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Class 11
CHEMISTRY

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Chemical Bonding and Molecular Structure

NCERT Solutions

Question1.

Explain the formation of a chemical bond.

Answer:

Chemical bond is an attractive force that bounds the constituents of a chemical species together.

Theories like valence shell electron pair repulsion theory, electronic theory, molecular orbital theory and valence bond theory have explained the formation of chemical bond.

The formation of a chemical bond is the tendency of the system to achieve stability. An atom is said to be stable when it attains noble gas configuration that is the outermost orbitals are completely filled.

Atoms combine with one another and fill their separate octets.

Question2.

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

Answer.

Mg:
Na.
.B:
:ö:
:N̈.

Question 3.

Write Lewis symbols for the following atoms and ions:

S and S^{2-}, Al and Al^{3+}, H and H^{-}

Answer:

Electronic configuration of S = 2, 8, 6

Electronic configuration of Al = 2, 8, 3

Electronic configuration of H = 1

Electronic configuration of S = 2, 8, 6

Electronic configuration of Al = 2, 8, 3

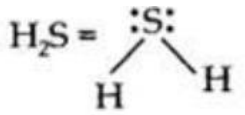
Electronic configuration of H = 1

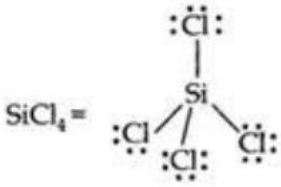
Question 4.

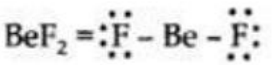
Draw the Lewis structures for the following molecules and ions:

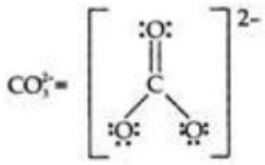
H_2S, $SiCl_4$, BeF_2, CO_3^{2-}, HCOOH

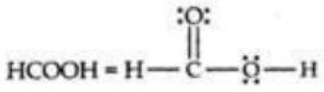
Answer.











Question 5.

Define octet rule. Write the significance and limitations.

Answer:

Atoms of elements combine with each other in order to complete their respective octets so as to acquire stable gas configuration, this is octet rule. This is also called as electronic theory.

It was given by Kossel and Lewis.

Significance of Octet rule: This explains the chemical bond formation depending upon the nature of element.

Different atoms combine with each other to form ionic or covalent compounds.

Limitations of Octet rule:

1. Octet rule fails to predict the relative stability and shape of the molecules.

2. Octet rule is based on the inert nature of noble gases. But some inert gases like Kr and Xe forms compounds.

3. This does not account for shape of molecules.

4. If compound is having less than 8 electrons surrounding central atom, then octet rule cannot be applied to such compound. For example: BeH_2

Question 6.

Write the favourable factors for the formation of ionic bond.

Answer:

Factors affecting the formation of ionic bond:

1. High electron affinity of atoms of non-metal.

2. High lattice energy of compound which is formed.

3. Low ionization enthalpy of metal atom.

Question7.

Discuss the shape of the following molecules using the VSEPR model.

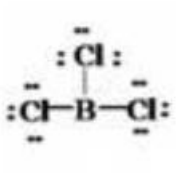
$BeCl_2$, BCl_3, $SiCl_4$, AsF_5, H_2S, PH_3

Answer:

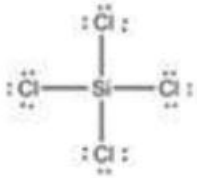
$BeCl_2$

Cl: Be: Cl

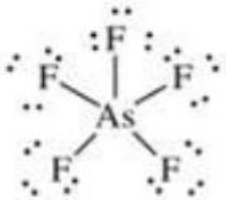
BCl_3



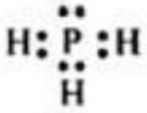
$SiCl_4$



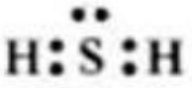
AsF_5



PH_3



H_2S



Question 8.

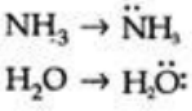
Although geometries of NH_3 and H_2O molecules are distorted tetrahedral, bond angle in water is less than that of ammonia. Discuss.

