8. (a)	19. (b)	30. (c)	41. (b)	52. (b)	63. (d)	74. (a)	85. (b)
9. (a)	20. (d)	31. (a)	42. (a)	53. (c)	64. (b)	75. (b)	86. (c)
10. (a)	21. (b)	32. (a)	43. (b)	54. (a)	65. (c)	76. (c)	
11. (c)	22. (c)	33. (d)	44. (c)	55. (c)	66. (a)	77. (a)	

Short / Detailed Answer Questions

Q.01 ***Define chemical bond and give its examples.*** ***Karachi Board: 2018***

Ans. ***Definition:*** An attractive force which holds ions, atoms or molecules together is called chemical bond.

Examples:

(i) The attractive force which holds Na^+ and Cl^- ions together is a chemical bond known as ionic or electrovalent bond.

(ii) The attractive force which holds two hydrogen atoms together is a chemical bond known as covalent bond.

(iii) The attractive force which holds together NH_3 and BF_3 molecules is a chemical bond known as co-ordinate bond.

(iv) The attractive force which holds cations of metals together is a chemical bond, known as metallic bond.

Q.02 ***Write down the causes of bond formation.***

Ans. The noble gases have the most stable electronic configurations. All the atoms of the other elements tends to attain the stable electronic configuration of their nearest noble gases either by gaining losing or sharing electron(s). In order to do so they have to combine chemically with each other.

In 1916 two kinds of chemical bonds were described:

The ionic bond by W. Kossel of Germany and covalent bond by G.N. Lewis of U.S.A. Both ideas were based on:

Octet Rule: The tendency of atoms to attain eight electrons in their valence shell.

Duplet Rule: The tendency of atoms to attain two electrons in the valence shell. All the elements except noble gases have incomplete valence shell and tend to complete them by chemical combination with the other atoms.

Q.03 ***Define electrovalent bond. Give examples of ionic compounds.***

Karachi Board: 2005, 2006, 2010, 2012, 2016

Ans. ***Ionic Bond:*** A bond formed by the electrostatic attraction between cations and anions by the complete transference of one or more electrons from one atom to another is called an ionic or electrovalent bond.

Explanation: During the formation of ionic bond, atoms involved attain the stable configuration of nearest noble gases.

This type of bond is formed between the metals of group I/II and the non metals of group VI / VII of the periodic table. This is because the values of ionization potential of the metals are relatively low while the values of electrons affinity of the non-metals are relatively high.

Examples: $NaCl$, $MgCl_2$, Al_2O_3, CaO.

Q.04 ***Describe the formation of sodium chloride in detail.***

Karachi Board: 2006, 2010, 2012, 2014, 2016 , 2018

Ans. ***Formation of sodium chloride (ionic crystal):***

By the complete transference of electron, sodium combines with chloride to form sodium chloride.

During the transference of electrons Na and Cl atoms attain the stable configuration of Ne and Ar, respectively.

$$Na \longrightarrow Na^{+} + e^{-}$$

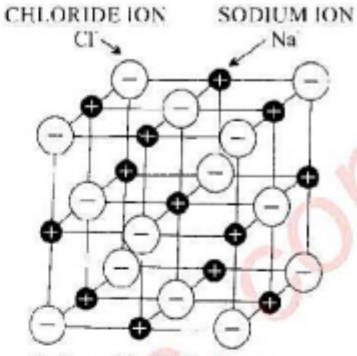
$(1s^2, 2s^2, 2p^6, 3s^1)$ $(1s^2, 2s^2, 2p^6)$ Ne

Ne "Configuration"

$$Cl + e^{-} \longrightarrow Cl^{-}$$

$(1s^2, 2s^2, 2p^6, 3s^2, 3p^5)$ $(1s^2, 2s^2, 2p^6, 3s^2, 3p^6)$

Ar - "Configuration"



Sodium chloride lattice structure
Fig: 4.1.

Energy changes taking place during the formation of ionic bond between Na^{+} and Cl^{-} ions.

(i) Sodium loses one electron by absorbing energy equal to its ionization potential.

$$Na_{(g)} \longrightarrow Na^{+} + e^{-} \qquad \Delta H = +496 \text{ KJ / Mol} \quad \ldots\ldots\ldots\ldots \text{(i)}$$

(ii) Chlorine accepts the electron lost by sodium and releases energy equal to is electron affinity.

$$Cl_{(g)} + e^{-}_{(g)} \longrightarrow Cl^{-}_{(g)} \qquad \Delta H = -348 \text{ KJ / Mol} \quad \ldots\ldots\ldots\ldots \text{(ii)}$$

(iii) The greater attractive forces in the crystal lattice greatly reduce the energy of the system there by making it stable.

$$Na^{+}_{(g)} + Cl^{-}_{(g)} \longrightarrow Na^{+}Cl^{-}_{(s)} \qquad \Delta H = -787 \text{ KJ / Mol} \quad \ldots\ldots\ldots\ldots \text{(iii)}$$

During attractions Na^{+} and Cl^{-} ions arrange themselves to from a crystal lattice of sodium chloride (NaCl) in which each Na^{+} ion is surrounded six Cl^{-} ions and each Cl^{-} ion is surrounded by six Na^{+} ions (See Fig #. 4.1)

Q.05 ***What is Lattice energy?***

Ans. ***Lattice energy :*** The energy released when one gram mole of a crystal is formed from its gaseous ions, is called lattice energy. The lattice energy compensates the loss of energy which occurs in the formation of ions.

Q.06 ***Describe the characteristics of ionic compounds?*** ***Karachi Board: 2006, 2016***

Ans. Ionic compounds are made of (+) and (-) ions held by electrostatic forces in a crystal lattice, each ion is surrounded by the opposite ions in alternate positions in a definite order in all directions. This explains the common properties of ionic compounds.

(i) Ionic compounds are solid at room temperature.

(ii) They have high melting and boiling points due to strong attraction between ions.

(iii) They are generally soluble in water or in polar solvents. The polar molecules detach the (+) and (-) ions from the crystal lattice, these ions then get surrounded by water molecules.

(iv) They are good conductors of electricity in molten state or in aqueous solution (electrolytes).

(v) The ionic bond is non-directional, therefore their compounds do not exhibit isomerism.

(vi) They are non-volatile compounds.

(vii) The reactions of ionic compounds are very fast.

Q.07 ***Write a short note on covalent bond.*** *Karachi Board: 2006-2019*

Ans. ***Definition:*** According to Lewis and Kossel a bond formed by the mutual sharing of electrons between two atoms is called covalent bond.

Explanation: Bonded atoms contribute equal number of electrons. During the formation of a covalent bond, atoms involved attain the stable configuration of noble gases nearer to them. This bond is formed between the atoms of non metals. A shared pair of electrons is represented by a line. A covalent bond may be single, double or triple covalent bond.

Examples: H - H, O = O, N ≡ N

Q.08 ***Write down types of covalent bond.***

Ans. ***Types of covalent bond depend upon different conditions:***

(1) According to number of shared pair of electrons.

(i) Single covalent bond e.g: H - H, C - C, H - C

(ii) Double covalent bond e.g: O = O, C = C, C = O

(iii) Triple covalent bond e.g: C ≡ C, N ≡ N, C ≡ N

(2) According to ionic character (polarity).

(i) Polar covalent bond e.g: $H^{+\delta}$ $Cl^{-\delta}$, $H^{+\delta}$—$O^{-\delta}$

(ii) Non-polar covalent bond e.g: H — H, Cl — Cl,

(3) According to overlapping of atomic orbitals.

(i) Sigma bond (axial overlapping)

(ii) Pi bond (parallel overlapping)

Q.09 ***Define and explain formation of covalent bond.***

Ans. In 1916, G. N. Lewis suggested that two atoms could achieve stable 2 or 8 electrons in the valence shell by sharing electrons between them.

Let us consider a case of chlorine, where both atoms having seven electrons in its valence shell unite by sharing two of these fourteen electrons between them, thus acquire stable 8 electrons in the outer shell.

Unpaired electrons Shared pair of electrons covalent bond

The shared pair is indicated by a dash (-) between two bonded atoms therefore we can say that a covalent bond is formed due to sharing of electrons and shared pair of electrons constitutes a covalent bond.

Q.10 ***Describe the cause of covalent bond formation.***

Ans. Consider two hydrogen atoms H_A & H_B each contain one proton in the nucleus and one electron revolving in their shell. There are six possibilities of attraction and repulsion

(1) Proton of H_A & electron of H_A = attraction

(2) Electron of H_A & electron of H_B = repulsion

(3) Proton of H_B & electron of H_B – attraction

(4) Proton of H_A & proton of H_B = repulsion
(5) Proton of H_A & electron of H_B = attraction
(6) Proton of H_B & electron of H_A = attraction

As the attraction is more than repulsions and atoms come closer and overlap to a certain distance. There is the net attractive force between the shared electrons and the nuclei that holds the atoms together.

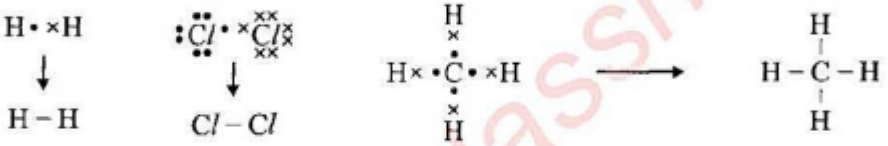
Q.11 ***Give the types of covalent bond according to number of shared pair of electrons.***

Ans. ***Types of covalent bond:***

(a) ***Single covalent bond:***

It is a covalent bond which is formed by the sharing of two electrons between two atoms. It is represented by one dash (-) each atom contributes one electrons.

Example:



When two chlorine atoms form a single covalent bond, 242 KJ/mole of energy is released

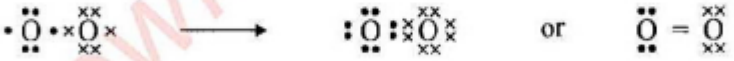
$$Cl_{(g)} + Cl_{(g)} \longrightarrow Cl - Cl_{(g)} \qquad \Delta H = -242 \text{ KJ mol}^{-1}$$

The release of energy lowers the energy of the molecule and thus makes it more stable.

(b) ***Double Covalent bond:***

It is a covalent bond, which is formed by the sharing of four electrons between two atoms. It is represented by two short lines. Each atom contributes two electrons.

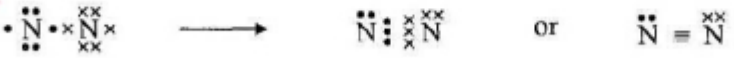
Example:



(c) ***Triple covalent bond:***

It is formed by sharing of six electrons between two atoms. It is represented by three short lines each atom contributes three electrons.

