

CHAPTER 4

Chemical Bonding And Molecular Structure

VEDA
ACADEMY

CLASS 11TH

NCERT EXERCISE AND SOLUTIONS - CHEMISTRY



Q. 1. Explain the formation of a chemical bond

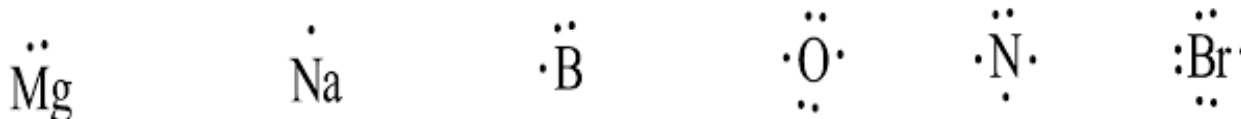
ANSWER:-

A chemical bond is the attractive force that holds together the particles (atoms, ions, or molecules) within a chemical species. Atoms either share, gain, or lose electrons in order to achieve a stable electronic configuration, resulting in a state of minimum energy and the formation of a chemical bond. This process leads to maximum stability. When two atoms share electrons, a covalent bond is formed, while an ionic bond is created when atoms gain or lose electrons.

Q. 2. Write Lewis dot symbols for atoms of the following elements : Mg, Na, B, O, N, Br.

ANSWER:-

The correct lewis symbols are shown above:



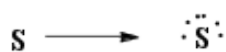
Q. 3. Write Lewis symbols for the following atoms and ions:

S and S²⁻; Al and Al³⁺; H and H⁻

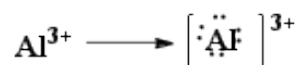
ANSWER:-

The lewis symbols are shown below

Lewis dot symbol of atoms



Lewis dot symbol of ions



+91 98103 37915

1

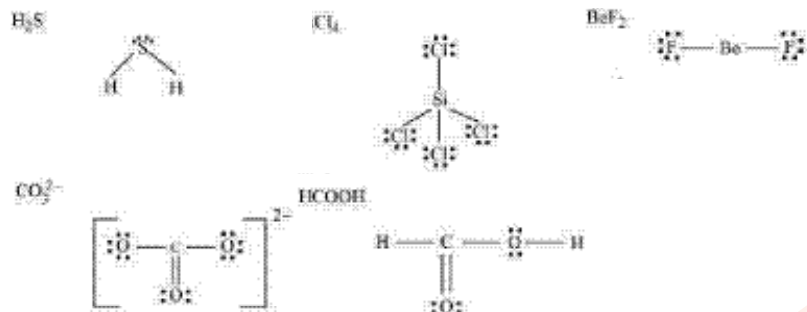


Q. 4. Draw the Lewis structures for the following molecules and ions:



ANSWER:-

The Lewis structures are shown above:



Q. 5. Define octet rule. Write its significance and limitations.

ANSWER:-

The tendency or urge of elements to attain stable configuration of eight electrons in their valence shell is called **octet rule**.

Significance

- (i) It is useful for understanding the structure of the organic compounds.
- (ii) it mainly applies to the elements of second period of periodic table.

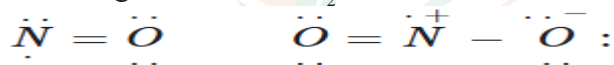
Limitations

- (i) The incomplete octet of the central atom

Some compounds do not follow the octet rule. Their central atom contain less than eight electrons. for example, $\text{Li}:\text{Cl}:\text{H}:\text{Be}:\text{H}$.

- (ii) Odd - electron molecules

Octet rule is not followed by the molecules having odd number of electrons like-nitric oxide, NO and nitrogen dioxide, NO_2 .



- (iii) The expanded octet

Some compounds have than eight valence electrons around the atom. this is known as the expanded octet. For examole, PF_2 , SF_6 , H_2SO_4 and a number of co-ordination compounds.

- (iv) Octet rule is based upon chemical inertness of noble gases. However noble gases also combine with oxygen and fluorine to from a number of compounds like XeF_2 , KrF_2 , XeOF_2 etc.
- (v) Octet theory does not account for the shape of molecules.
- (vi) It does not explain the relative stability of the molecules.