Answer:

Electron dot structures of these molecules are given below:

Since, there are two lone pairs of electrons on O-atom, repulsion on bond pairs is greater in water as compared to ammonia.

Thus, bond angle is less in water molecules.



Question 9.

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

Answer:

Bond strength is directly proportional to bond order. Greater the bond order more is the bond strength.

In order words, as bond strength increases, the bond becomes stronger and bond order increases.

Question 10.

Define the bond length.

Answer:

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

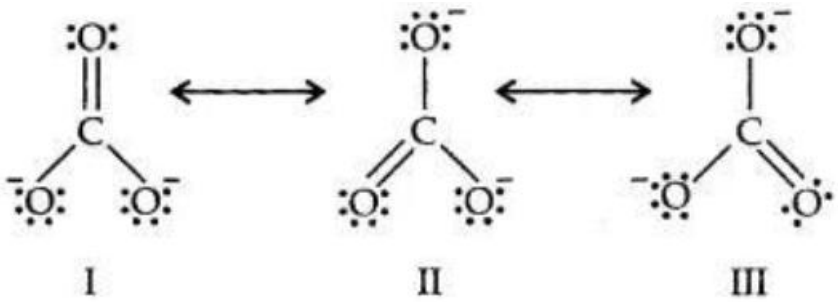
Bond lengths are measured by spectroscopic methods.

Question 11.

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

Answer:

Resonance in CO_3^{2-}. I, II and III represents three canonical forms.



I II III

1. In all these structures, position of nuclei is same.

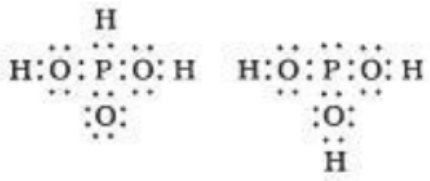
2. All of them have almost equal energy.

3. They have same number of paired and impaired electrons, they differ only in their position.

Question 12.

H_3PO_4 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_4 ? If not, give reasons for the same.



Answer:

These are structures cannot be taken as canonical forms because the positions of atoms have been changed.

Question 13.

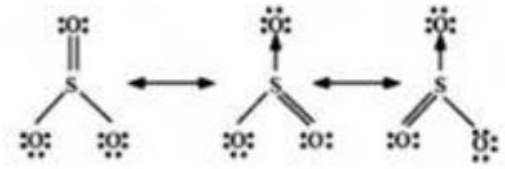
Write the resonance structures for SO_3, NO_2 and NO_3^-.

Answer.

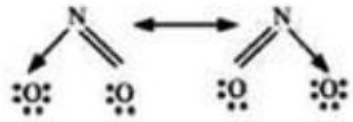
SO_3

NO_2

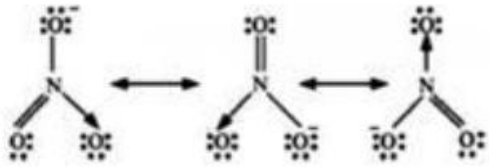
NO_3



NO_2



NO_3^-



Question 14:

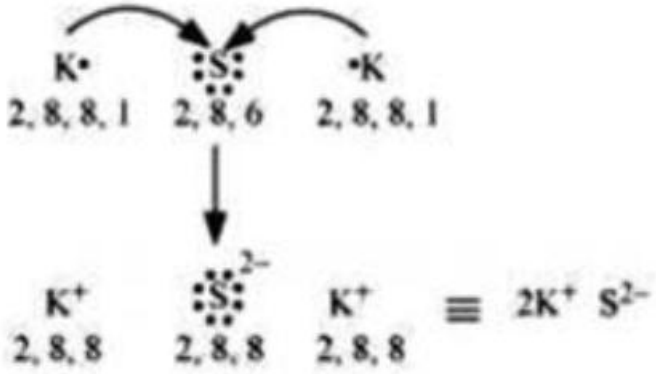
Use Lewis symbols to shows electron transfer between the following atoms to form cations and anions: (a) K and S (b) Ca and O (c) Al and N.

Answer.

