CHAPTER > 04

Chemical Bonding and Molecular Structure

KEY NOTES

Chemical Bond

- The attractive force which holds various constituents (atoms, ions, etc.) together in different chemical species is called a chemical bond.
- Factors due to which atoms interact with each other are :
  (a) Forces of attraction overpowers the forces of repulsion due to decrease in energy.
  (b) Tendency to achieve nearest noble gas configuration.

Kossel-Lewis Approach to Chemical Bonding (Octet Rule)

According to this approach, the atoms of different elements take part in chemical combination in order to complete their octet (to have eight electrons in the outermost valence shell) or duplet (to have two valence electrons) in some cases such as H, Li, Be etc., or to attain the nearest noble gas configuration. This is known as octet rule.

The group valence of the elements is generally either equal to the number of dots in Lewis symbols or 8 minus the number of dots or valence electrons.

Limitations of octet rule are as follows :

- In accordance to this rule, the shape of the molecule cannot be predicted.
- The relative stability of molecule cannot be known by this rule.

Exceptions to Octet Rule

The octet rule is violated in a significant number of cases. These are :

- Electron deficient compounds : $BeCl_2$, BF_3, $AlCl_3$ etc.
- Hypervalent compounds : PCl_5, SF_6, IF_7, H_2SO_4 etc.
- Compounds of noble gases : XeF_2, XeF_6, XeF_4, KrF_2 etc.
- Odd electron molecules : NO, NO_2, O_2^-, O_3 etc.
- Others like : H_2^+, He_2^+, O_2, NO, NO_2, ClO_2 are some of the examples of stable molecules having odd electron bonds (bonds formed by sharing of usually one or three electrons).

Types of Chemical Bonds

The three types of bonds or linkages which hold the atoms together in a molecule are as follows :

- **Covalent bond** It is formed by mutual sharing of electrons between two atoms so as to attain nearest noble gas configuration.
- **Electrovalent bond** It is formed as a result of the electrostatic attraction between the positive and negative ions.
- **Coordinate bond** It is a type of covalent bond in which shared pair of electrons come from one atom only.

Lewis Dot Structure

The Lewis dot structures provide a picture of bonding in molecules and ions in terms of the shared pair of electrons and the octet rule.

Lewis dot structures can be written by adopting the following steps :

- The total number of electrons required for writing the structures are obtained by adding the valence electrons of the combining atoms.
- For anions each negative charge would mean addition of one electron. Similarly, for cations, each positive charge would result in substraction of one electron from total number of valence electrons.
- In general, the least electronegative atom occupies the central position in the molecule/ion.
- The basic requirement is that each bonded atom gets an octet of electrons.

Formal Charge

Formal charge on an atom in a molecule/ion

$$= \begin{bmatrix} \text{total number of valence} \\ \text{electron in the free atom} \end{bmatrix} - \begin{bmatrix} \text{total number of} \\ \text{non-bonding (lone pair)} \\ \text{electrons} \end{bmatrix} - \frac{1}{2} \begin{bmatrix} \text{total number of bonding} \\ \text{(shared) electrons} \end{bmatrix}$$

Ionic or Electrovalent Bond

It is formed as a result of electrostatic force of attraction between an electropositive atom and an electronegative atom due to complete transfer of electrons.

To form an ionic bond, the electronegativity difference between two atoms should be ≥1.9.

So, ionic bonds will be formed more easily between elements with comparatively low ionisation enthalpies and elements with comparatively high negative value of electron gain enthalpy.

Some important characteristics of ionic compounds are as follows :

- They are generally crystalline in nature. The constituent ions are arranged in a regular way in their crystal lattices.
- They possess high melting and boiling points as they are held by strong electrostatic forces of attraction.
- They are hard and brittle in nature.
- In solid state, they do not conduct electricity. In molten state or in solution, they are good conductors of electricity due to the presence of free ions in aqueous state.
- They are soluble in polar solvent and insoluble in non-polar solvent.
- The electrovalent bonds are non-rigid and non-directional. Thus, these compounds do not show configurational isomerism, i.e. geometrical and optical isomerism.
- Electrovalent compounds show isomorphism (compounds with similar number of valence electrons, i.e. similar configuration of their cation and anion, e.g. NaF and MgO, both have same number of valence electrons in Na^+, F^-, Mg^{2+} and O^{2-}).
- They show variable electrovalency. They differ in number of electrons used by an atom during the formation of bond. This occurs due to unstability of core.

Lattice Enthalpy

The lattice enthalpy of an ionic solid is defined as the energy required to completely separate one mole of a solid ionic compound into gaseous constituent ions.