Q. 6. Write the favourable factors for the formation of ionic bond.

ANSWER:-

1. The two atoms involved must be different elements.
2. The ionization energy of one atom should be relatively low.



- The electron affinity of one atom should be relatively high.
- The electronegativity of one of the atoms should be high.
- The difference in electronegativity between the two atoms should be greater than or equal to 1.7

Q. 7. Discuss the shape of the following molecules using the VSEPR model:



ANSWER:-

The shape according to VSEPR theory is given below :

| Molecule | Number of electron pairs around central atom | Molecular geometry |
|----------------------|--|----------------------|
| BeCl_2 | 2 | Linear |
| BCl_3 | 3 | trigonal planar |
| SiCl_4 | 4 | tetrahedral |
| AsF_5 | 5 | trigonal bipyramidal |
| H_2S | 6 | non linear/bent |
| PH_3 | 5 | trigonal pyramidal |

Q. 8. Although geometries of NH_3 and H_2O molecules are distorted tetrahedral, bond angle in water is less than that of ammonia. Discuss.

ANSWER:-

The molecular geometry of NH_3 and H_2O can be described as follows: In NH_3 , the central nitrogen atom has one lone pair and three bond pairs. In H_2O , the central oxygen atom has two lone pairs and two bond pairs. The two lone pairs on the oxygen atom in H_2O cause greater repulsion with the bond pairs, which is stronger than the repulsion between the lone pair and the three bond pairs on the nitrogen atom in NH_3 . Since the repulsion between the bond pairs in H_2O is greater than in NH_3 , the bond angle in water is smaller compared to that in ammonia.

Q. 9. How do you express the bond strength in terms of bond order ?

ANSWER:-

Bond order is directly proportional to bond strength. More the bond order, more will be the bond strength. Bond strength increases with increase in bond order.

Q. 10. Define the bond length.

ANSWER:-

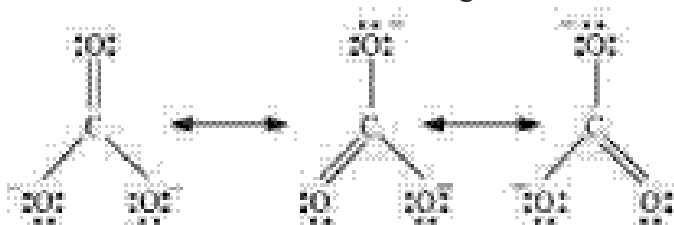
Bond length is defined as the average distance between the centers of nuclei of the two bonded atoms in a molecule.



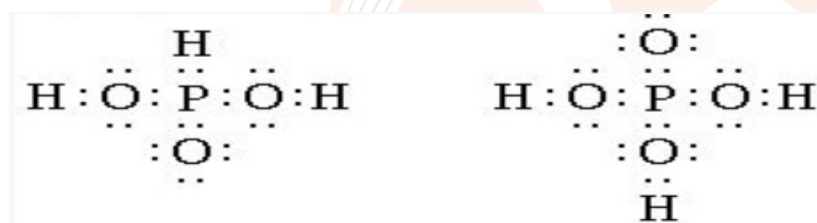
Q. 11. Explain the important aspects of resonance with reference to the CO_3^{2-} ion.

ANSWER:-

The carbonate ion cannot be represented by one single structure but its properties can be described by two or more resonance structures. The actual structure of carbonate ion is the resonance hybrid of the contributing structures. In the resonance hybrid, all the three bond lengths are equal and the bonds are intermediate between single and double bonds.



Q. 12. H_3PO_3 can be represented by structures 1 and 2 shown below. Can these two structures be taken as the canonical forms of the resonance hybrid representing H_3PO_3 ? If not, give reasons for the same.



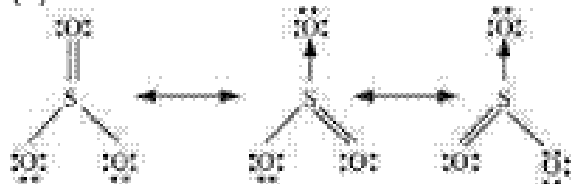
ANSWER:-

In the canonical forms, the position of atoms remains same but the position of electrons change. In the given canonical forms, the position of atoms changes. Hence, they cannot be taken as canonical forms.