(a)S and K

S – 2, 8, 6

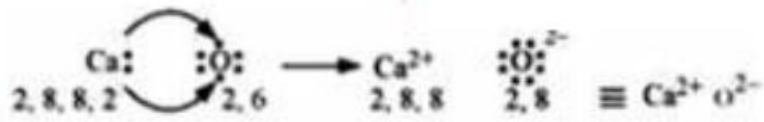
K – 2, 8, 8, 1



(b) Ca and O

Ca - 2, 8, 8, 2

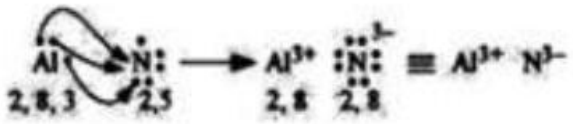
O – 2, 6



(c) Al and N

N – 2, 5

Al – 2, 8, 3



Question 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.

In CO_2 molecule, there are two C=O bonds. Each C-O bond is polar bond. The net dipole of CO_2 molecule is zero.

This is possible if the shape of molecule is linear as dipole moments of bond between C-O is equal and opposite, so they cancel out each other.

In water molecule, net dipole moment is 1.84 D. Water molecule has a bent structure because O-H bonds are oriented at an angle of 104.5^{o} and do not cancel each other.

Question 16.

Write the significance/application of dipole moment.

Answer.

1. It helps in predicting the nature of molecules.
2. It helps in determining the shapes of molecules.
3. It helps in calculating the percentage ionic character.

Question 17.

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

Answer.

Electronegativity is the tendency of an atom to attract shared pair of electrons.

Electron gain enthalpy is the tendency of an atom to attract outside electron.

Question 18.

Explain with the help of suitable example polar covalent bond.

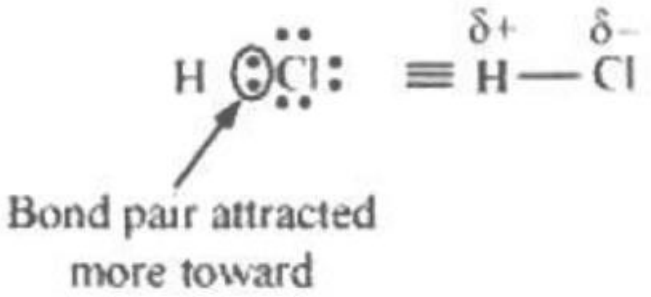
Answer.

When two atoms with different electronegativity are linked to each other by covalent bond, bond pair of electrons is not shared equally.

For example:

HCl is having polar covalent bond. In HCL, Cl-atom is having more electronegativity than H^- atom.

Bond pair shift towards Cl-atom due to which it acquires positive charge.



Question 19.

Arrange the bonds in order of increasing ionic character in the molecules: LiF, K_2O, N_2, SO_2 and ClF_3.

Answer.

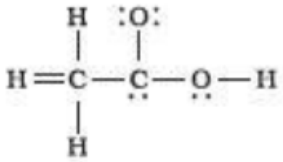
Ionic character of a molecule depends on different in electronegativity between constituent atoms.

$N_2 < SO_2 < ClF_3 < K_2O < LiF$

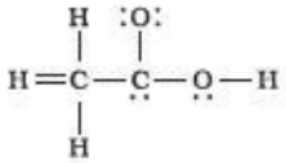
Question 20.

The skeletal structure of CH_3COOH as shown below is correct, but some of the bonds are shown incorrectly.

Write the correct Lewis structure for acetic acid.



Answer.



Question 21.

Apart from tetrahedral geometry, another possible geometry for CH_4 is square planar with the four H atoms at the corners of the square and the C atoms at its centre.

Explain why CH_4 is not square planar?

Answer.

According to VSEPR theory, if methane (CH_4) is square planar, the bond angle would be 90^o.

For a tetrahedral structure, bond angle is $109^o.28'$.

In square planar structure, repulsion between bond pairs would be more and thus stability is less.

Question 22.

Explain why BeH_2 molecule has a zero dipole moment although the be-H bonds are polar.

Answer.

BeH_2 is a linear molecule, bond angle is 180^o. Be-H bonds are polar due to difference in their electronegativity.

But bond polarities cancel out each other. Dipole moment of BeH_2 is zero.

Question 23.

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

Answer.