Bond Parameters

The various characteristics shown by a bond are called parameters. These are as follows :

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

  $$\text{Bond length} \propto \text{size of atom} \propto \frac{1}{\text{bond multiplicity}}$$

- **Covalent radius** is measured as the radius of an atom's core which is in contact with the core of an adjacent atom in a bonded situation.
- **The van der Waals' radius** represents the overall size of the atom which includes its valence shell in a non-bonded situation.
- **Bond angle** is defined as the angle between the orbitals containing bonding electron pairs around the central atom in a molecule or ion. It can be determined by spectroscopic methods.
- **Bond enthalpy** is defined as the amount of energy required to break one mole of bonds of a particular type between two atoms in a gaseous state. Its unit is kJ mol^{-1}

  $$\text{Bond enthalpy} \propto \frac{1}{\text{size of an atom}} \propto \text{bond multiplicity}$$

- **Mean or average bond enthalpy** It is obtained by dividing total bond dissociation enthalpy by the number of bonds broken.
- **Bond order** is given by the number of bonds between the two atoms in a molecule.

  $$\text{Bond order} \propto \frac{1}{\text{bond length}} \propto \text{bond enthalpy}$$

  Isoelctronic molecules and ions have identical bond order.

  With increase in bond order, bond enthalpy increases and bond length decreases.

Resonance Structure

The phenomenon of resonance was put forward by **Heisenberg**. According to this concept, whenever, a single Lewis structure cannot describe all the properties of a molecule, a number of structures with similar energy, positions of nuclei, bonding and non-bonding pairs of electrons are written to describe all the properties. The actual structure is in between of all these contributing structures and is known as the **resonance hybrid** and the different individual structures are termed as **resonating structures** or canonical forms. This phenomenon is called **resonance**.

Polarity of Bonds

- The polarity of covalent bonds results in the formation of electric dipole possessing a permanent **dipole moment** (μ).
- Dipole moment is a vector quantity.
  Dipole moment (μ) = charge (e) × bond length (d)

  Unit of dipole moment is Debye (D).

  $1D = 3.33564 \times 10^{-30}$ Cm (Coulomb metre).

- Just as all the covalent bonds have some partial ionic character, the ionic bonds also have some partial covalent character. The partial covalent character of ionic bonds was discussed by Fajan's in terms of rules called **Fajan's rule**.

  Percentage of covalent character in ionic bond ∝ charge on ion ∝ size of anion

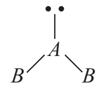
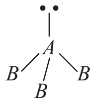
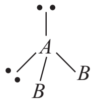
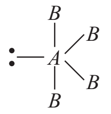
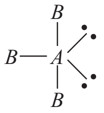
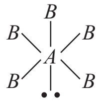
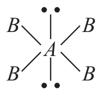
  $$\propto \frac{1}{\text{size of cation}} \text{ [Fajan's rule].}$$

The Valence Shell Electron Pair Repulsion (VSEPR) Theory

- The main postulates of VSEPR theory are :
  - The number of valence shell electron pairs present around the central atom decides the shape of the molecules.
  - Electron pairs of valence shell repel one another.
  - These electron pairs arrange themselves such 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 multiple bond is treated as, if it is a single electron pair and the two or three electron pairs of a multiple bond are treated as a single super pair.
  - If a molecule has several resonating structures, the VSEPR model is applicable to any such structure.
  - The repulsion between the different electron pairs follow the order :

    Lone pair-lone pair > lone pair-bond pair
    > bond pair-bond pair
- The geometry of molecules in which central atom has no lone pair of electrons are as follows :
  - Linear (e.g. $BeCl_2$) = electron pairs.
  - Trigonal planar (e.g. BF_3) = 3 electron pairs.
  - Tetrahedral (e.g. CH_4, NH_4^+) = 4 electron pairs.
  - Trigonal bipyramidal (e.g. PCl_5) = 5 electron pairs.
  - Octahedral (e.g. SF_6) = 6 electron pairs.

Shape of Some Molecules or Ions with Central Ions having One or More Lone Pairs of e^- on the Basis of VSEPR Theory

Molecule type	No. of bonding pair	No. of lone pair	Arrangement of electron pairs and geometry of molecule	Shape	Examples
AB_2E	2	1	 Trigonal planar	Bent	SO_2, O_3, $SnCl_2$, $PbCl_2$, NO_2^+
AB_3E	3	1	 Tetrahedral	Trigonal pyramidal	PH_3, $BiCl_3$, NH_3, PCl_3, $AsCl_3$, XeO_3, ClO_3^-, SO_3^{2-}, $P(CH_3)_3$
AB_2E_2	2	2	 Tetrahedral	Bent	H_2S, $\bar{N}H_2$ H_2O, OF_2, Cl_2O $Cl_2\dot{O}$, ClO_2^-, $Cl\dot{O}F$, SCl_2
AB_4E	4	1	 Trigonal bipyramidal	*see-saw*	SF_4, SCl_4, $TeCl_4$, XeO_2F_2
AB_3E_2	3	2	 Trigonal bipyramidal	T-shape	ClF_3, IF_3, BrF_3, $XeOF_2$
AB_5E	5	1	 Octahedral	Square pyramidal	IF_5, BrF_5, SbF_5^{2-}
AB_4E_2	4	2	 Octahedral	Square planar	XeF_4, ICl_4^-