Q. 13. Write the resonance structures for SO_3 , NO_2 and NO_3^- .

ANSWER:-

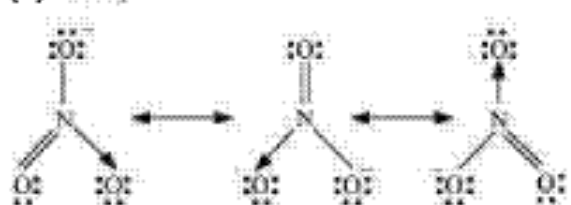
(a) SO_3 :



(b) NO_2 :



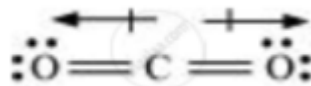
(c) NO_3^- :



Q. 15. Although both CO_2 and H_2O are triatomic molecules, the shape of H_2O molecule is bent while that of CO_2 is linear. Explain this on the basis of dipole moment.

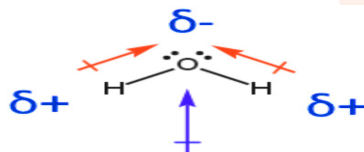
ANSWER:-

According to experimental results, the dipole moment of carbon dioxide is zero. This is possible only if the molecule is linear so that the dipole moments of C – O bonds are equal and opposite to nullify each other.



Resultant $\mu = 0\text{D}$

H_2O , on the other hand, has a dipole moment value of 1.84 D (though it is a triatomic molecule as CO_2). The value of the dipole moment suggests that the structure of H_2O molecule is bent where the dipole moment of O – H bonds are unequal.



Q. 16. Write the significance/applications of dipole moment.

ANSWER:-

Significance/Applications of Dipole Moment:

(i) Distinction between Polar and Non-Polar Molecules:

Non-polar molecules, such as nitrogen, oxygen, and hydrogen, have a dipole moment of zero, while polar molecules have a non-zero dipole moment. For instance, the dipole moments of water, HF, HCl, and H_2S are 1.85 D, 1.78 D, 1.07 D, and 0.95 D, respectively.

(ii) Degree of Polarity in a Molecule:

The greater the dipole moment value, the higher the degree of polarity. This relationship is particularly evident in diatomic molecules. For example, HF (1.78 D) is more polar than HCl (1.07 D).

(iii) Shapes of Molecules:

Water and carbon dioxide have dipole moments of 1.85 D and 0 D, respectively. This results in water having an angular (bent) shape, while carbon dioxide adopts a linear shape.

(iv) Ionic Character in a Molecule:

The percentage of ionic character in a molecule is calculated by the ratio of the observed dipole moment to the dipole moment for a fully ionic molecule, multiplied by 100.

Q. 17. Define electronegativity. How does it differ from electron gain enthalpy ?

ANSWER:-

Electronegativity is the tendency of an atom to attract the shared pair of electrons towards it in a covalent bond. It is the property of atoms in molecules.

Electron gain enthalpy is the tendency of an isolated atom in its gaseous state to accept an additional electron to form a negative ion. It is the property of isolated atoms.



Q. 18. Explain with the help of suitable example polar covalent bond.

ANSWER:-

Polar covalent bonding is a type of chemical bond where a pair of electrons are unequally shared between two atoms. The bonding of hydrogen and chlorine atoms leans more towards Cl atom because Cl is more electronegative in nature than the hydrogen.

Q. 19. Arrange the bonds in order of increasing ionic character in the molecules: LiF, K₂O, N₂, SO₂ and ClF₃

ANSWER:-

The ionic character in the molecule is dependent on the electronegativity difference between the constituting atoms.

The greater difference, the greater will be the ionic character of the molecule.

