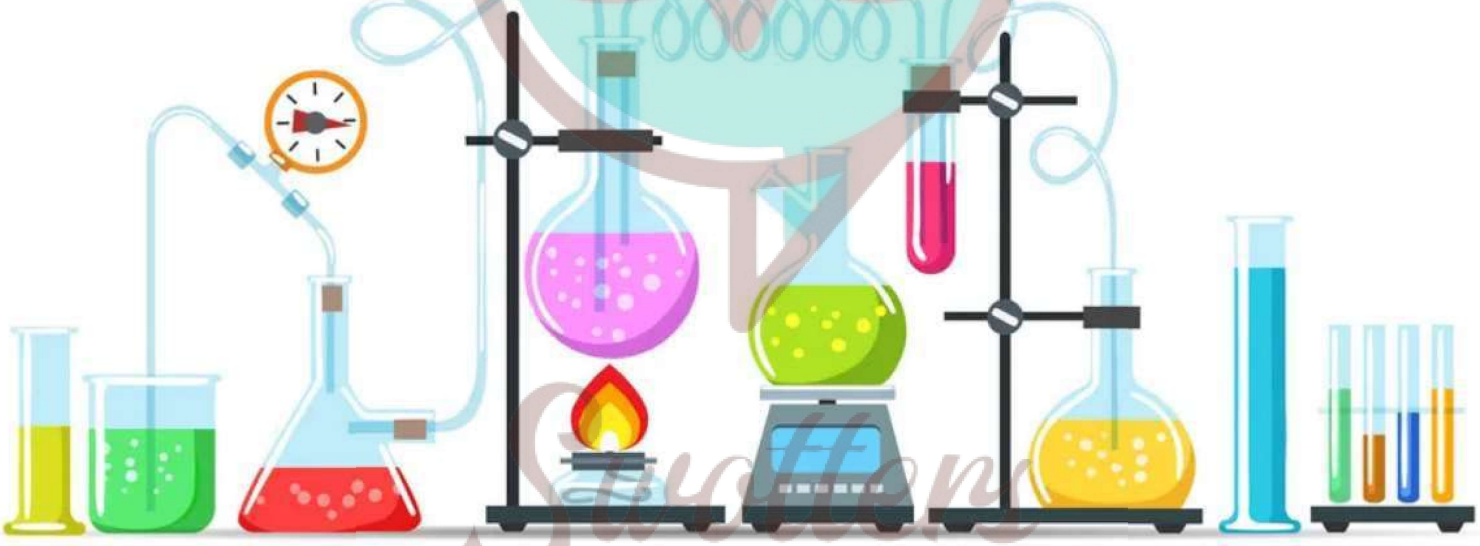
# CHEMISTRY



# Important Questions

## Multiple Choice questions-

Question 1. Based on VSEPR theory, the number of 90° F-Br-F angles in $BrF_5$ is

(a) 0

(b) 2

(c) 4

(d) 8

Question 2. The hybrid state of Sulphur in $SO_2$ molecule is:

(a) $sp^2$

(b) $sp^3$

(c) sp

(d) $sp^3d$

Question 3. In allene ($C_3H_4$), the type(s) of hybridization of the carbon atoms is (are)

(a) sp and $sp^3$

(b) sp and $sp^2$

(c) Only $sp^2$

(d) $sp^2$ and $sp^3$

Question 4. The state of hybridization of the central atom and the number of lone pairs over the central atom in POCl3 are

(a) sp, 0

(b) $sp^2$, 0

(c) $sp^3$, 0

(d) $dsp^2$, 1

Question 5. The charge/size ratio of a cation determines its polarizing power. Which one of the following sequences represents the increasing order of the polarizing order of the polarizing power of the cationic species, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Be^{2+}$?

(a) $Ca^{2+} < Mg^{2+} < Be^{+} < K^{+}$

(b) $Mg^{2+} < Be^{2+} < K^{+} < Ca^{2+}$

(c) $Be^{2+} < K+ < Ca^{2+} < Mg^{2+}$

(d) $K+ < Ca^{2+} < Mg^{2+} < Be^{2+}$

Question 6. Which one of the following does not have $sp^2$ hybridized carbon?

(a) Acetone

(b) Acetic acid

(c) Acetonitrile

(d) Acetamide

Question 7. Which one of the following is paramagnetic?