Example:



Q.12 ***Describe the properties of covalent compounds.***

Ans. As covalent compounds can exist as a separate covalent molecule. There is no electrostatic force of attraction between the individual molecules. There is only weak Vander waal's forces which hold the molecules together.

(1) The covalent compounds are often gases, liquid or relatively soft solids under ordinary conditions.
(2) They possess low melting and boiling points due to absence of attractive forces.

(4) Proton of H_A & proton of H_B = repulsion
(5) Proton of H_A & electron of H_B = attraction
(6) Proton of H_B & electron of H_A = attraction

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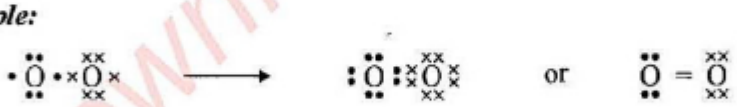

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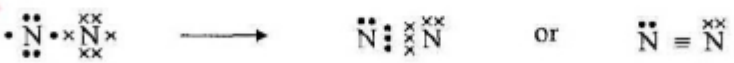

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(1) The covalent compounds are often gases, liquid or relatively soft solids under ordinary conditions.
(2) They possess low melting and boiling points due to absence of attractive forces.

(3) They are usually insoluble in water, but mostly soluble in organic solvents like alcohol, ether and benzene etc.
(4) The are highly volatile.
(5) They do not conduct electricity either in molten or in aqueous solution.
(6) Rate of reaction of covalent compounds are very slow.

Q.13 ***Define co-ordinate (dative) covalent bond and give its explanation.***

Karachi Board: 2004, 2005, 2013

Ans. ***Definition:*** A covalent bond in which shared pair of electrons is donated by one of the bonded atom is called co-ordinate covalent bond.

Explanation: The atom which donates a pair of electrons for sharing is called donor, whereas the atom which accepts the electron pair is called acceptor. Co-ordinate covalent bond is represented by arrow (→) with the direction from donor to acceptor. Sidgwick first developed the use of this type of bond and he called it as dative bond.

Q.14 ***Write down the examples of co-ordinate covalent bond.***

Karachi Board: 2005, 2007, 2008, 2013

Ans. ***Examples of co-ordinate covalent bond:***

(i) ***Formation of NH_4Cl:***

When NH_3 and HCl are reacted together to form NH_4Cl.

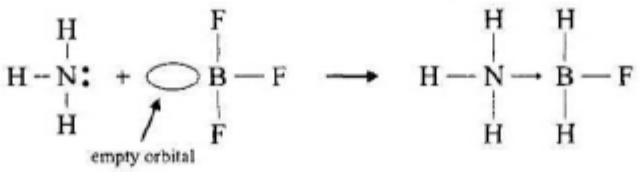
Here in NH_4^+ ion nitrogen is bonded to three hydrogen atoms by covalent bond and to one hydrogen atom by a coordinate bond, while the bond between NH_4^+ ion and Cl^- ion is ionic.

(ii) ***Formation of Hydronium ion $(H_3O)^+$:***

It is formed between the oxygen atom of water and proton (H^+) of any acid. In water molecule oxygen atom has two lone pair of electrons therefore it acts as donor atom while (H^+) accept lone pair of electron form oxygen atom and form coordinate covalent bond.

(iii) ***Formation of coordinate covalent bond between NH_3 and BF_3:***

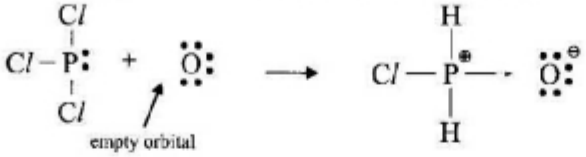
Nitrogen of the NH_3 molecule has a lone pair while boron in BF_3 has an empty orbital. Nitrogen donates the lone pair of electrons to the vacant orbital of boron. In this way a co-ordinate covalent bond is formed between nitrogen and boron.



(iv) ***Formation of $POCl_3$*** *Karachi Board: 2004*

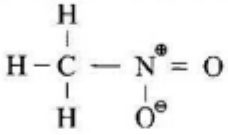
In the formation of $POCl_3$ phosphorous possess a lone pair of electrons and therefore

called donor, while oxygen atom lacks too electrons. The lone pair is shared by both oxygen and PCl_3 to form a co-ordinate covalent bond.



(v) Coordinate covalent bond in Nitro methane:

Nitrogen donates the lone pair of electrons into the outer most shell of oxygen atom and forms a coordinate covalent bond.



Q.15 ***Briefly explain dipole moment and mention its units.*** ***Karachi Board: 2005, 2007, 2009***

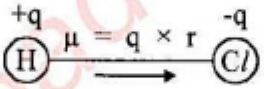
Ans. ***Dipole moment:*** The degree of polarity of a molecule is known as the dipole moment.

Definition: It is the product of the electric charge (q) and the distance between the positive and negative center's (r).

It is a represented by μ (mew).

$$\mu = d \times e$$

It is a vector quantity.



where μ = dipole moment,
d = distance between two nuclei,
e = charge on one pole,

Unit: Dipole moment were expressed in Debye but now they are expressed in S.I. Units as coulomb metre (Cm).

1 debye = 10^{-18} esu × Cm = 3.335×10^{-30} Cm ($1C = 2.998 \times 10^{9}$ esu)

Q.16 ***Why has CO_2 zero dipole moment where as SO_2 is polar?*** ***Karachi Board: 2007, 2018***

Ans. The dipole moment is a vector quantity which has a magnitude as well direction. If a molecule is poly atomic and contains two or more dipoles, then net dipole moment is the resultant of the vector addition of the individual dipole moments. Both SO_2 and CO_2 contain polar bonds but the angular structure of SO_2 results in a dipole moment of 3.336×10^{-30} Cm, which for linear CO_2, $\mu = 0$, (as shown in fig.4.3) In CO_2 the double bonds lie on one straight line and molecule is symmetrical, hence bond in CO_2 are polar the two dipole moments of the molecule are equal oppositely directed thus the molecule as a whole is non-polar.

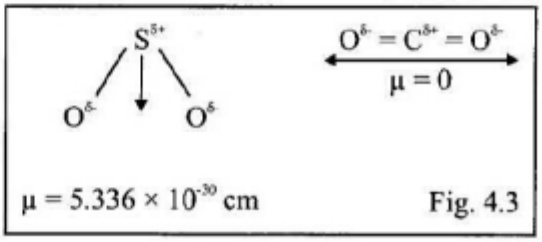


Fig. 4.3

Q.17 ***Explain the significance of dipole moment.***

Ans. ***The following are the significance of dipole moment:***

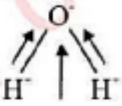
(1) It helps to calculate the percentage ionic character in a bond.

(2) It helps to determine the polarity of molecule. Molecules with zero dipole moment are non-polar whereas molecules which have dipole moment greater than zero are polar.

(3) It helps to determine the angular and linear structure of tri-atomic molecules.

e.g: $\mu = 0$, O = C = O Linear structure

$\mu = 1.80$ D, Angular structure



(4) Dipole moment measurement gives an idea about the degree of polarity in a diatomic molecule. The greater the dipole moment the greater is the polarity in such a molecule.

Q.18 ***Explain the ionic character of covalent bond. OR Discuss polar and non-polar covalent bond.***

Karachi Board: 2005-2009-2013-2018-2019

Ans. ***Types of covalent bond according to ionic character:***

(i) ***Non-polar Covalent bond:***

It is a covalent bond in which shared pair of electrons is equally attracted by the two bonded atoms. In this bond, distribution of electron cloud is symmetrical. It is formed between two atoms of the same element or different atoms of no significant difference of electronegativity. It does not acquire even partial charges.

Examples:

$H\bullet \times H \longrightarrow H-H$

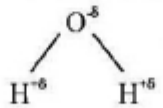
$:\ddot{\underset{\cdot\cdot}{Cl}}\bullet \times \underset{\times}{\overset{\times\times}{Cl}}\times \longrightarrow Cl-Cl$

$H\bullet \times \underset{\times}{\overset{\times}{Cl}}\times \longrightarrow H-Cl$

(ii) ***Ionic character (polar) covalent bond:*** It is a covalent bond in which shared pair of electrons is not attracted equally by the two bonded atoms. In this bond, distribution of electron cloud is unsymmetrical. It is formed between two atoms of the different elements having different values of electronegativity. It acquires partial positive ($\delta+$) and partial negative ($\delta-$) charges on the ends of the bond.

Examples: $H^{+\delta}\text{-}Cl^{-\delta}$ (polar covalent bond)

$H^{+\delta}\text{-}F^{-\delta}$



Q.19 ***Which of the following compounds have dipole momnt?***

NH_3, H_2O, CO_2, CCl_4

Karachi Board: 2008

Ans.

(i)	NH_3 = 1.46 D	m = 5.002×10^{-30} Cm	polar
(ii)	H_2O = 1.84 D	m = 6.137×10^{-30} Cm	polar
(iii)	CO_2 = 0 D	m = 0	non-polar
(iv)	CCl_4 = 0 D	m = 0	non-polar

(i) and (ii) have dipole moments.

Q.20 ***Write a short note on bond energy.*** ***Karachi Board: 2006, 2008***

Ans. ***Bond Energy:*** The average amount of energy required to break all the bonds of a particular type in one mole of the substance is called bond energy.

OR

It is the same amount of energy which is released when all the bonds of a particular type are formed in one mole of the substance.

Unit: Kilo joules per mole or KJ ./ mol

Example:

$$H - H_{(g)} \longrightarrow 2H_{(g)} \qquad \Delta H = 435 \text{ KJ mol}^{-1}$$

Hydrogen molecule → atoms of hydrogen

$$O_{(g)} + O_{(g)} \longrightarrow O=O \text{ or } O_{2(g)} \qquad \Delta H = -498 \text{ KJ mol}^{-1}$$

Q.21 ***Why the bond energy of polar molecule is greater than the non-polar?*** ***OR*** ***Why the calculated bond energy of a polar molecule ($H^{+\delta} - Cl^{-\delta}$) is less than the bond energy found experimentally?***

Ans. The experimentally found bond energy of H-Cl per mole is greater than the calculated one this means that H-Cl bond is strong than expected. This is because the bonded electron pair is not equally shared by H and Cl atom. The Cl atom being more electronegative attracts the electron pair more towards itself and makes the bond polar, which causes to increases the attraction between the bonded atoms and hence the bond energy increases than a non-polar molecule.

Q.22 ***Describe the bond energies of single, double and triple bonds.***

Ans. The value of bond energy also depends upon the bond distance. Shorter the bond distance, stronger the bond and greater would be the bond energy. For example triple bonds are usually shorter than the double bonds which in turn are shorter than the single bond. Hence the bond energies for multiple bonds would generally be greater than those of single bonds.