On the basis, the increasing order of ionic character in given molecule is

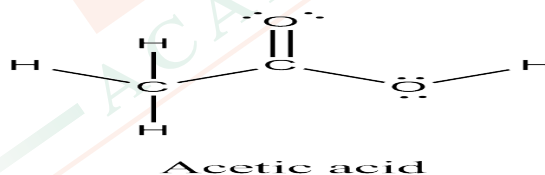
N₂ < SO₂ < ClF₃ < K₂O < LiF.

Q. 20. The skeletal structure of CH₃COOH as shown below is correct, but some of the bonds are shown incorrectly. Write the correct Lewis structure for acetic acid.



ANSWER:-

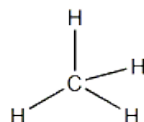
The correct Lewis structure for acetic acid is shown below



Q. 21. Apart from tetrahedral geometry, another possible geometry for CH₄ is square planar with the four H atoms at the corners of the square and the C atom at its centre. Explain why CH₄ is not square planar?

ANSWER:-

The square planar geometry has a bond angle of 90°. This is lesser than the tetrahedral bond angle which is 109.5°. Due to this, in the square planar geometry, the repulsive forces are more and hence, square planar geometry is less stable.



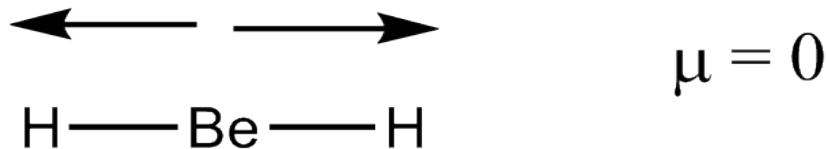
Tetrahedral geometry



Q. 22. Explain why BeH_2 molecule has a zero dipole moment although the Be–H bonds are polar.

ANSWER:-

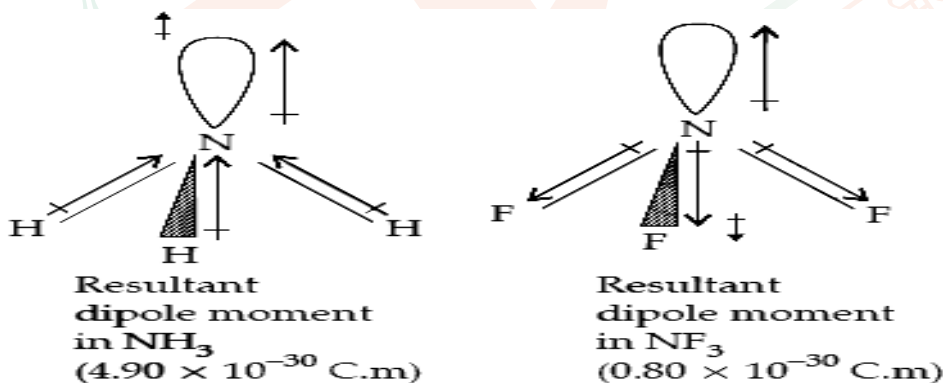
In the linear BeH_2 molecule, the resultant dipole moment of two Be–H bonds cancel each other. Due to this, the over all dipole moment of the molecule is zero.



Q. 23. Which out of NH_3 and NF_3 has higher dipole moment and why?

ANSWER:-

The dipole moment of ammonia is higher than the dipole moment of NF_3 . The molecular geometry is pyramidal for both the molecules. In each molecule, N atom has one lone pair. F is more electronegative than H and N–F bond is more polar than N–H bond. Hence, NF_3 is expected to have much larger dipole moment than NH_3 . However reverse is true as in case of ammonia, the direction of the lone pair dipole moment and the bond pair dipole moment is same whereas in case of NF_3 it is opposite. Thus, in ammonia molecule, individual dipole moment vectors add whereas in NF_3 , they cancel each other.