(a) NO+

(b) CO

(c) $O_2^-$

(d) CN

Question 8. Which of the following structures will have a bond angle of 120° around the central atom?

(a) Linear

(b) Tetrahedral

(c) Triangular

(d) Square planar

Question 9. An atom of an element A has three electrons in its outermost orbit and that of B has six electrons in its outermost orbit. The formula of the compound between these two will be

(a) $A_3 B_6$

(b) $A_2 B_3$

(c) $A_3 B_2$

(d) $A_2 B$

Question 10. In which of the following, the angle around the central atom is largest?

(a) $CS_2$

(b) $SF_4$

(c) $SO_2$

(d) $BBR_3$

Question 11. Based on lattice enthalpy and other considerations which one the following alkali metals chlorides is expected to have the higher melting point?

(a) RbCl

(b) KCl

(c) NaCl

(d) LiCl

Question 12. In which of the following substances, the intermolecular forces are hydrogen bonds?

(a) Hydrogen Chloride

(b) Hydrogen Sulphide

(c) Dry Ice

(d) Ice

Question 13. Which one of the following pairs of species have the same bond order?

(a) $CN^-$ and $NO^+$

(b) $CN^-$ and $CN^+$

(c) $O2^-$ and $CN^-$

(d) $NO^+$ and $CN^+$

Question 14. Dipole-induced dipole interactions are present in which of the following pairs?

(a) $H_2O$ and alcohol

(b) $Cl_2$ and $CCl_4$

(c) HCl and He atoms

(d) $SiF_4$ and He atoms

Question 15. In allene ($C_3H_4$), the type(s) of hybridisation of the carbon atoms is (are)

(a) Sp and $sp^3$

(b) Sp and $sp^2$

(c) Only $sp^2$

(d) $sp^2$ and $sp^3$

## Very Short:

1. What change in energy takes place when a molecule is formed from its atoms?
2. Arrange the following in order of increasing bond strengths.
3. Name the shapes of the following molecules: $CH_4$, $C_2H_2$, $CO_2$.
4. Arrange the following in order of increasing strengths of hydrogen bonding O, F, S, Cl, N
5. Identify the compound/compounds in the following in which S does not obey the Octet rule: $SO_2$, $SF_2$, $SF_4$, $SF_6$.
6. Name one compound each involving $sp^3$, $sp^2$, sp hybridization.

7. s-s, s-p, p-p form a bond, and only p-p form π bond.

## Short Questions:

1. Which out of $CH_3F$ and $CH_3Cl$ has a higher dipole moment and why?
2. Define the term chemical bond. What are its different types?
3. Why covalent bonds are called directional bonds whereas ionic bonds are called non-directional?
4. $AlF_3$ is a high melting solid whereas SiF4 is a gas. Explain why?
5. Using the VSEPR theory identifies the type of hybridization and draw the structure of $OF_2$ What are oxidation states of O and F?
6. Account for the following: The experimentally determined N-F bond length in $NF_3$ is greater than the sum of the single covalent radii of N and F.

## Long Questions:

1. State with reasons, which is more polar $CO_2$ or $N_2O$?
2. Out of peroxide ion ($O_2$) and superoxide ion ($O_2$) which has larger bond length and why?
3. Explain the formation of the following molecules according to the orbital concept, F2, HF, $O_2$, $H_2O$, $N_2$, $NH_3$ molecules.
4. What is a hydrogen bond, what are its causes, and give the conditions for hydrogen bonding? What is the strength of hydrogen bonding? Describe the two types of hydrogen bonding.

## Assertion Reason Questions:

1. In the following questions, a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

   **Assertion (A) :** Sodium chloride formed by the action of chlorine gas on sodium metal is a stable compound.

   **Reason (R) :** This is because sodium and chloride ions acquire octet in sodium chloride formation.

   (i) A and R both are correct, and R is the correct explanation of A.

   (ii) A and R both are correct, but R is not the correct explanation of A.

   (iii) A is true but R is false.

(iv) A and R both are false.

2. In the following questions, a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

   **Assertion (A) :** Though the central atom of both NH3 and $H_2O$ molecules are sp3 hybridised, yet H–N–H bond angle is greater than that of H–O–H.

   **Reason (R) :** This is because nitrogen atom has one lone pair and oxygen atom has two lone pairs.

   (i) A and R both are correct, and R is the correct explanation of A.

   (ii) A and R both are correct, but R is not the correct explanation of A.