Valence Bond Theory

- Valence bond theory (VBT) was introduced by **Heitler** and **London** in 1927 and further improved by **Pauling** and **Slater** in 1931. It is based on the knowledge of atomic orbitals, electronic configuration of elements, the criteria of overlapping of atomic orbitals and the hybridisation of atomic orbitals and the principles of variation and superposition.
- **Orbital overlap concept** In the formation of hydrogen molecule there is a minimum energy state when two hydrogen atoms are so near that their atomic orbitals undergo partial interpenetration. This partial merging of atomic orbitals is called overlapping of atomic orbitals which results in pairing of electrons.
- The extent of overlap decides the strength of a covalent bond. In general, greater the overlap, stronger is the bond formed between two atoms.
- The VBT explains the formation and directional properties of bonds in polyatomic molecules in terms of overlap and hybridisation of atomic orbitals.
- When orbitals of two atoms overlap to form bond, their overlap may be positive, negative or zero. It depends upon the sign and direction of orientation of amplitude of orbital wave function for the wave functions of atomic orbitals.

Sigma and Pi Bond

- **Sigma (σ) bond** is formed by the end to end (head on) overlap of bonding orbitals along the internuclear axis. This is called as head on overlap or axis overlap, e.g. s-s, s-p, p-p overlapping.
- **Pi (π) bond** is formed when the atomic orbitals overlap in such a way that their axis remain parallel to each other and perpendicular to the internuclear axis, e.g. p_y-p_y and p_z-p_z orbitals.
- σ-bonds are always stronger than π-bonds because extent of overlapping occurs to a smaller extent in π-bond.

Hybridisation

The concept of hybridisation was put forward by **Pauling**. He suggested that the atomic orbitals mix together to generate a new set of equivalent orbitals, called the **hybrid orbitals** or **hybridised orbitals**. These orbitals are used in bond formation. The phenomenon is called hybridisation.

Salient Features of Hybridisation

The main features of hybridisation are as follows :

- The number of hybrid orbitals generated is equal to the number of atomic orbitals that hybridised.
- The hybridised orbitals are always equivalent in energy and shape.
- The hybrid orbitals are more effective in forming stable bonds than the pure atomic orbitals.
- These hybrid orbitals arrange themselves in space in such a direction so that there is minimum repulsion between electron pairs.

The geometry of a molecule can be determined by its hybridisation which is given in the table.

Number of lone pair	Hybridisation	Geometry	Examples
0	sp	Linear	$BeCl_2$, C_2H_2, BeF_2, CO_2, CS_2
0	sp^2	Trigonal planar	BF_3, $AlCl_3$, BCl_3, C_2H_4, NO_3^-, CO_3^{2-}
1	sp^2	Angular or V-shape	SO_2, O_3
0	sp^3	Tetrahedral	CH_4, ClO_4^-, SiF_4, NH_4^+, SO_4^{2-}
1	sp^3	Pyramidal	NH_3, XeO_3
2	sp^3	V-shape	H_2O, Cl_2O
3	sp^3d	Linear	XeF_2, I_3^-
0	sp^3d	Trigonal bipyramidal	PCl_5, PF_5, $[Fe(CO)_5]$
1	sp^3d	Distorted structure	XeO_2F_2
2	sp^3d	T-shape	ClF_3
0	sp^3d^2	Octahedral	SF_6, UF_6, TeF_6
1	sp^3d^2	Square pyramidal	IF_5
2	sp^3d^2	Square planar	XeF_4
0	sp^3d^3	Pentagonal bipyramidal	IF_7

Note $d_{x^2-y^2}$, *orbital is involved in* d_{sp^2}, d_{z^2} *in* sp^3d, $d_{x^2-y^2}$ *and* d_{z^2} *in* sp^3d^2 *or* d^2sp^3 *and* d_{xy}, d_{yz}, d_{xz} *in* sp^3d^3 *hybridisation.*

Molecular Orbital Theory

- The main features of molecular orbital theory (MOT) are :
  - The electrons in a molecule occupy various molecular orbitals.
  - Molecular orbitals are obtained when atomic orbitals of comparable energies and proper symmetry combine together.
  - An atomic orbital is called monocentric while a molecular orbital is termed as polycentric.
  - When two atomic orbitals combine, two types of molecular orbitals are obtained which are **bonding molecular orbital** (obtained by adding wave functions of atomic orbitals) and **antibonding molecular orbital** (obtained by subtracting wave functions of atomic orbitals).
  - The bonding molecular orbital have greater stability than the corresponding antibonding molecular orbital.
  - A molecular orbital shows the electron probability distribution around a group of nuclei in a molecule.
  - The molecular orbitals are filled in accordance with the Aufbau principle obeying the Pauli's exclusion principle and the Hund's rule.