Q. 24. What is meant by hybridisation of atomic orbitals? Describe the shapes of sp , sp^2 , sp^3 hybrid orbitals.

ANSWER:-

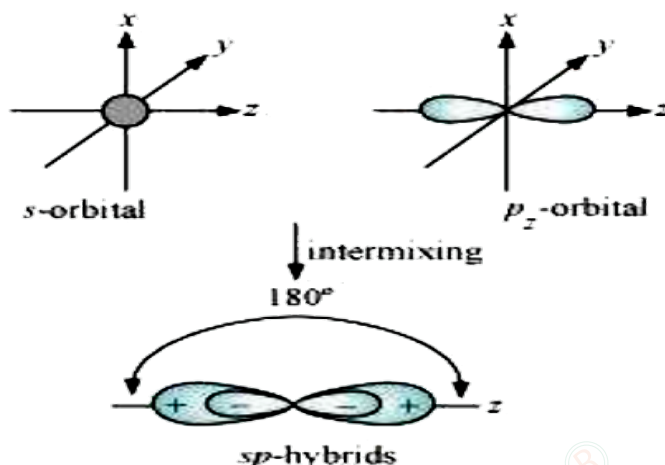
Hybridization is defined as an intermixing of a set of atomic orbitals of slightly different energies, thereby forming a new set of orbitals having equivalent energies and shapes.

For example, one $2s$ -orbital hybridizes with two $2p$ -orbitals of carbon to form three new sp^2 hybrid orbitals.

These hybrid orbitals have minimum repulsion between their electron pairs and thus, are more stable. Hybridization helps indicate the geometry of the molecule.

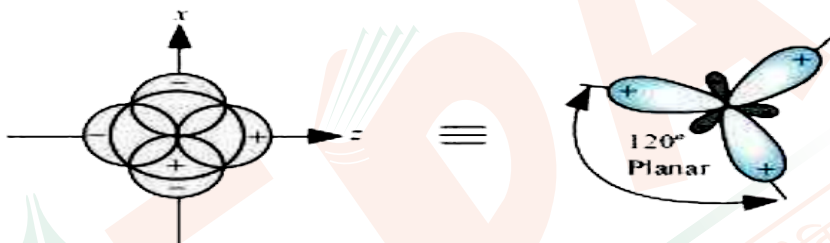
Shape of sp hybrid orbitals: sp hybrid orbitals have a similar shape. They are formed by the intermixing of s and p orbitals as:





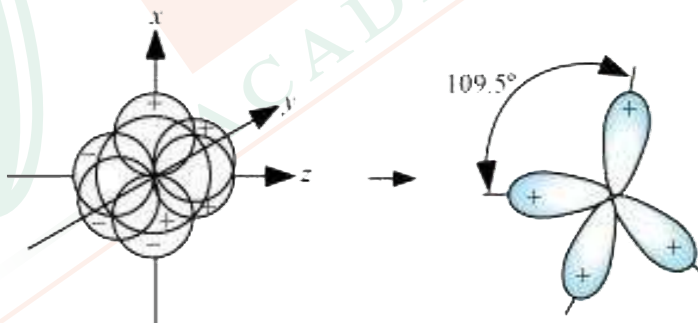
Shape of sp^2 hybrid orbitals:

sp^2 hybrid orbitals are formed as a result of the intermixing of one s -orbital and two $2p$ -orbitals. The hybrid orbitals are oriented in a trigonal planar arrangement as :



Shape of sp^3 hybrid orbitals:

Four sp^3 hybrid orbitals are formed by intermixing one s -orbital with three p -orbitals. The four sp^3 hybrid orbitals are arranged in the form of a tetrahedron as



- Q. 25.** Describe the change in hybridisation (if any) of the Al atom in the following reaction.
 $\text{AlCl}_3 + \text{Cl}^- \rightarrow \text{AlCl}_4^-$

ANSWER:-

The hybridization of Al atom changes from sp_2 in AlCl_3 to sp_3 in AlCl_4^- .

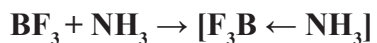
In AlCl_3 , Al contains 3 bond pairs of electrons and zero lone pair of electrons.

Hence, it is sp_2 hybridized. In AlCl_4^- , Al atom contains 4 bond pairs of electrons and zero lone pairs of electrons.

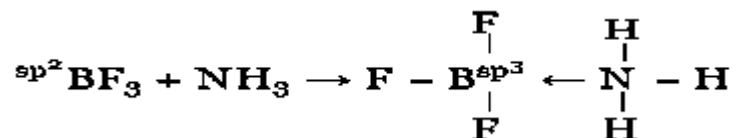
Hence, it is sp^3 hybridized.