   (iii) A is true but R is false.

   (iv) A and R both are false.

## Case Study Based Question:

1. Read the passage given below and answer the following questions:

   Chemical bonding, involve interactions that account for the association of atoms into molecules, ions, crystals, and other stable species that make up the familiar substances of the everyday world. When atoms approach one another, their nuclei and electrons interact and tend to distribute themselves in space in such a way that the total energy is lower than it would be in any alternative arrangement. If the total energy of a group of atoms is lower than the sum of the energies of the component atoms, then bond together and the energy lowering is the bonding energy.

   The ideas that helped to establish the nature of chemical bonding came to fruition during the early 20th century, after the electron had been discovered and quantum mechanics had provided a language for the description of the behaviour of electrons in atoms. However, even though chemists need quantum mechanics to attain a detailed quantitative understanding of bond formation, much of their pragmatic understanding of bonds is expressed in simple intuitive models. These models treat bonds as primarily of two kinds- namely, ionic and covalent.

   The type of bond that is most likely to occur between two atoms can be predicted on the basis of the location of the elements in the periodic table, and to some extent the properties of the substances so formed can be related to the type of bonding.

   A key concept in a discussion of chemical bonding is that of the molecule. Molecules are the smallest unit of compounds that can exist. One feature of molecules that can be predicted with reasonable success is their shape. Molecular shapes are of considerable

importance for understanding the reactions that compounds can undergo, and so the link between chemical bonding and chemical reactivity is discussed briefly in this article.

(1) According to molecular orbital theory, which of the following will not be available molecule?

(a) $He_2^{2+}$

(b) $He_2^{+}$

(c) $H_2^{-}$

(d) ) $H_2^{2-}$

(2) Which of the following compounds of chlorine contains both ionic as well as covalent bonds?

(a) NaCl

(b) $NaClO_4$

(c) $PCl_3$

(d) $POCl_3$

(3) In $PO_4^{3-}$, the formal charge on each oxygen atom and P — O bond order respectively are:

(a) - 0.75, 1.25

(b) - 0.75, 1.0

(c) - 0.75, 0.6

(d) - 3, 1.25

(4) On the basis of valence bond theory, the formation of H2 molecules from two H-atoms involves.

(a) The overlap of vacant is orbitals of two H-atom

(b) The lowering of potential energy of the system as the two H-atom come near to each other

(c) The maximum energy of the system at the equilibrium internuclear distance

(d) Stabilisation of the molecule; when the nuclei are brought still closer to each other from the equilibrium inter-nuclear distance.

2. Read the passage given below and answer the following questions:

In order to explain the shapes of molecules adequately, Sidgwick and Powell in 1940 proposed a theory based on the repulsive interaction of the electron pairs in the valence shell of the atoms.

Nyholm and Gillespie (1950) further developed and redefined the concept. The mai postulates of this theory are as follows:

The number of valence shell electron pairs (bonded or non-bonded) present around the central atom decides the shape of the molecules. The shared electron pairs are called bond pairs and unshared or non-bonding electrons are called lone pairs. Electron pairs of valence shell repel one another because their electron clouds are negatively charged.

These electron pairs arrange themselves in such a way so that there is minimum repulsion and maximum distance in between them. The valence shell is considered as a sphere in which the electron pairs are localised on the spherical surface at maximum distance from one another.

A lone pair occupies more space than a bonding pair, since it lies closer to the central atom. This means that the repulsion between the different electron pairs follow the order:

Lone pair-lone pair > lone pair-bond pair > bond pair-bond pair

$$(lp - lp) > (lp - bp) > (bp - bp)$$

(1) Which of the following molecule has net dipole moment zero?

(a) HF

(b) $H_2O$

(c) $BF_3$

(d) $CHCl_3$

(2) Which one of the following species contains three bond pairs and one lone pair around the central atom?

(a) $H_2O$

(b) $BF_3$

(c) $NH_2^-$

(d) $PCl_3$

(3) Why do the deviations occur from idealised shape of $H_2O$ and $NH_3$ molecules?