S. No.	*Bonds*	*Bond Distance Å*	*Bond Energy (KJ / mol)*
1.	C – C	1.54 Å	347
2.	C = C	1.34 Å	598
3.	C ≡ C	1.20 Å	820

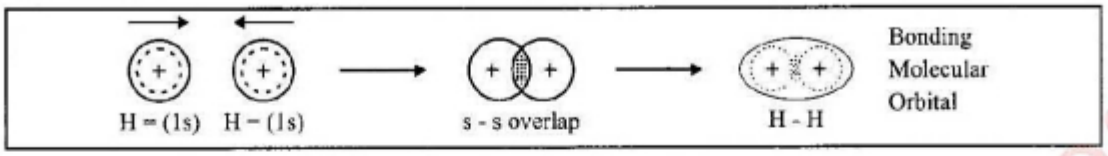
Q.23 ***Describe sigma (δ) bond with examples.*** ***Karachi Board: 2008, 2013***

Ans. ***Sigma (δ) bond:*** According to molecular orbital theory proposed by Hund, Huckle and Mulliken, a covalent bond is formed due to overlapping of atomic orbitals. The orbitals may give rise to two molecular orbitals.

(i) A molecular orbital which is of lower energy is more stable than the parent atomic orbitals is called "bonding molecular orbital."

(ii) A molecular orbital which has higher energy is less stable than the parent atomic orbitals is called an anti bonding molecular orbital. The bonding molecular orbital which is formed due to linear overlapping of two atomic orbital and has maximum electron density around the bond axis is called sigma (δ) molecular orbital. This is also called sigma bond.

Examples: ***s - s Orbital Overlapping:***



In the above example the probability of finding the electronic cloud of two electrons is greater between the two nuclei, due to which the force of attraction on each electronic cloud is doubled. This releases energy and system becomes of lower energy hence stabilized. So H_2 molecule is formed. It is called sigma bond.

The other molecular orbital having higher energy with a nodal plane or of low electron density between the two nuclei is less stable than either of the parent atomic orbitals is known as anti bonding molecular orbital (δ^*) is shown by the energy diagram in (fig. 4.5)

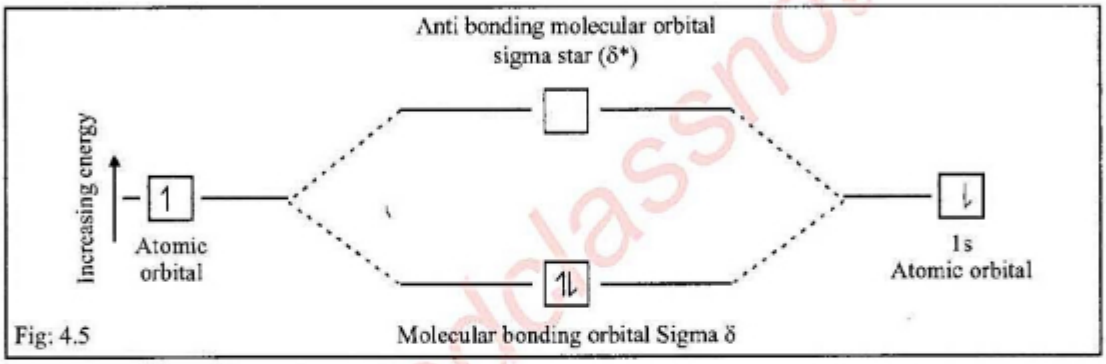


Fig: 4.5

Q.24 ***Show diagrammatically the formation of sigma (δ) and sigma star (δ*) by s-p and p-p overlap ?***

Ans. ***(i)*** ***<u>s - p type overlap:</u>*** This overlap occurs in HF molecule when $1s^1$ orbital of hydrogen overlaps 2p orbital of fluorine to form sigma bonding orbital which forms a single covalent bond in HF molecule. (Fig. 4.6)

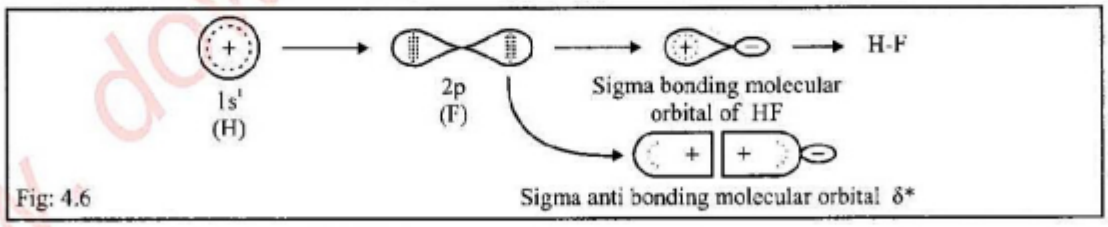


Fig: 4.6

(ii)* ***<u>p-p type overlap:</u>*** This overlap is seen in F_2 molecule where $2p_x$ orbital of one fluorine overlaps $2p_x$ orbital of the other fluorine to from F - F sigma bond (Fig: 4.7).

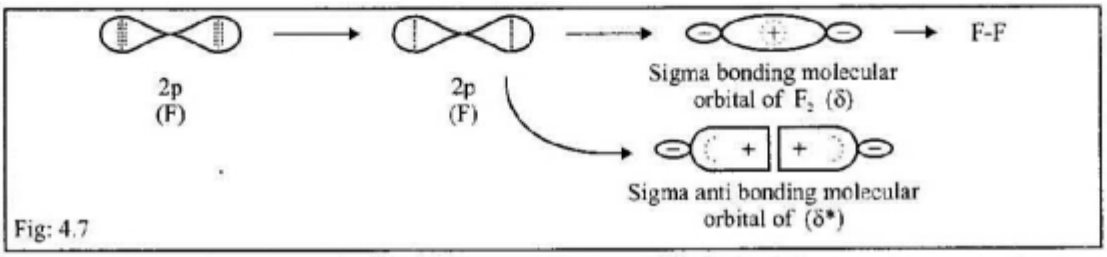


Fig: 4.7

Q.25 ***Describe pi (π) bond with example.***

Ans. ***Pi (π) bond:*** The bond formed by side-wise (parallel) overlapping of p orbitals of two already sigma bonded atoms is called pi (π) bond.
When p-orbitals are parallel to each other, they give rise to bonding pi (π) and anti bonding pi-star (π*) molecular orbital.
In bonding π molecular orbital the electronic cloud remain above and below the electronic cloud sigma bond but in π* molecular orbital there is force of repulsion due to which π bond does not form (as shown in fig. 4.8).

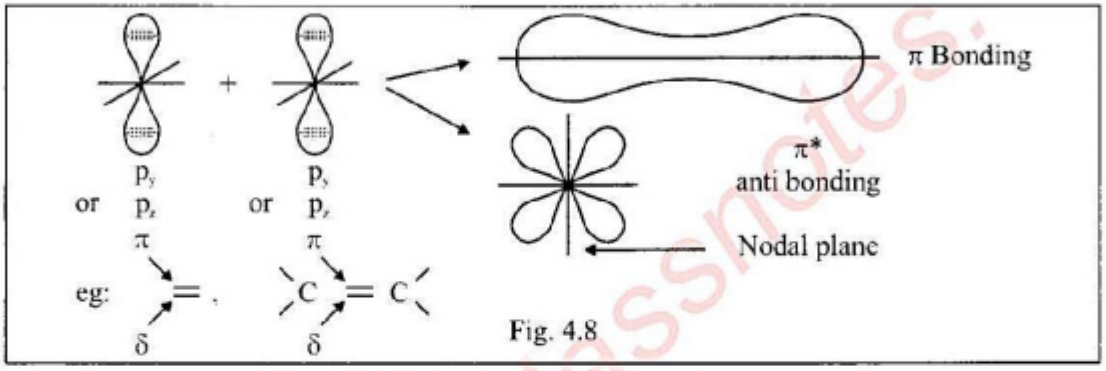


Fig. 4.8

Q.26 ***What is orbital hybridization?*** ***Karachi Board: 2005-2008-2013-2015-2017-2019***

Ans. ***Hybridization:*** The orbital of different shape and energy are mixed together to form a set of orbitals of same shape and energy which are called hybrid orbitals and the phenomenon is called hybridization.
Type of Hybridization: There are different types of hybridization which depend on the number and nature of the orbitals, e.g. sp^3, sp^2, sp, d etc.

Q.27 ***Define sp^3 hybridization. Explain it with CH_4, NH_3 and H_2O molecules.***

Karachi Board: 2005, 2008, 2010, 2013, 2015

Ans.

sp^3 Hybridization: One s and three p orbitals of different shape and energies mix together to form a set of four hybrid orbitals of the same shape and energy are called sp^3 orbitals and the phenomenon is called sp^3 Hybridization.

Examples: (i) Methane, CH_4: In a molecule of methane C-atom is sp^3 hybridized. Electronic configuration of valence shell of C-6 is:

	2s	$2p_x$	$2p_y$	$2p_z$
Ground State:	↿⇂	1	1	
Excited State:	1	1	1	1

In methane molecule one 2s and three 2p orbitals of C-atom mix together to from four sp^3 hybrid orbitals which have tetrahedral geometry (as shown in fig. 4.9). Each sp^3 orbital overlaps linearly with 1s orbital of hydrogen atom to form one C-H sigma bond so four C-H bonds are formed. Since the geometry of four sp^3 orbitals is tetrahedral, therefore molecule of methane would be tetrahedral. The sp^3 hybrid orbitals are oriented in such a way that angle between any two orbitals is 109.5°.