Q. 26. Is there any change in the hybridisation of B and N atoms as a result of the following reaction?



ANSWER:-

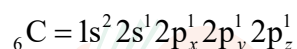


The hybridization of B changes from sp^2 to sp^3 whereas the hybridization of N remains same i.e. sp^3 .

Q. 27. Draw diagrams showing the formation of a double bond and a triple bond between carbon atoms in C_2H_4 and C_2H_2 molecules.

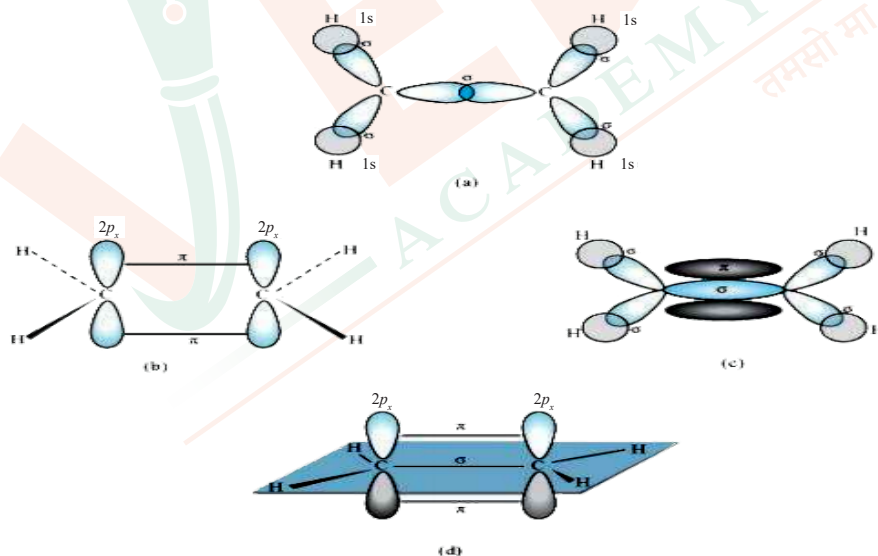
ANSWER:-

The electronic configuration of C -atom in the excited state is:



In the formation of an ethane molecule (C_2H_4), one sp^3 hybrid orbital of carbon overlaps a sp^3 hybridized orbital of another carbon atom, thereby forming a C-C sigma bond.

The remaining two sp^3 orbitals of each carbon atom form sp^3 -s sigma bond with two hydrogen atoms. The unhybridized orbital of one carbon atom undergoes sidewise overlap with the orbital of a similar kind present on another carbon atom to form a weak π -bond.



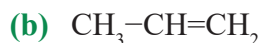
C_2H_2 :

In the formation of C_2H_2 molecule, each C-atom is sp hybridized with two $2p$ -orbitals in an unhybridized state.

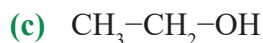
One sp orbital of each carbon atom overlaps with the other along the internuclear axis forming a C-C sigma bond. The second sp orbital of each C-atom overlaps a half-filled $1s$ -orbital to form a σ bond.

The two unhybridized p -orbitals of the first carbon undergo sidewise overlap with the $2p$ orbital of another carbon atom, thereby forming two pi (π) bonds between carbon atoms. Hence, the triple bond between two carbon atoms is made up of one sigma and two π -bonds.





The carbon atom of methyl group is sp^3 hybridized whereas other two carbon atoms are sp^2 hybridized.



Both the carbon atoms are sp^3 hybridized.



The carbon atom of methyl group is sp^3 hybridized whereas the other carbon atom is sp^2 hybridized.



The carbon atom of methyl group is sp^3 hybridized whereas the other carbon atom is sp^2 hybridized.

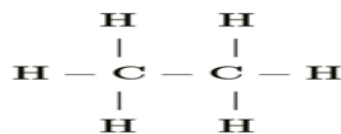
Q. 31. What do you understand by bond pairs and lone pairs of electrons? Illustrate by giving one example of each type.