(a) Same hybridisation

(b) Different hybridisation

(c) Repulsive effect

(d) None of the above

(4) The species, having bond angles of 120° is:

(a) $PH_3$

(b) $ClF_3$

(c) $NCl_3$

(d) $BCl_3$

# Answer Key:

## MCQ

1. (a) 0
2. (a) $Sp^2$
3. (b) Sp and $sp^2$
4. (c) $sp^3$, 0
5. (d) $K^+ < Ca^{2+} < Mg^{2+} < Be^{2+}$
6. (c) Acetonitrile
7. (c) $O_2^-$
8. (c) Triangular
9. (b) $A_2 B_3$
10. (b) $SF_4$
11. (c) NaCl
12. (d) Ice
13. (d) $NO^+$ and $CN^+$
14. (c) HCl and He atoms
15. (b) sp and $sp^2$

## Very Short Answer:

1. There is a fall in energy.
2. $F_2 < Cl_2 < O_2 < N_2$
3. $CH_4$: Tetrahedral; $C_2H_2$: Cylindrical; $CO_2$: linear

4. Cl < S < N < O <F.

5. $SF_4$, $SF_6$.

6. $sp^3$: $CH_4$: $sp^2$: $C_2H_4$: sp: $C_2H_2$

7. s-s, s-p, p-p form a bond, and only p-p form π bond.

## Short Answer:

**Ans: 1.** The dipole moment of $CH_3Cl$ is greater than that of $CH_3F$. The C-F bond length in $CH_3F$ is smaller than the C-Cl bond length in $CH_3Cl$. The charge separation in the C-F bond is more than in the Cl-C bond- fluoride being more electronegative than chlorine. The bond length has a greater effect than the charge separation. Hence the dipole moment of $CH_3C1$ is greater than that of $CH_3F$.

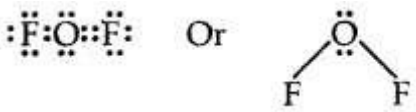
**Ans: 2.** The attractive forces which hold the constituent atoms in molecules or species in lattices etc. are called a chemical bond.
They are of the following types:

1. Electrovalent or ionic bond
2. Covalent bond
3. Coordinate or dative bond
4. metallic bond
5. hydrogen bond
6. van der Waals forces.

**Ans: 3.** A covalent bond is formed by the overlap of half-filled atomic orbitals which have definite directions. Hence covalent bond is directional. In ionic compounds, each ion is surrounded by a number of oppositely charged ions and hence there is no definite direction.

**Ans: 4.** $AlF_3$ is an ionic solid due to the large difference in electronegativities of Al and F whereas $SiF_4$ is a covalent compound and hence there are only weak van der Waal's forces among its molecules.

**Ans: 5.** The electron dot structure of $OF_2$ is



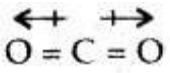

Thus, the central atom (O-atom) has 4 pairs of electrons (2 bond pairs and 2 lone pairs). Hence oxygen in $OF_2$ is $sp^3$ hybridized and the molecule is V-shaped oxidation state of F = – 1,

oxidation state of O = + 2.

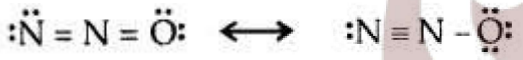
**Ans: 6**. This is because both N and F are small and hence have high-electron density. So they repel the bond pairs thereby making the N-F bond length larger.

## Long Answer:

**Ans: 1.** $N_2O$ is more polar than $CO_2$ which is a linear molecule and thus symmetrical. Its net dipole moment is zero.



$N_2O$ is linear but unsymmetrical. It is a resonance hybrid of the following canonical structures:

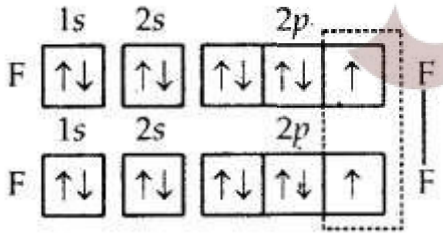


It has a net dipole moment of 0.116 D.

**Ans: 2.** The bond order of $O_2^-$ is 1.5 while that of $O_2^{2-}$ is 1.0.

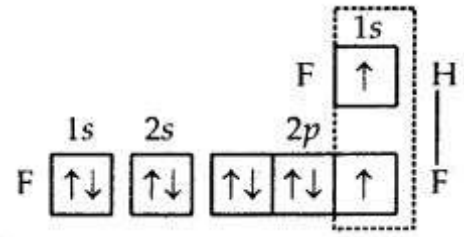
The lesser the bond order, the greater is the bond length as the bond order is inversely proportional to bond length. (Hence $O_2^{2-}$ has a larger bond length than $O_2^{2-}$.