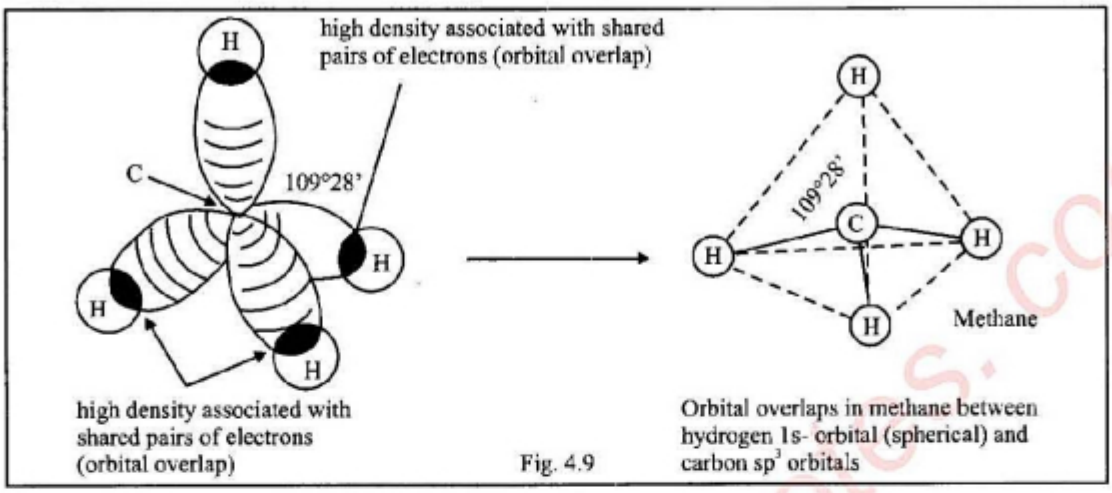


Fig. 4.9

(ii) ***Ammonia NH_3:*** (shape in terms of hybrid orbital theory)

In the molecule of ammonia N-atom is sp^3 hybridized. Electronic configuration of valence shell of nitrogen is:

2s	$2p_x$	$2p_y$	$2p_z$
1	1	1	1

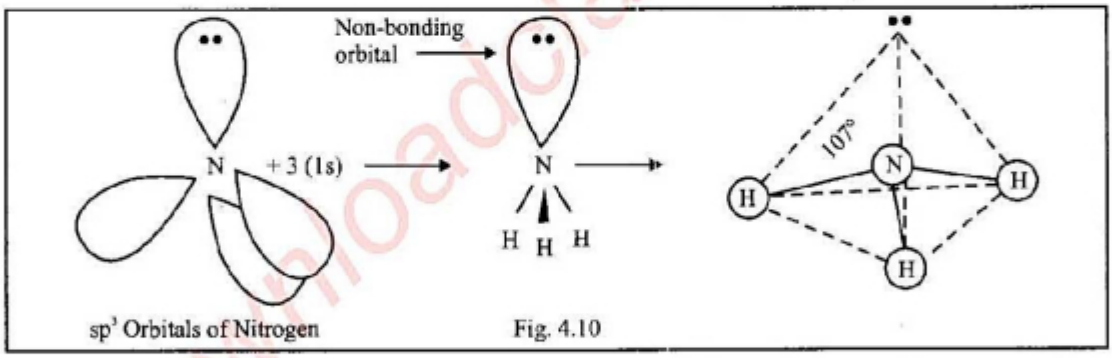


Fig. 4.10

In the molecule of ammonia one 2s and three 2p orbitals of N-atom mix together to form four sp^3 hybrid orbitals, which have tetrahedral geometry. Out of the four sp^3 orbitals, one is completely filled, where as three are partially filled. Each of the these partially filled sp^3 orbitals overlap linearly with 1s orbital of hydrogen atom to form three N-H sigma bonds. Fourth sp^3 hybrid orbital, which have a lone pair of electrons, does not form bond since the geometry of four sp^3 orbitals is tetrahedral, therefore shape of NH_3 molecule would be tetrahedral. (Fig 4.10)

Experimentally the value of angle determined is 107°. The decrease in angle is due to the reason that lone pair - bond pair repulsion is greater than the bond paid - bond pair repulsion. Hence the bond angle is decreased to 107° form 109.5°.

(iii) ***Water, H_2O:***

In the molecule of H_2O, O atom is sp^3 hybridized.

Electronic configuration of valence shell of O is given below:

2s	$2p_x$	$2p_y$	$2p_z$
⇅	⇅	1	1

In the molecule of water one 2s and three 2p orbitals of O-atom mix together to form four sp^3 hybrid orbitals which have tetrahedral geometry. As per Lewis structure the central oxygen atom is surrounded by the four electron pairs.

According to the electron pair repulsion model the tetrahedral arrangement would give maximum separation and minimum repulsion. However the bond angle is 104.5° (Fig. 4.11). The deviation in the angle is due to the presence of two lone pairs and two bond pairs. The repulsion of the lone pair and the bond pairs reduces the angle form 109° to 104.5°.

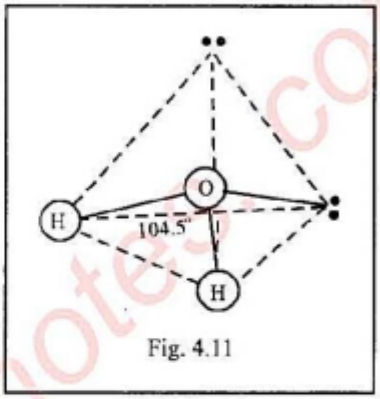


Fig. 4.11

According to hybrid orbital model, oxygen utilizes two of its sp^3 hybrid orbitals to form sigma bonds with the two hydrogen atoms. The non-bonding orbitals occupy the large volume of space, hence they compress the bonding orbitals and reduce the angle H-O-H in water to 104.5° giving angular or bent structure. (Fig. 4.12)

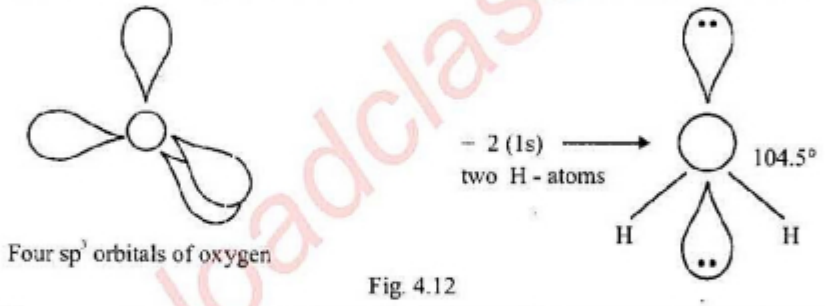


Fig. 4.12

Q.28 ***Define sp^2 - hybridization*** ***Karachi Board: 2009, 2010, 2011, 2013***

Ans. ***sp^2 Hybridization:*** One s and two p orbitals of different shapes and energies mix together to form a set of three hybrid orbitals of the same shape and energy which are called sp^2 orbitals and the phenomenon is called sp^2 hybridization.

Three sp^2 orbitals are planer and oriented at angles of 120°. One p orbital remains un-hybridized.

Q.29 ***Explain sp^2 hybridization in the BF_3 and C_2H_4 molecules.***

Karachi Board: 2005, 2007, 2009, 2010, 2011, 2017

Ans.

Hybridization in BF_3 molecule:

In the molecule of boron trifluoride, 'B' atom is sp^2 hybridized.

Electronic configuration of valence shell of B (5) is given below:

	2s	$2p_x$	$2p_y$	$2p_z$
Ground State:	↿⇂	1		
Excited State:	1	1	1	

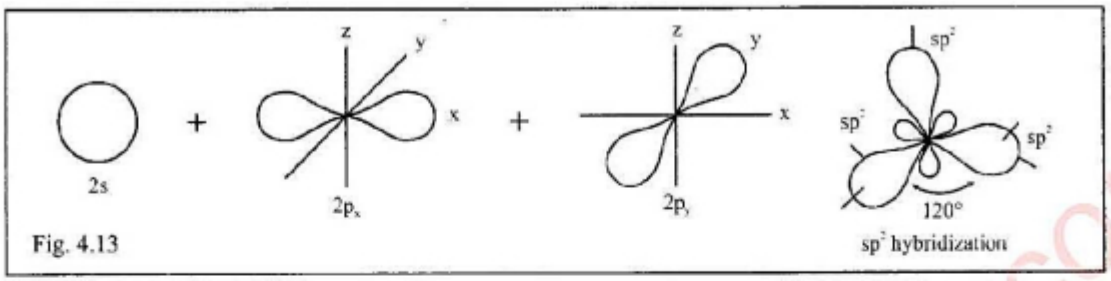


Fig. 4.13 sp^2 hybridization

In the molecule of boron fluoride, our 2s and two sp orbitals of B-atom mix together to form three sp^2 hybrid orbitals which are planer and oriented at angles of 120°.

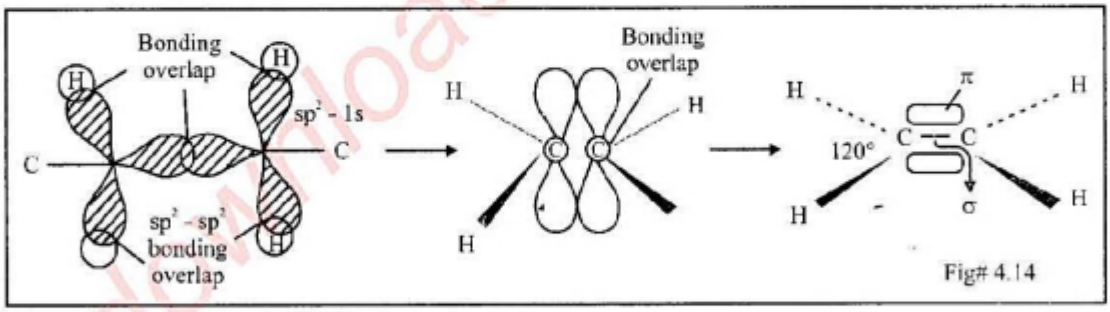
Each sp^2 orbital overlaps linearly with partially filled p orbital of fluorine atom to form one B-F sigma bond. So three B-F bonds are formed. The molecule of boron fluoride is trigonal planer and angle F-B-F is 120°.

sp^2 Hybridization in ethene (C_2H_4) molecule: *Karachi Board: 2019*

Electronic configuration of valence shell of C(6)

	2s	2p$_x$	2p$_y$	2p$_z$
Ground State:	↿⇂	1	1	
Excited State:	1	1	1	1

In the molecule of ethene, there are two carbon atoms. One 2s and two 2p orbitals of each C-atom mix together to form three sp^2 hybrid orbitals which are planer and are oriented at angles of 120° (See Fig: 4.14)



Fig# 4.14

Two 2p^2 orbitals of each C-atom overlap linearly with 1s orbital of hydrogen atom to form two C-H sigma bond, so four C-H sigma bonds are formed. The remaining one sp^2 orbital of each C-atom overlaps with each other of to form one C-C sigma bond. The un-hybridized p$_z$ orbitals of both the C-atoms overlap sideways to form C=C pi bond since three sp^2 orbitals are planer and are oriented at angles of 120°.

Other examples are C_6H_6, >C=O, >C=N- all contain one sigma and other pi bond making a double bond.

Q.30 ***Define sp^2- hybridization. Explain it with example.***

Ans. ***sp (diagonal) Hybridization:***

When one s and one p orbitals of different shapes and energies mix together to form a set of two hybrid orbitals of the same shape and energy are called sp orbitals and the phenomenon is called sp hybridization.