In NH_3 and NF_3, difference in electronegativity is nearly same but there is difference in dipole moment.

In NH_3, dipole moment of the three N-H bonds are in the same directions as the lone pair of electron.

In NF_3, dipole moment of three N-F bonds are in the direction opposite to that of the lone pair.

The resultant dipole moment in NH_3 is more than in NF_3.

Question 24.

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

Answer.

Hybridization is defined as the intermixing of a set of atomic orbitals of slightly different energies to give rise to new hybridized orbitals having equivalent energy and identical shapes.

Shape of sp hybridization:

1s –orbital hybridizes with 1p-orbitals to form 2 sp hybrid orbitals. Sp hybrid orbital is having linear shape.

Shape of sp^2 hybridization:

1s-orbital hybridizes with 2p-orbitals to form 3 sp^2 hybrid orbitals. Shape of sp^2 orbital is trigonal planar.

Shape of sp^3 hybrid orbital

1s-orbital hybridizes with 3 p orbitals to form 4 sp^3 hybrid orbitals. Shape of sp^3 orbital is tetrahedron.

Question 25.

Describe the change in hybridization (if any) of the Al atom in the following reaction.

$AlCl_3 + Cl^- \rightarrow AlCl_4^-$

Answer.

Electronic configuration of Al is $1s^2\ 2s^2\ 3p^6\ 3s^1\ 3px^1\ 3py^1$

Hybridisation will be sp^2.

In $AlCl_3$, there is empty 3pz orbital is also involved. So the hybridization in sp^3 and the shape is tetrahedral.

Question 26.

Is there any change in the hybridization of B and N atoms as a result of the following reaction?

$BF_3 + NH_3 \rightarrow F_3B.\ NH_3$

Answer.

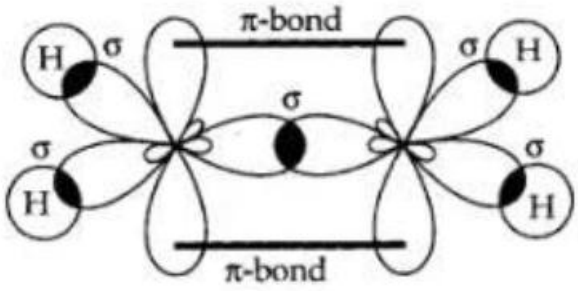
In BF_3, B atom is sp_2 hybridization. In NH_3, N is sp^3 hybridized. After combining with F, hybridization of B changes from sp^2 to sp^3.

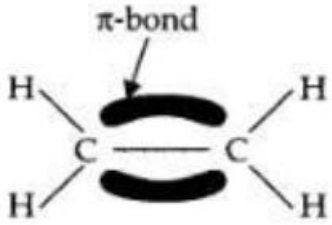
Question 27.

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.

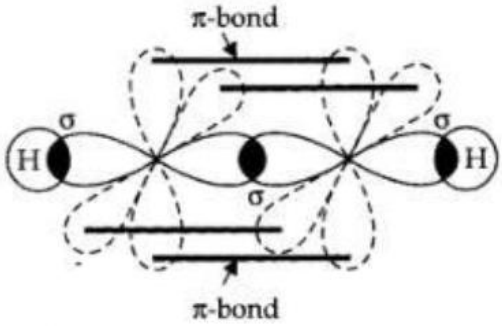
Answer.

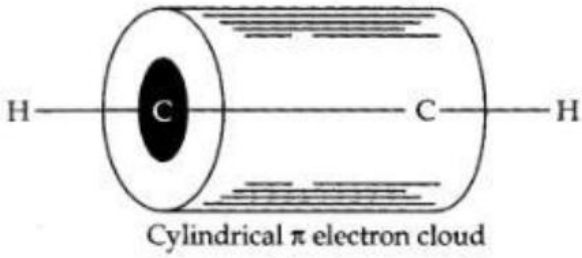
In case of ethene (C_2H_4)





In case of ethyne (C_2H_2)





Question 28:

What is the total number of sigma and pi bonds in the following molecules?

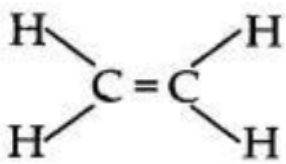
(a) C_2H_2 (b) C_2H_4

Answer.