**Ans: 3**. 1. Formation of F2 molecule. Atomic number (Z) of fluorine is 9 and its orbital electronic configuration is $1s^2\ 2s^2\ 2p^2x,\ 2p^2y,\ 2p^1z$. Thus, a fluorine atom has one half-filled atomic orbital. Therefore, two atoms of fluorine combine to form the fluorine molecule as a result of the combination for their half-filled atomic orbitals shown in Fig. The two atoms get linked by a single covalent bond

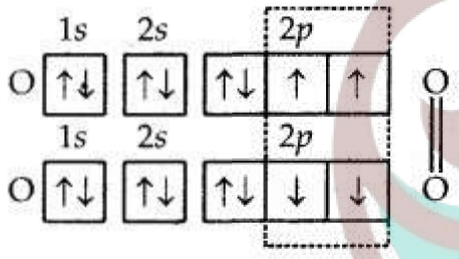



Formation of $F_2$ molecule

2. Formation of HF molecule. Fluorine atom, as stated above, has one half-filled atomic orbital. Hydrogen atom (Z = 1) has only one electron in Is orbital. Thus, the hydrogen fluoride (HF) molecule. is formed as a result of the combination (or overlap) of the half-filled orbitals belonging to the participating atoms.



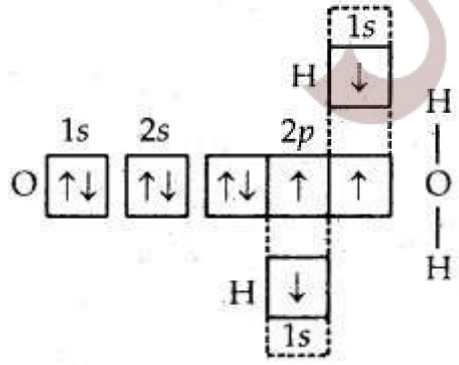

3. Formation of $O_2$ molecules. The atomic number (Z) of oxygen is 8 and its orbital electronic configuration is $1s^2\ 2s^2\ 2p^2x\ 2p^1x\ 2p^1z$. This means that an oxygen atom has two half-filled orbitals with one electron each. Two such atoms will combine to form a molecule of oxygen as a result of the overlap of the half-filled orbitals with opposite spins of electrons.




Formation of $O_2$ molecule

Thus, the two atoms of oxygen are bonded to each other by two covalent bonds or double bonds (O = O).

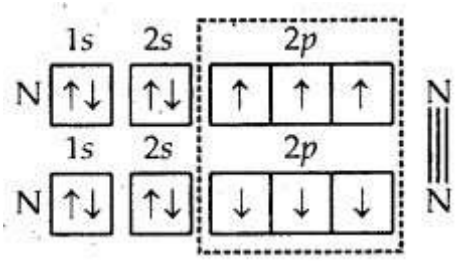
4. Formation of $H_2O$ molecule. In the formation of the $H_2O$ molecule, the two half-filled orbitals of the oxygen atom combine with the half-filled orbitals (1s) of the hydrogen atoms. Thus, the oxygen atom gets linked to the two hydrogen atoms by single covalent bonds as shown in




Formation of $H_2O$ molecule

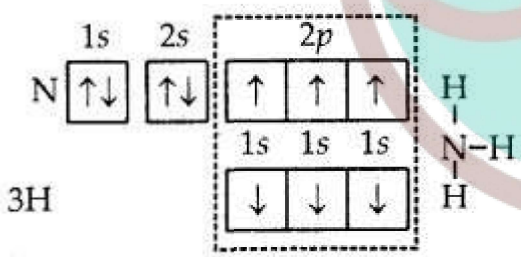
5. Formation of $N_2$ molecule. The atomic number of nitrogen is 7 and its orbital electronic configuration is $1s^2\ 2s^2\ 2p^1x\ 2p^1y\ 2p^1\ z$. This shows that the nitrogen atom has three

half-filled atomic orbitals. Two such atoms combine as a result of the overlap of the three half-filled orbitals and a triple bond gets formed (N = N)



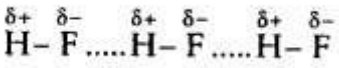

Formation of $N_2$ molecule

6. Formation of $NH_3$ molecule. In the formation of ammonia ($NH_3$) molecule, three half-filled orbitals present in the valence shell of nitrogen atom combine with 1s orbital of three hydrogen atoms with one electron each. As a result, the nitrogen atom completes its octet and a molecule of $NH_3$ is formed in which the nitrogen atom is linked to three hydrogen atoms by covalent bonds.