Two sp orbitals are linear i.e., they are oriented at 180°, remaining two 'p' orbitals (p_y & p_z) are un-hybridized, (Fig. 4.14)

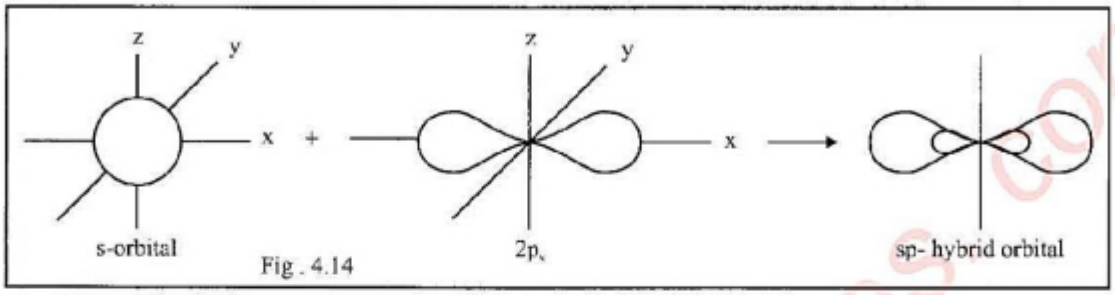


Fig. 4.14

Example: Ethyne (C_2H_2)

Electronic configuration of valence shell of C (6) is given below:

	2s	$2p_x$	$2p_y$	$2p_z$
Ground State:	↿⇂	1	1	
Excited State:	1	1	1	1

In the molecule of Ethyne, there are two carbon atoms. One 2s and one $2p_x$ orbitals of each C-atom mix together to form two sp hybrid orbitals, which are linear and are oriented at angles of 180° (Fig. 4.15)

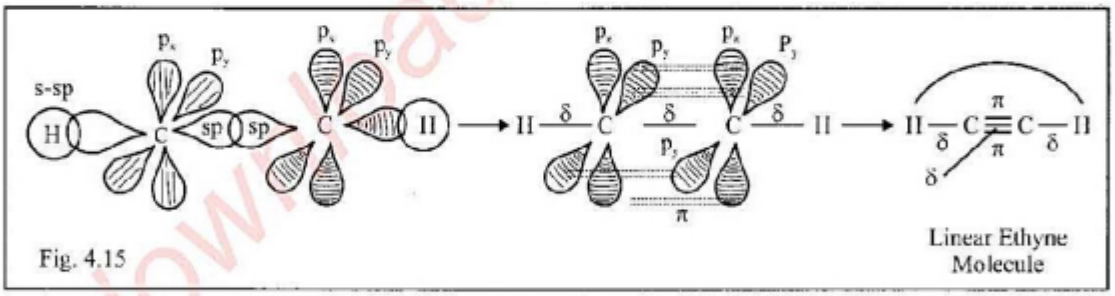


Fig. 4.15

One sp orbital of each C-atom overlaps linearly with 1s orbital of hydrogen atom to form one C-H sigma bond. So two C-H sigma bonds are formed. The remaining one sp orbital of each C atom overlaps with each other to form one C-C sigma bond. The remaining unhybridized p orbitals (p_y & p_z) of both the C-atoms overlap sideways to form two C-C pi bond. Since two sp orbitals are linear and are oriented at angles of 180°.

Q.31 ***Name the shapes of simple molecules***

Ans. ***A simple molecule may acquire one of the following shapes:***

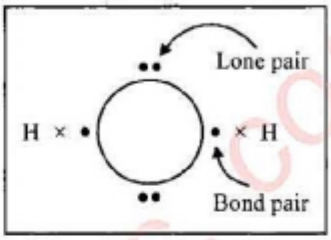
Linear, trigonal, planer, tetrahedral, pyramidal, bent or angular. These shapes are predicted from the bond angles determined experimentally and are explained in terms of two theories:

(i) Electron pair repulsion theory (VSEPR)

(ii) Hybrid orbital theory.

Q.32 ***Discuss the electron pair repulsion theory.*** *Karachi Board: 2009, 2011, 2012, 2013, 2018*

Ans. This theory was given by Sigwick and Powell in 1940. There may be two types of electron pair surrounding the central atom.



(1) *(a)* ***Lone pair:*** These are the paired electron which have not taken part in sharing.

(b) ***Bond pairs:*** These are the result of the sharing of unpaired electrons of central atom with unpaired electrons of surrounding atom.

(2) Being similarly charged i.e. negative, the bond pairs as well as the lone pairs repel each other.

(3) An bending pair of electrons (lone pair) in the valence shell of central atom occupies more space than binding electron pair.

(4) The repulsion between the bonding electron pair decreases with increasing electronegativity of atoms forming bonds with the central atom.

(5) Two electron pairs of a double bond or three electrons pair of a triple bond take up more space than the electrons pair of a single bond. However, multiple bond behave as single electron pair bond for the purpose of VSEPR.

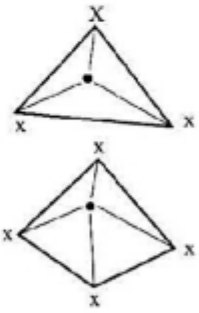
(6) The force of repulsion between lone pairs and bond pairs is not the same. The order of repulsion is as follows:

Lone pair - lone pair repulsion > lone pair - bond pair repulsion > bond pair - bond pair repulsion.

(7) The shape of molecule depends upon total number of electron pairs (bonding and lone pairs).

Q.33 ***Discuss the rules for predicting shape of molecule.***

Ans. As per Lewis Steuctuse, if the distribution of electron pairs about the central atom is known then the shape of the molecule can be predicted. Following are the examples:



(i) If there are two pairs, the shape of the molecule is linear, angle 180°,
x----------o----------x e.g. $BeCl_2$, C_2H_2, CO_2, CS_2

(ii) If there are three pairs the shapes of the molecule will be triangular, angle = 120°. e.g. BF_3, C_2H_4, SO_2, CO_3^{-2}

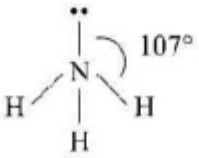
(iii) If there are the four pairs the shape of the molecule will be tetrahedral, angle = 109°. e.g. CH_4, NH_3, H_2O, CCl_4, CBr_4

(iv) If there are five pairs of electron the shape of the molecule will be trigonal (bi-pyramidal).

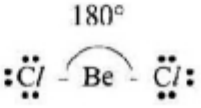
Q.34 ***Predict the shape of the following molecules on the basis of electron pair repulsion model:***
(a) NH_3 (b) $BeCl_2$ (c) H_2O (d) C_2H_4 (e) BF_3 (f) $CHCl_3$

Karachi Board: 2009-2010-2011-2012-2013-2016-2018-2019

Ans. (a) NH_3

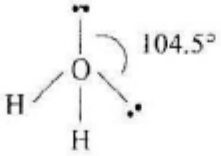


(b) $BeCl_2$

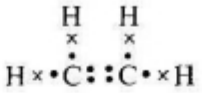


Linear

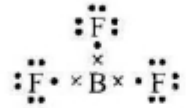
(c) H_2O Tetrahedral



(d) C_2H_4 Trigonal

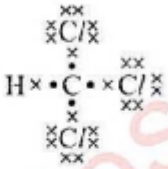


(d) BF_3



Trigonal Bond angle 120°

(d) $CHCl_3$



Tetrahedral

Q.35 ***Discuss the hybrid orbital theory.***

Ans. It is hybridization which determines the shape of a molecule.

(1) sp-hybridization in the central atom gives linear molecule with an angle of 180°.

(2) sp^2-hybridization in the central atom gives planer trigonal structure with an angle of 120°.

(3) sp^3-hybridization with no lone pair or non-bonding orbital on the central atom gives tetrahedral geometry with bond angles of 190.28°.

(4) sp^3-hybridization with one lone pair (one non-bonding orbital) gives pyramidal structure with an angles of 107°.

(5) sp^3-hybridization with two lone pair (non-bonding orbital) on central atom gives bent or angular structure with bond angle of 104.5°.

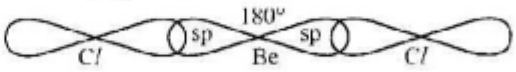
Q.36 ***Predict the shape of the following molecules on the basis of hybrid orbital model?***
(a) C_2H_4 (b) C_2H_2 (c) CH_4 (d) $BeCl_2$ ***Karachi Board: 2005, 2007, 2009, 2011, 2013***

Ans. *(a)* C_2H_4 for Answer see Q. 29 on page 152.

(b) C_2H_2 for Answer see Q. 30 on page 153.

(c) CH_4 for Answer see Q. 27 on page 150.

(d) $BeCl_2$ linear structure



Q.37 ***Describe hydrogen bond (secondary bond)*** ***Karachi Board: 2016***

Ans. ***Hydrogen Bond:*** The attractive force which combines the electropositive hydrogen atom ($H^{+\delta}$) of one molecule with the electronegative atom ($N^{-\delta}$, $O^{-\delta}$, $F^{-\delta}$) of the other molecule. This type of attractive force which involves hydrogen is known as Hydrogen bond. It is represented by dotted line. This is also called "protonic bridge"

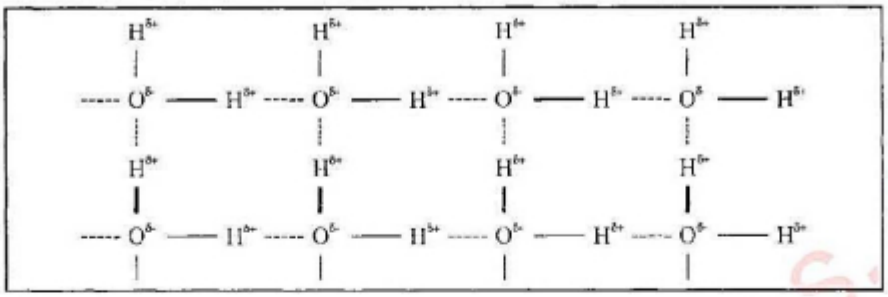
eg, $\cdots\cdots H^{+\delta}—F^{-\delta}\cdots\cdots H^{+}—F^{-\delta}\cdots\cdots H^{+\delta}—F^{-\delta}\cdots\cdots$

Hydrogen Bond

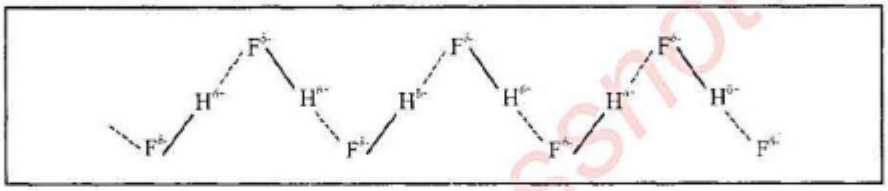
Q.38 ***What are the most important secondary bond present in H_2O and HF molecules? How do they effect the physical properties of the compound?*** ***Karachi Board: 2016***

Ans. The most important secondary bonds present in H_2O and HF are the "Hydrogen bonds." The association of HF and H_2O through hydrogen bonds are given as under:

(a) *(i)* ***Hydrogen bonds in H_2O molecules:***



(ii) ***Hydrogen Bonds in HF molecules:***



(b) ***Effect of hydrogen bonding on physical properties of compounds.***

It greatly effect the physical properties of molecules e.g. the hydrides of group V-A, VI-A and VII-A of the periodic table (NH_3 H_2O and HF) have higher melting and boiling points than the other hydrides of these groups (e.g., PH_3, H_2S, HCl etc.).