ANSWER:-

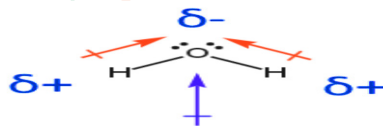
When two atoms combine by sharing their one or more valence electrons, a covalent bond is formed between them.

The shared pairs of electrons present between the bonded atoms are called bond pairs. All valence electrons may not participate in bonding. The electron pairs that do not participate in bonding are called lone pairs of electrons.

For example, in C_2H_6 (ethane), there are seven bond pairs but no lone pair present.



In H_2O , there are two bond pairs and two lone pairs on the central atom (oxygen)



Q. 32. Distinguish between a sigma and a pi bond.

ANSWER:-

| Sr.No. | sigma bond (σ) | pi bond (π) |
|--------|--|--|
| 1. | The bond formed due to overlapping along the same axis (axial overlapping) is called Sigma Bond. | The bond formed due to lateral overlapping between two p-orbitals is called a pi-bond. |
| 2. | The first or the only bond between two atoms is the sigma bond. | The pi bond is always an additional bond between two atoms. |
| 3. | The extent of overlapping is greater. | The extent of overlapping is less. |
| 4. | It is a strong bond. | It is a weak bond. |



| | | |
|----|---|---|
| 5. | Formation of sigma bonds involves s-s, s-p, p - p overlap, and overlap between hybrid orbitals. | Formation of pi bonds involves p-p or overlap. The overlap between hybrid orbitals is not involved. |
| 6. | The bond energy is high. | The bond energy is low. |

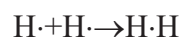
Q. 33. Explain the formation of H_2 molecule on the basis of valence bond theory.

ANSWER:-

The electronic configuration of hydrogen is $1s^1$.

Thus, it contains one unpaired electron in $1s$ orbital.

Two H atoms, each having one unpaired electron, combine and share their electron to form a covalent bond in which two electrons are paired.



Q. 34. Write the important conditions required for the linear combination of atomic orbitals to form molecular orbitals.

ANSWER:-

- (a) The energy of combining atomic orbitals should be approximately the same.
Thus, in case of homonuclear diatomic molecule, $1s$ orbital of an atom can combine with $1s$ orbital of second atom but not with $2s$ orbital of second atom.
- (b) To ensure maximum overlap, the combining atomic orbitals should have proper orientation.
- (c) The extent of overlap should be large.

Q. 35. Use molecular orbital theory to explain why the Be_2 molecule does not exist.

ANSWER:-

The electronic configuration of Beryllium is $1s^2 2s^2$

The molecular orbital electronic configuration for molecule can be written as:

$$\sigma_{1s}^2 \sigma_{1s}^2 \sigma_{2s}^2 \sigma_{2s}^2$$

Hence, the bond order for Be_2 is $\frac{1}{2}(N_b - N_a)$

Where,

N_b = Number of electrons in bonding orbitals

N_a = Number of electrons in anti-bonding orbitals

$$\text{Bond order of } Be_2 = \frac{1}{2}(4 - 4) = 0$$

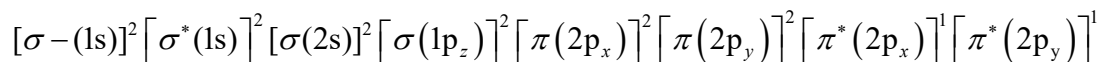
A negative or zero bond order means that the molecule is unstable. Hence, molecule does not exist.



Q. 36. Compare the relative stability of the following species and indicate their magnetic properties; O_2 , O_2^+ , O_2^- (superoxide), O_2^{2-} (peroxide)

ANSWER:-

There are 16 electrons in a molecule of dioxygen, 8 from each oxygen atom. The electronic configuration of oxygen molecule can be written as:



Since the 1 s orbital of each oxygen atom is not involved in bonding, the number of bonding electrons N_b and the number of anti-bonding orbitals $= 4 = N_a$.

$$\begin{aligned} \text{Bond order} &= \frac{1}{2}(N_b - N_a) \\ &= \frac{1}{2}(8 - 4) \\ &= 2 \end{aligned}$$