Formation of $NH_3$ molecule

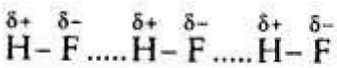
**Ans: 4.** When hydrogen is connected to small highly electronegative atoms such as F, O, and N in such cases hydrogen forms an electrostatic weak bond with an electronegative atom of the second molecule, this type of bond binds the hydrogen atom of one molecule and the electronegative atom of the 2nd molecule is called as hydrogen bond. It is a weak bond and it is denoted by dotted lines e.g., in HF, hydrogen forms a weak bond with the electronegative F atom of the 2nd molecule neighboring HF.




So it means hydrogen is acting as a bridge between two molecules by one covalent bond and the other by a hydrogen bond. Due to this hydrogen bonding, HF will not exist as a single molecule but it will exist as an associated molecule (HF)n. So hydrogen bond may be defined as a weak electrostatic bond that binds the hydrogen atom of one molecule and electronegative bond atoms (F, O, N) of the second neighboring molecule.

Cause of hydrogen bonding: When a hydrogen atom is bonded to an electronegative atom (say F, O, N) through a covalent bond, due to electronegativity difference, the electronegative atom attracts the shared pair of electrons towards its side with a great force as a result of which the shared pair of electrons will be displaced toward electronegative atom and away from a hydrogen atom.

Due to which hydrogen atom will acquire a slightly negative charge and if another molecule is brought nearer to it in such a way that electronegative atom of the second molecule faces hydrogen atom of the 1st molecule, due to opposite charges present on the atoms, an electrostatic bond will be formed between the hydrogen atom of one molecule and electronegative atom of 2nd molecule and this is called as hydrogen bond.




Conditions for hydrogen bonding. The following two necessary conditions for hydrogen bonding are:

1. Hydrogen atom should be connected to highly electronegative atom say F, O, or N.
2. The electronegative atom of which the hydrogen atom is connected should be the same in size.

The smaller the size of the electronegative atom greater will be the attraction of that atom for shared pair of electrons and hence that pair will be displaced more nearer to that atom and hence that atom will develop greater negative charge and the hydrogen atom will develop a greater positive charge and hence hydrogen atom of this molecule will easily attract negative atom of the Ian molecule and hence a hydrogen bond will be easily formed.

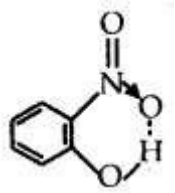
As both these conditions are satisfied only by F, O, N atoms so only three atoms show hydrogen bond.

Strength of Hydrogen Bond: A hydrogen bond is a very weak bond. It is weaker than an ionic or a covalent bond. Its strength ranges from 13 kJ mol-1 to 42 kJ $mol^{-1}$. The strength of the hydrogen bond for some of the molecules is the order H-F H (40 kJ mol-1) > O-H…… O (28 kJ $mol^{-1}$) > H-N…… H (13 kJ $mol^{-1}$) whereas the strength of a covalent bond is quite high. For example, the bond strength of the H-H bond in $H_2$ is 433 kJ $mol^{-1}$

Types of H-bonding

There are two types of hydrogen-bonds

1. Intermolecular hydrogen bond. It is formed between two different molecules of the same or different compounds. For example H-bond in case of HF, alcohol, or water.
2. Intramolecular Hydrogen bond. It is formed when a hydrogen atom is in between the two highly electronegative (F, O, N) atoms present within the same molecule. For example, in o-nitrophenol, hydrogen is in between the two oxygen atoms.



## Assertion Reason Answer:

1. (i) A and R both are correct, and R is the correct explanation of A.
2. (i) A and R both are correct, and R is the correct explanation of A.

## Case Study Answer:

**1. Answer:**

(1) (d) ) $H_2^{2-}$

(2) (b)$NaClO_4$

(3) (a) - 0.75, 1.25

(4) (b) The lowering of potential energy of the system as the two H-atom come near to each other

**2. Answer:**

(1) (c) $BF_3$

(2) (d) $PCl_3$

(3) (c) Repulsive effect

(4) (d) $BCl_3$