Q.39 ***Explain the chemical bonding in NH_4Cl.*** *Karachi Board: 2007*

Ans. In NH_4Cl molecule, ionic bond is formed between NH_4^+ and Cl^- ions, three covalent bonds are formed between N and H atoms and one coordinate bond is formed between N and one H atom.

Q.40

Do as directed in the following:

(i) ***Covalent bonds in ethyne (C_2H_2).*** ***[Draw the Lewis structure]***

(ii) ***Co-ordinate covalent bond in ammonium ion.*** ***[Draw the Lewis only]***

(iii) ***Association of water molecules through hydrogen bond. [Draw the diagram only]***

(iv) ***Metallic bonds in the atomic crystals of metals.*** ***[Draw the diagram only]***

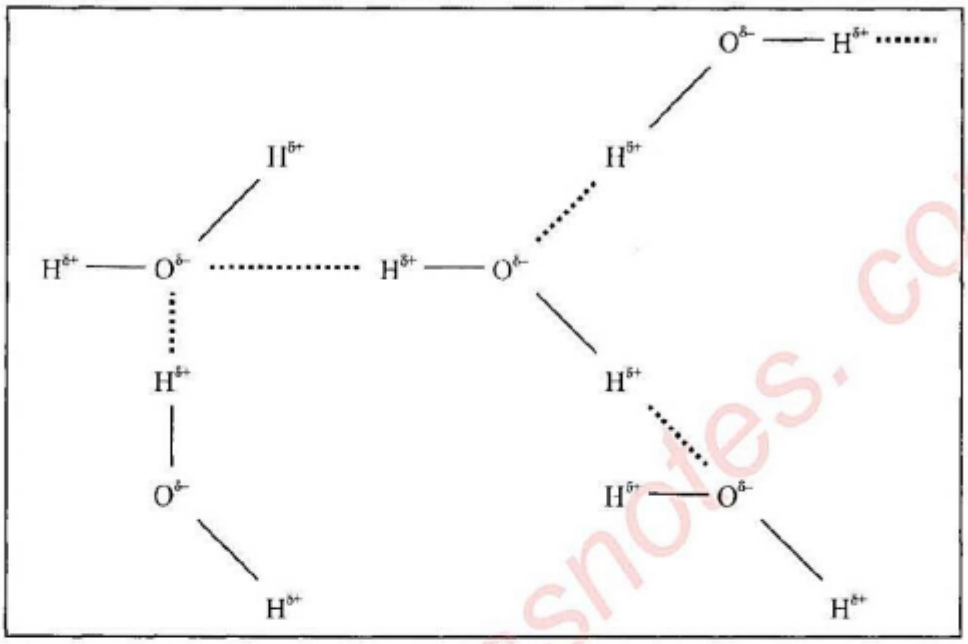
Karachi Board: 2007

Ans.

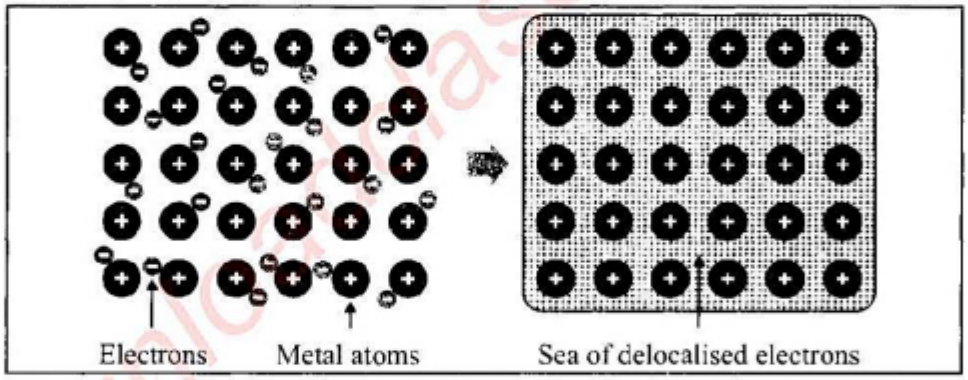
(i) H : C ::: C : H H — C ≡ C — H

(ii)

(iii)

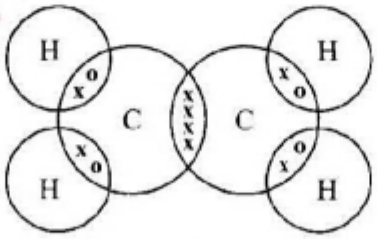


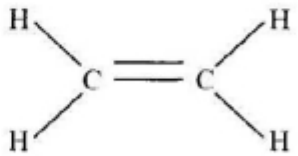
(iv)

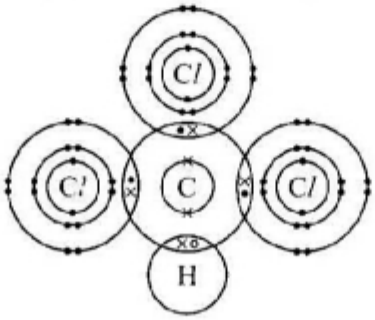


Q.41 ***Draw cross and dot structures of C_2H_4 and $CHCl_3$.*** *Karachi Board: 2009*

Ans.



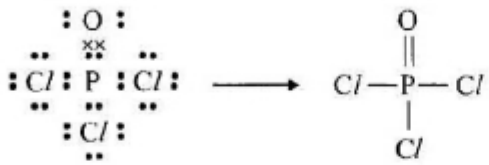


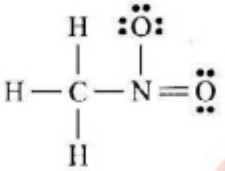


Q.42 ***Draw the electronic structures of :***
(i) Phosphorus oxychloride (ii) Nitromethane ***Karachi Board: 2016***

Ans.

(i) Phosphorus oxychloride ***(ii)***

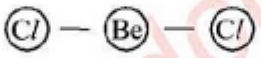




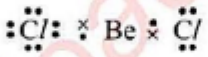
Nitromethane

Q.43 ***Explain the shapes of the following molecules on the basis of electron pair repulsion model and hybrid orbital model. (i) H_2O (ii) $BeCl_2$*** ***Karachi Board: 2016***

Ans. (i) All the diatomic molecules such as HF, HCl etc. are linear regardless of the number of active electron pairs surrounding the central atom. It is because, there are only two atoms in a diatomic molecule. Molecules containing is because, there are only two atoms in a diatomic molecule. Molecules containing more than two atoms can also have the linear shapes, for example. Beryllium Chloride ($BeCl_2$) is a triatomic linear molecule with the bond angle 180°.



The Lewis structure of $BeCl_2$ is represented as:



Here there are two active sets of electrons surrounding the Beryllium atoms. In terms of electron repulsion model, these pairs must be arranged as far apart as possible, that is, the two chlorine atoms should be placed on the opposite side of beryllium which would give the linear structure of $BeCl_2$.

In terms of hybrid model, beryllium uses its sp hybrid orbitals in bond making (i.e. beryllium is sp hybridized).

Be = $1s^2$, $2s^2$, Excited $1s^2$, $2s^1$, $2p_x^1$ Hybridization Two sp^1 orbitals.

Both the sp^1 orbitals are arranged linearly at an angle of 180°. These orbitals overlap with $3p_x$ orbitals of the two chlorine atoms to form two sigma bonds, all the three atoms being in straight line (Fig. 4.16)

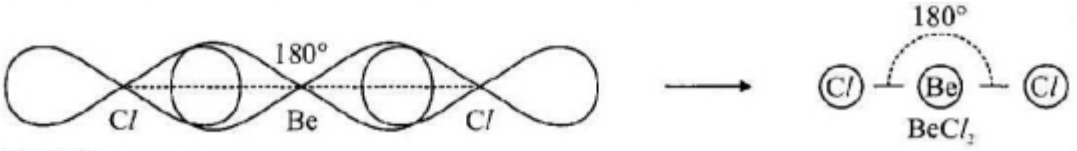


Fig: 4.16
The formation of two α-bonds in $BeCl_2$ by overlap of $3p_x$ orbitals from two chlorine atom with two hybrid sp orbitals from a beryllium atom.

Shape of H_2O: As per Lewis Structure, the central atom oxygen is surrounded by the four active sets of electrons and according tot he electron pair repulsion model, the tetrahedral arrangement would give maximum separation and minimum repulsion. However, the bond angle (H ⁄ O ＼ H) is 104.5° (Fig: 4.21). The deviation in the angle is due to the presence of two lone pairs as explained in case of NH_3. The repulsion of the lone pairs and the bonded pairs reduces the angle from 109° to 104.5°.

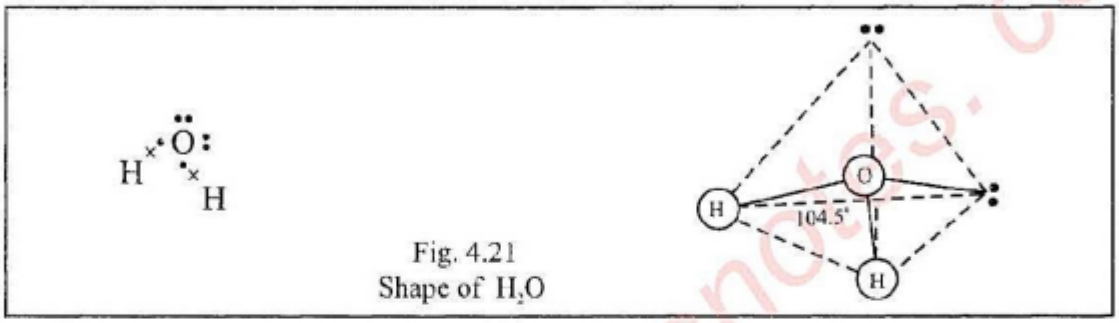
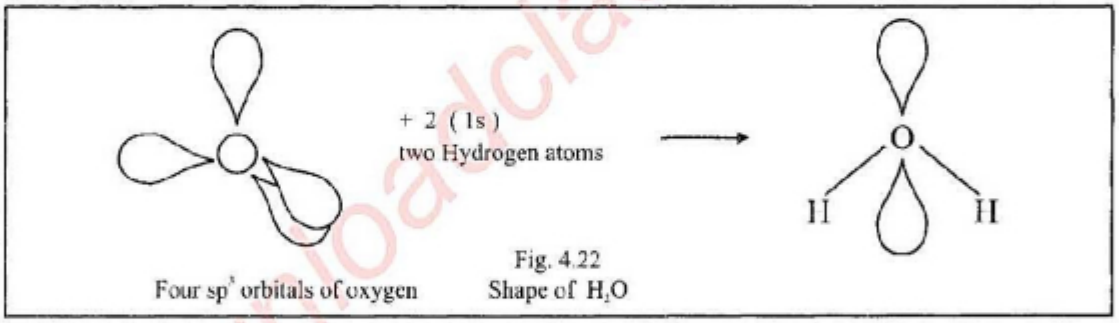


Fig. 4.21
Shape of H_2O

In terms of hybrid orbital model, oxygen utilizes two of its sp^3 orbitals to form sigma bonds with the two hydrogen atoms, leaving two non-bonding orbitals on the oxygen.