(a) H – C = C – H

Sigma bond = 3, π bonds = 2

(b) Sigma bond = 5, π bonds = 1



Question 29.

Considering x-axis as the internuclear axis which out of the following will not form a sigma bond and why? (a) 1 s and 1s

(b) 1s and 2px

(c) 2py and 2py

(d) 1s and 2s

Answer.

Correct option is (c)

It will not form a s-bond because taking x-axis as the internuclear axis, lateral overlap between two 2py orbitals will occur forming a pie bond.

Question 30.

Which hybrid orbitals are used by carbons atoms in the following molecules?

(a) CH_3-CH_3

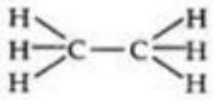
(b) CH_3-CH=CH_2

(c) CH_3-CH_2-OH

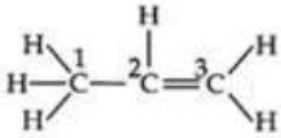
(d) CH_3-CHO

(e) CH_3COOH

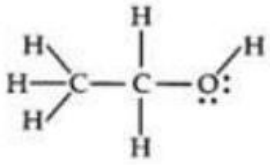
Answer.



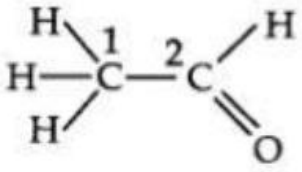
(b) C_1 has sp^3; C_2 and C_3 have sp^2 hybrid orbitals.



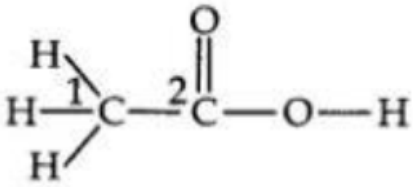
(c) Both C-atoms have sp^3 hybrid orbitals



- C_1 has sp^3 hybrid orbitals and C_2 has sp^2 hybrid orbitals.



- C_1 has sp^3 hybrid orbitals and C_2 has sp^2 hybrid orbitals.



Question 31.

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

Answer.

The electron pair involved in sharing of electrons between two atoms during covalent bonding is called bond pair.

The electron pair which is not involved in sharing is called lone pair of electrons.

Question 32.

Distinguish between a sigma and a pi bond.

Answer.

Pi BOND SIGMA BOND

It is comparatively weak bond. It is comparatively strong bond.

It is formed by lateral overlapping of orbitals.

It is formed by end to end overlapping of orbitals.

There is only one overlapping orbital is p-p.

The overlapping orbitals are s-s. s-p, p-p.

Rotation around pi bond is restricted. Rotation is possible around sigma bond.

Electron cloud is not symmetrical. Electron cloud is symmetrical.

Question 33.

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

Answer.

Let us consider the combination between atoms of hydrogen H_X and H_Y and e_X and e_Y their respective electrons.

As they come closer, two difference forces operate between nucleus and electron of the other and vice versa.

The nuclei of the atoms as well as their electrons repel each other. Energy is required to overcome the force of repulsion.

Here, the number of new attractive and repulsive forces are same.

When two H-atoms approach each other, overall potential energy of system decreases, finally stable molecule of hydrogen is formed.

Question 34.

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

Answer.

1. Joining of orbital orbitals must have approximately same energy.

2. Joining of atomic orbitals must have legitimate orientations to ensure the maximum overlap.

3. Overlapping must be in a large extent.

Question 35.

Use molecular orbital theory to explain why the Be2 molecule does not exist.

Answer.

Electronic configuration of Be = $1s^2\ 2s^2$

Molecular Orbital Electronic Configuration = $\sigma^2 1s\ \sigma^{*2} 1s\ \sigma^2 2s\ \sigma^{*2} 2s$

Bond order = ½ (4-4) = 0

Be_2 does not exist.

Question 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.

O_2 – Bond order = 2 (Paramagnetic)

O^+_2 – Bond order = 2.5 (Paramagnetic)

O^-_2 – Bond order = 1.5 (Paramagnetic)

O^{2-}_2 – Bond order = 1 (Diamagnetic)

Order of relative stability will be

$O_2^+ > O_2 > O_2^- > O_2^{2-}$

Question 37.