Similarly, the electronic configuration of O_2^+ can be written as:

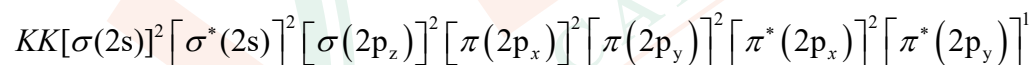


$$N_b = 8$$

$$N_a = 3$$

$$\text{Bond order of } O_2^+ = \frac{1}{2}(8 - 3) = 2.5$$

Electronic configuration of O_2^- ion will be:

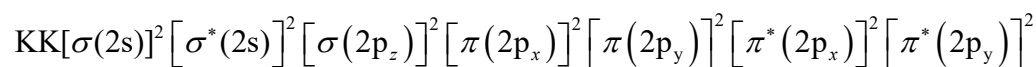


$$N_b = 8$$

$$N_a = 5$$

$$\text{Bond order of } O_2^- = \frac{1}{2}(8 - 5) = 1.5$$

Electronic configuration of O_2^{2-} ion will be:

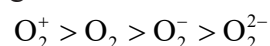


$$N_b = 8$$

$$N_a = 6$$

$$\text{Bond order of } O_2^{2-} = \frac{1}{2}(8 - 6) = 1$$

Bond dissociation energy is directly proportional to bond order. Thus, the higher the bond order, the greater will be the stability. On this basis, the order of stability is



Q. 37. Write the significance of a plus and a minus sign shown in representing the orbitals

ANSWER:-

Molecular orbitals are represented by wave functions. A plus sign in an orbital indicates a positive wave function while a minus sign in an orbital represents a negative wave function.

Q. 38. Describe the hybridisation in case of PCl_5 . Why are the axial bonds longer as compared to equatorial bonds?

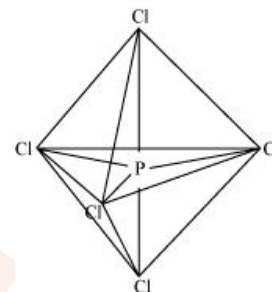
ANSWER:-

P has ground state valence shell electronic configuration $3s^23p^3$ and the first excited state valence shell electronic configuration is $3s^13p^33d^1$.

P undergoes sp^3d hybridization and has trigonal bipyramidal geometry.

Axial Cl atoms experience higher electron repulsion than equatorial chlorine atoms.

Hence, the axial bonds are longer as compared to equatorial bonds.



Q. 39. Define hydrogen bond. Is it weaker or stronger than the van der Waals forces?

ANSWER:-

A hydrogen bond is the electrostatic attraction between polar groups that occurs when a hydrogen (H) atom bound to a highly electronegative atom such as nitrogen (N), oxygen (O) or fluorine (F) experiences attraction to some other nearby highly electronegative atom. These hydrogen-bond attractions can occur between molecules (intermolecular) or within different parts of a single molecule (intramolecular). The hydrogen bond (5 to 30 kJ/mole) is stronger than a van der Waals interaction, but weaker than covalent or ionic bonds. This type of bond can occur in inorganic molecules such as water and in organic molecules like DNA and proteins.

Q. 40. What is meant by the term bond order? Calculate the bond order of N_2 , O_2 , O_2^+ and O_2^- .

ANSWER:-

Bond order: The number of chemical bonds present between two atoms of a molecule.

$$\text{In } \text{N}_2 \Rightarrow \text{Bond order} = \frac{10-4}{2} = 3 \Rightarrow \text{N} \equiv \text{N}$$

$$\text{In } \text{O}_2 \Rightarrow \text{Bond order} = \frac{10^2-6}{2} = 2 \Rightarrow \text{O} = \text{O}$$

In O_2^+ , no. of electrons in bonding orbital is 9

$$\text{Bond order} = \frac{9-6}{2} = \frac{3}{2} = 1.5$$

$$\text{In } \text{O}_2^-, \text{ no. of electrons in anti-bonding orbital is 7 Bond order} = \frac{10-7}{2} = \frac{3}{2} = 1.5$$