Four sp^3 orbitals of oxygen

Fig. 4.22
Shape of H_2O

As explained above, the non-bonding orbitals occupy the large volume of space, hence they compress the bonding orbitals and reduce the angle H — O — H in water to 104.5° giving angular or bent structure (Fig: 4.22)

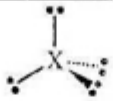
Q.44 ***Draw and explain the geometrical shapes of molecules with the following number of electrons pair:***

(i) two bond pairs
(ii) three bond pairs and one lone pair
(iii) two bond pairs and two lone pairs

Karachi Board: 2016

Ans.

(i)	*No of Electron pairs (Lewis Structure)*	*Arrangement of Electron Pairs*	*No of Bond Pairs*	*No of Lone Pairs*	*Molecular Geometry*	*Examples*
	2	: — X — : Linear	2	0	Linear	$BeCl_2$, CO_2, N_3^-

	4	 Tetrahedral	3	1	Trigonal Pyramid	H_3O^-, NH_3, XeO_3
	4	 Tetrahedral	2	2	Angular	H_2O, NH_2^-, ClO_2^-

Scientific Reasons

Q.01 ***The boiling point of water is grater than that of HF even through fluorine has greater electronegativity than oxygen.*** *Karachi Board: 2011-2013-2019*

Ans. This is because the oxygen atom has two non-bonded pairs (lone pairs) of electrons and there are two polar hydrogen atoms ($H^{+\delta}$) present. This enable three- dimensional bonding in H_2O molecules.
Where as in HF there is only one polar hydrogen atom (H^+) and it forms chains of limited length and hence less hydrogen bonds than in water molecules. Therefore, water molecules have a higher boiling point than HF.

Q.02 ***HF form stronger bond than HI.*** *Karachi Board: 2012*

Ans. Strength of bonding depends on polarity. Fluorine is more electronegative and smaller in size than iodine hence, the bond in HF is stronger than HI.

Q.03 ***The reaction between ionic compounds are fast.*** *Karachi Board: 2010*

Ans. Generally the chemical reactions between ionic compounds are extremely fast and occur in fraction of second. This is because their reaction involve the mutual interactions of ions which combine very fast to from new compounds.

Q.04 ***CO_2 is non-polar in spite of having two polar bonds.*** *Karachi Board: 2009*

Ans. In CO_2 the double bonds lie on straight line and the molecule is symmetrical. It has no dipole moment. This is because CO_2 is linear and the bond moment of each C=O bond is opposite and equal which cancels out each other. The net dipole moment is zero i.e., $\mu = 0$ D.

Q.05 ***s - s sigma bond is relatively weaker than p - p bond.***

Ans. The relative strength of a sigma bond is related to the extent of overlap of the atomic orbitals. Due to spherical charge distribution of s-orbital, generally s-s overlapping is not as effective as s-p and p-p overlapping; on the other hand in the case of p-orbitals there is a longer directional charge distribution which causes its overlapping more effective.

Q.06 ***Covalent bond may be non polar but coordinate covalent bond is always polar.***

Ans. In case of identical atoms the shared electrons are equally attached due to identical electronegativities and the electron density is distributed equally over the two atoms in a molecule and the covalent bond is non-polar.
In coordinate covalent bond the atom which accepted electron pair being shared acquires partial negative charge and creates partial positive charge on donor atom. This makes the coordinate covalent bond polar.

Q.07 ***Bond energy of C = C is less than that of C ≡ C bond.***

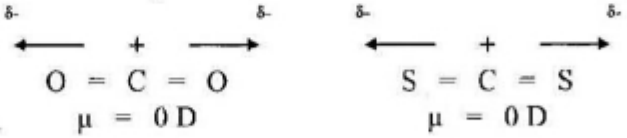
Ans. The value of bond energy depends upon the bond distance. Shorter the bond distance, the stronger the bond and greater would be bond energy. Therefore, the bond energy of multiple bonds would generally be greater than those of single bonds, because greater the number the bonds formed in between two combining atoms shorter will be the distance. Due to this reason, bond energy of C = C is less then C ≡ C bonds.

Q.08 ***Why the bond angle of H_2O is smaller than NH_3 ?***

Ans. In NH_3 the central nitrogen atom possesses only one lone pair electron but in H_2O the oxygen atom possesses two lone pairs of electrons. According to electron pair repulsion theory the repulsion of two lone pairs is greater than bond pair. This is why the bond angle in water (104.5°) is less than NH_3 (107°).

Q.09 ***CO_2 and CS_2 both have zero dipole moment.*** ***Karachi Board: 2018***

Ans. The dipole moment of a tri-atomic linear molecule is zero. This is because bond moment of the two polar bond is equal and opposite which cancels the effect of each other out. Both CO_2 and CS_2 due to above reason show zero dipole moments.



Q.10 ***Why pi (π) bond is weaker than sigma (δ) bond?***

Ans. Sigma bond is formed by the head on overlap of two partially filled atomic orbital. Since parallel overlap (p_y & p_z) is less effective than head on overlap, the sigma bonds are stronger than pi bonds.

Q.11 ***The boiling point of water is higher than H_2S ?***

Ans. See Q 38 (b) on page 157.

Q.12 ***O, N and C atoms are sp^3 hybridized in H_2O, NH_3 and CH_4 but bond angles are not equal.***

Ans. O, N and C atoms are sp^3 hybridized in H_2O, NH_3 and CH_4 but bond angles are not equal. This is because CH_4, NH_3 and H_2O have one and two lone pair electrons respectively. Orbitals occupying lone pair of electron repels the orbitals and change the bond angles of CH, NH_3 and water.

Q.13 ***Polar covalent bond is stronger than non-polar covalent bond.*** *Karachi Board: 2007*

Ans. Polar bond will be stronger between the two. There will be high electronegativity difference between the atoms with polar bonds and vice versa for non-polar bond. Polar bond can have dipole-dipole forces, Hydrogen bonds are also metallic bond whereas non-polar bond has London dispersion forces which is weak forces if you compare with the rest. Therefore, Polar bonds will be harder to break.

Q.14 **Graphite is very soft whereas diamond is very hard.**

Ans. In graphite, each carbon atom is attached with three other carbon atoms in such a way that each atom contributed itself in the formation of hexagonal ring. These rings are responsible for the formation of layers one over the other and the distance between each layer is that of 3.35°A. There are very weak forces that exist in between the layers. Therefore each layer can slip or slide over the other. Hence, graphite appears to be slippery on touching.

In case of diamond, each carbon atom is attached with four carbon atoms by means of covalent bond. This resulted in tetragonal shape of the unit crystal of diamond. The distance between carbon-carbon atoms is 1.54°A. By acquiring such shape the diamond shows the hardest texture. Further all the carbon atoms keep their position firmly fixed so that it is impossible for these atoms to slide or slip from their positions, which is the main reasons for its hardest texture.

Q.15 ***Phosphorous combines with chloride to form PCl_5 but it does not form PI_5 with iodine.***

Ans. The electron affinity of chlorine is -348 KJ mole while that of iodine is -297 KJ mole. Similarly, the electronegativity of chlorine is 3.0 while that of iodine is 2.5. In other words, the electrons affinity as well as electronegativity of chlorine is quite higher as compared with iodine. For that reason, phosphorus combines with chlorine to form PCl_5 compound. Instead of this the atom of iodine has bigger ionic radius and lesser value of electronegativity and electron affinity (comparatively) it is impossible for iodine to form PI_5 compound.

Q.16 ***No liquid ionic compounds are known but many of the known covalent compounds are liquids and some are gases. Account for these differences.*** *Karachi Board: 2011*

Ans. In Ionic compounds, there is strong electrostatic force of attraction between the positive cation and negative anion. A lot of energy is required to break this force hence it has a very high melting point/boiling point, this leads to most of ionic compounds being solid.

In covalent compounds, weak Van der Waals forces exist between discrete molecules (due to dipole attraction). These weak forces require little energy to break hence it has very low melting point/boiling point, this leads to most of the covalent compounds being volatile and hence more of liquid and gases form.

Q.17 ***s-s sigma bond is weaker than s-p sigma bond.*** *Karachi Board: 2014*

Ans. s-s sigma bond is weaker than s-p sigma bond due to spherical charge distribution in s-orbital. s-s sigma bond the extend of overlapping between two 's' orbitals is minimum because both orbitals are rounded in shape. On the other hand, directional charge distribution and longer lobes make more effective overlapping between 's' and 'p' orbitals.

Q.18 ***Li^+ ion is more hydrated than Cs^+ ion.*** *Karachi Board: 2015*

Ans. Due to smaller ionic size of Li^+ ion, it possesses greater charge density than Cs^+ ion. Hence Li^+ ion attract more number of water molecules as compared to Cs^+ ion. Therefore, Li^+ ion is more hydrated than Cs^+ ion.

Q.19 ***Compounds having hydrogen bond generally have high boiling points.***

Karachi Board: 2017

Ans.

Hydrogen bonds play very important role in physical properties of the compounds. For example, water possesses hydrogen bonds and H_2S does not. This is because the boiling point of water is greater than hydrogen sulphide.

Q.20 ***The shorter the bond length, the stronger will be the bond.***

Karachi Board: 2017

Ans.

Value of bond energy depends upon bond distance, the shorter the bond distance the stronger, the bond and greater would be the bond energy. Since multiple bonds are shorter than single bonds this is because molecules with multiple bonds have greater bond energy.

Differences

Q.01 ***What is the difference between the following:***
(i) Sigma and Pi Bonds (ii) Polar and Non-polar covalent bond

Ans. ***Karachi Board: 2008-2013-2015-2017-2019***

S. No.	*Sigma Bonds*	*Pi Bonds*
1.	It is a strong type of bond.	It is weak type of bond.
2.	It is formed by the overlapping of orbitals along the inter-nuclear axis.	It is formed by the lateral overlap of the orbitals.
3.	It involves the overlap of s-s, s-p and p-p orbitals.	It involves the overlap of p-p orbitals.
4.	Around s sigma bond free rotation is possible.	Free rotation about pi bond is not possible.
5.	Only a sigma bond exists between two atom.	One or two pi bonds can be formed between two sigma bonded atoms.
6.	It is represented by δ .	It is represented by π .