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

Answer.

Molecular orbitals are represented by the wave function.

Positive sign represents a molecular orbital indicates positive wave function.

Negative sign represents a molecular orbital indicates negative wave function.

Question 38.

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

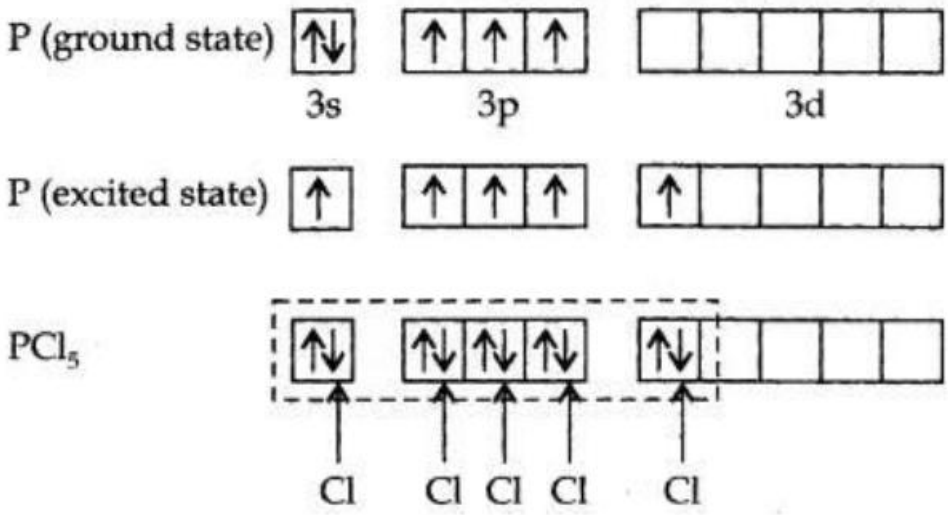
Answer.

Electronic configuration of phosphorous in ground and excited state is represented as

One s- three p and one d-orbital hybridize to yield five sets of sp^3d hybrid orbitals which are directed towards the five corners of a trigonal bipyramidal.

This is because axial bond pairs suffer more repulsive interaction from the equatorial bond pairs.

Axial bond are slightly longer and hence, weaker than equatorial bonds.



Question 39.

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

Answer.

Hydrogen bond is defined as an attractive force acting between hydrogen attached to an electronegative atom of one molecule and an electronegative atom of a different molecule. Hydrogen bond is stronger than the Van der Waals forces.

Question 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 is defined as 0.5 times the difference between the number of electrons present in bonding orbitals and number of electrons present in anti-bonding orbitals of a molecule.

Bond order = $0.5 (N_b - N_a)$

N_a is the number of anti-bonding electrons.

N_b is the number of bonding electrons.

o Molecular Orbital configuration of N_2 =

$$[\sigma 1s]^2[\sigma^* 1s]^2[\sigma 2s]^2[\sigma^* 2s]^2[\pi 2p_x]^2[\pi 2p_y]^2[\sigma 2p_z]^2$$

Bond Order (B.O.) = 0.5 [8 – 2] = 3

o Molecular Orbital configuration of O_2 =

$$[\sigma 1s]^2[\sigma^* 1s]^2[\sigma 2s]^2[\sigma^* 2s]^2[\sigma 2p_z]^2$$

B.O. = 0.5 [8 – 4] = 2

(iii) Molecular Orbital configuration of O_2^+ =

$$KK[\sigma 2s]^2[\sigma^* 2s]^2[\sigma 2p_z]^2[\pi 2p_x]^2[\pi 2p_y]^2[\pi^* 2p_x]^1$$

B.O. = 0.5 [8 – 3] = 2.5

(iv) Molecular orbital configuration of O_2^- =

$$KK[\sigma 2s]^2[\sigma^* 2s]^2[\sigma 2p_z]^2[\pi 2p_x]^2[\pi 2p_y]^2[\pi^* 2p_x]^2[\pi^* 2p_y]^1$$

B.O. = 0.5 [8 – 5] = 1.5

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