Karachi Board: 2005, 2008, 2016

S. No.	*polar Covalent Bonds*	*Non-polar Covalent Bonds*
1.	In this bond, shared pair of electrons is not attracted equally by the two bonded atoms.	In this bond, shared pair of electrons is attracted equally by the two bonded atoms.
2.	Bonded atoms have different electronegativities.	Bonded atoms have same electronegativities.
3.	Distribution of electron cloud is asymmetrical.	Distribution of electron cloud is symmetrical.
4.	It is formed between the atoms of different elements.	It is formed between the two atoms of same element.
5.	It acquires partial positive and partial negative charges.	It dose not acquire even partial charges.
6.	Bond energy of HCl is = 431 KJ / mol	Bond energy of Cl-Cl = 243 KJ / mol

Q.02 ***Differential between the following :***
(i) Valence band theory and Molecular orbital theory
(ii) Atomic and molecular orbital

Ans. ***Karachi Board: 2005, 2014, 2017***

S. No.	*Valence Band Theory*	*Molecular Orbital Theory*
1.	Overlapped atomic orbitals retain their identity.	Overlapped atomic orbitals lose their identity.
2.	In VBT, only half-filled orbital are participated.	Both half-filled as well completely filled orbitals are participated.
3.	No molecular orbital is formed.	Molecular orbital is formed.

Karachi Board: 2004, 2015

S. No.	*Atomic orbital*	*Molecular Orbital*
1.	Orbital that surrounds only one nucleus.	Orbital that surrounds two or more nuclei.
2.	Atomic orbital may be pure or hybridized.	Molecular orbital may be bonding or anti bonding.
3.	Atomic orbital is less stable than bonding molecular orbital.	Bonding molecular orbital is more stable than atomic orbital.
4.	Atomic orbital is more stable than anti-bonding molecular orbital.	Anti bonding molecular orbital is less stable than atomic orbital.
5.	Examples: s, p, d, f, sp^3, sp^2 and sp.	Examples: δ, δ^*, π, π^* orbital.

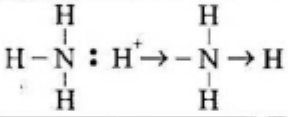
Q.03 ***Differential between the following:***
(i) Ionic bond and Covalent bond (ii) Co-ordinate covalent and Covalent bonds

Ans. ***Karachi Board: 2004***

S. No.	*Ionic Bond*	*Covalent Bond*
1.	It is formed by complete transference of electrons from one atom to another atoms	It is formed by the mutual sharing of electrons between two atoms.
2.	This bond is usually formed between the metals and non-metals.	This bond is usually formed between the non-metals only.

3.	Bonded atoms in ionic bond have very large difference of electro-negativity and ionization energy.	Bonded atoms in covalent bond have no or very small difference of electro-negativity and ionization energy.
4.	It is formed when difference of electro-negativity of combining atoms is 1.7 or more.	It is formed when difference of electron-negativity of combining atoms is less than 1.7.
5.	This bond is very strong.	This bond is comparatively less strong.

Karachi Board: 2004, 2015

S. No.	*Co-ordinate Covalent Bond*	*Covalent Bond*
1.	In this bond, the shared electron pair is donated by one atom only.	This bond is formed by mutual sharing of electrons.
2.	Lewis acids and bases always form this bond.	Lewis acids and bases do not form this bond.
3.	It is represented by an arrow (⟶) from donor to acceptor atom.	It is represented by short line (-) between two bonded atoms.
4.	Example: 	Example: H – H, H – Cl

Solution of Textbook Progress Text - 4

Q.01 ***Describe the main type of bonds. What physical properties are associated with the molecules containing these bonds ?***

Ans. See Q 3 on page 141, Q 7 on page 143 and Q 13 on pages 145.
The physical properties associated with these bonds are:
(i) type (ii) nature (iii) direction (iv) melting & boiling points (v) solubility etc.

Q.02 ***What is poler covalent bonds? Do all polar molecules contain polar covalent bonds? Do polar covalent bonds necessarily have polarity on a polar molecule as a whole? Support your answer with more specific examples.***

Ans. See Q 18 on page 147 for polar covalent bond.

- All polar molecules do not contain polar bonds e.g. CO_2
- The bonds may be polar in the compound but they do not necessarily leave polarity on a polar molecule as a whole.

Example: In CCl_4 the C-Cl bond is polar and having a dipole of 2.05D but due to the symmetrical distribution of four C-Cl bonds the cancellation of all dipole moments take place, hence $\mu = 0$.

Q.03 ***Distinguish between the following :***
(i) Atomic orbital and molecular orbital
(ii) Sigma and pi bonds
(iii) Valence band theory and molecular orbital theory

Ans. For (i) See Q 2 on page 166.
For (ii) See Q 1 on page 165.
For (iii) See Q 2 on page 166.

Q.04 ***What do you understand by the term dipole moment? Explain the significance of dipole moment.***

Ans. See Q 15 and Q 17 on pages 146 and 147.

Q.05 ***What is meant by sp^3 hybrid orbitals? How do they differ from s and p orbitals?***

Ans. See Q. 27 on page 150.
sp orbitals are of spherical and dumbbell shape with different energies whereas sp^3 orbitals are hybrid orbitals of same shape and energy.

Q.06 ***Describe how electronegativity of atoms can be used to predict the nature of bond formed between two elements. Explain giving examples.***

Ans. Diatonic molecules, consist of different atoms and it is polar. Greater the difference of electronegativity between the two atoms the greater will be the polarity of the molecule.

Electronegativity confirms ionic or covalent nature of a compound.

For example: Sodium and chlorine have a difference of electronegativity 2. Therefore they form ionic bond. Hydrogen has electronegativity of 2.1 while that of nitrogen is 3.0. These two elements will form a covalent bond due to difference of electronegativity less than one.

Electronegativity predicts the length of a bond.

Electronegativity predicts polarity and polarity gives ionic character to a bond and ionic character reduces the bond distance and the bond energy increases.

Theoretically the bond distance of H-F is 1.01 Å and the calculated value of bond length of $H^{\delta+}$-$F^{\delta-}$ is 0.92 Å. Thus electronegativity helps to determine the nature of bond.

Q.07 ***Write a note on bond energy.***

Ans. See Q 20 on page 148.

Q.08 ***What are the most important secondary bonds present in H_2O and HF molecules? How do they affect the physical properties of compound?***

Ans. See Q 38 on page 156.

Q.09 ***How can the theory of electron pair repulsion be used to rationalize the shapes of simple molecules?***

Ans. See Q 33 on page 155.

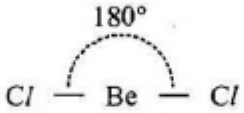
Q.10 ***Beryllium Chloride has a linear shape where as water molecule has angular shape. Account this difference in terms of electron pair repulsion model and hybrid model.***

Ans. ***For $BeCl_2$:*** Shape of $BeCl_2$ in terms of electron pair repulsion theory.

The Lewis structure of $BeCl_2$ can be represented as:

$$:\ddot{\underset{\cdot\cdot}{Cl}}\ \cdot\times\ Be\ \times\cdot\ \ddot{\underset{\cdot\cdot}{Cl}}:$$

It indicates that two electron pairs are there in the valence shell around the central atom Be. The distance between the two electron pairs would be maximum if they are placed at the opposite ends of a line with Be atom in the centre. In this orientation two electrons pairs will experience minimum repulsion. If we attach two Cl atoms with electron pairs placed at the opposite ends of a line with Be atom in the centre then the geometric shape of $BeCl_2$ molecule would be linear of 180°

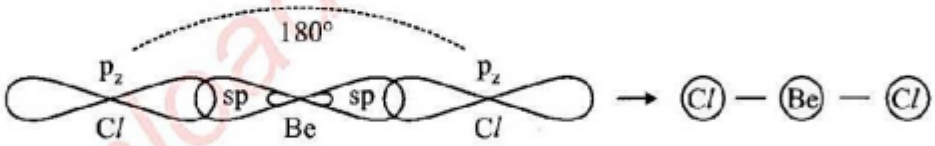


Shape of $BeCl_2$ in terms of hybrid orbital theory: Be in hybridized as follows:

Ground state : $Be = 1s^2, 2s^2$

Excited state : $Be = 1s^2, 2s^1, 2p_x^1$ (sp hybrid)

Thus this sp hybrid orbital arrange themselves at an angle of 180° form a linear structure. The $3p_z$ orbitals of the two chlorine atoms overlap the sp orbitals to give two sigma bonds as follows:



For water molecule: See Q 27 (iii) on page 150.

Q.11 ***Predict the shapes of the following molecules:***
PCl_3, PH_3, H_2S, SCl_2

Ans.

PCl_3

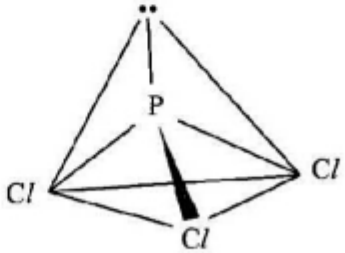
Cl = Terminal atom

Total valence electron

P = 5 × 1 = 5

Cl = 7 × 3 = 21

26



Bond angle = 107°

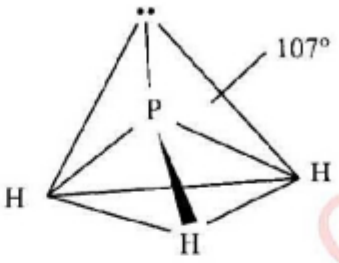
Bond pairs = 3

Hybridization = sp^3

PH_3

P = central atom
H = Terminal atom
Total valence electron
P = 5 × 1 = 5

H_3 = 1 × 3 = $\frac{3}{8}$

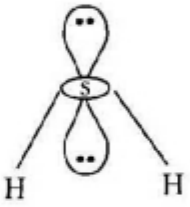


Hybridization = sp^3
shape = Trigonal pyramid
Bond pair = 3
Lone pair = 1

H_2S

S = Central atom
H = Terminal atom
Total valence electron
S = 6 × 1 = 6

H_2 = 1 × 2 = $\frac{2}{8}$

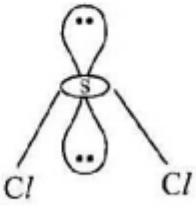


Hybridization = sp^3
Bond pairs = 2
Line pairs = 2

SCl_2

S = Central atom
Cl = Terminal atom
Total valence electron
S = 6 × 1 = 6

Cl_2 = 7 × 2 = $\frac{14}{20}$



Hybridization = sp^3
angle = 104°
Bond pairs = 2
Lone pairs = 2