- The linear combination of atomic orbitals (LCAO) to form molecular orbitals is possible only when the following conditions are satisfied :
  - The combining atomic orbitals must have the same or nearly the same energy.
  - The combining atomic orbitals must have the same symmetry about the molecular axis.
  - The combining atomic orbitals must overlap to the maximum extent.
- In case of diatomic molecules, molecular orbitals are designated as σ (sigma), π (pi), δ (delta) etc. If the molecular orbital is symmetrical about the internuclear axis (or bond axis) it is called **σ-molecular orbital** and if it is not symmetrical about the internuclear axis, it is called a π-molecular orbital.
- If internuclear axis is taken to be in the z direction,it can be seen that a linear combination of $2p_z$ orbital of two atoms also produces two sigma molecular orbitals designated as $\sigma 2p_z$ and $\sigma 2p_z^*$.
- The energy order of molecular orbitals for O_2 and F_2 is as follows :

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

- For B_2, C_2, N_2 (i.e. upto total = 14 electrons),

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

- **Stability of molecules** If the number of electrons occupying bonding orbitals are represented by N_b and the number of electrons occupying the antibonding orbitals by N_a then,
  - the molecule is stable, if $N_b > N_a$ and
  - the molecule is unstable, if $N_b < N_a$.
- **Bond order** $= \dfrac{N_b - N_a}{2}$ where, N_b = number of bonding orbital electrons and N_a = number of antibonding orbital electrons.
- **Nature of the bond** If bond order is 1, 2 or 3 it shows the presence of single, double or triple bonds, respectively.
- Bond length decreases as the bond order increases.

  Magnetic nature Molecules/ions having no unpaired electrons gives rise to diamagnetic character. e.g. hydrogen molecule.

  Molecules/ions having unpaired electrons give rise to paramagnetic character. e.g. oxygen molecule.

Hydrogen Bonding

- The attractive force which binds hydrogen atom of one molecule with the highly electronegative atom (F, O or N) of the same or another molecule is called **hydrogen bonding**.
- The magnitude of H-bonding depends on the physical state of the compound.
- **Intermolecular hydrogen bond** exists between two different molecules of the same or different compounds.
- **Intramolecular hydrogen bond** exists when hydrogen atom is in between the two highly electronegative (F, O, N) atoms present with in the same molecule.

Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ *Chemical Bonding : Covalent and Ionic Bonds*

1 The evolution of various theories of valence and the interpretation of the nature of chemical bonds have closely been related to the developments in the understanding of
(a) structure of atom
(b) electronic configuration of elements
(c) periodic table
(d) All of the above

2 Kossel and Lewis approach was based on the
(a) reactivity of elements
(b) inertness of noble gases
(c) reactivity of metals
(d) inertness of non-metals

3 Lewis pictured the atom in terms of kernel and the outermost shell that could accommodate a maximum of
(a) 6 electrons
(b) 10 electrons
(c) 8 electrons
(d) 2 electrons

4 Lewis postulated that atoms achieve the stable octet when they are linked by
(a) ionic bonds
(b) covalent bonds
(c) coordinate bonds
(d) chemical bonds

5 In the formation of a molecule, only the outer shell electrons take part in chemical combination and are known as

(a) valence electrons

(b) inner electrons

(c) inert electrons

(d) reactive electrons

6 The group valence of the element is generally equal to the

(a) number of dots in Lewis symbol

(b) eight minus the number of dots

(c) valence electrons

(d) All of the above

7 Which postulation provide the basis for the modern concepts regarding ion formation by electron transfer and the formation of ionic crystalline compounds?

(a) Kossel's postulations

(b) Langmuir's postulations

(c) Newton's postulations

(d) Lewis' postulations

8 Atoms can combine either by transfer of valence electrons from one atom to another or by sharing of valence electrons in order to have an octet in their valence shells. This is called

(a) octet rule

(b) duplet rule

(c) quartet rule

(d) None of these

9 Which theory can be best understood by considering the formation of the chlorine molecule, Cl_2?

(a) Lewis theory

(b) Langmuir theory

(c) Lewis-Langmuir theory

(d) Kossel-Lewis theory

10 Consider the following atoms with their electronic configuration :

$L\,(1s^2\,2s^2\,2p^1)$; $M\,(1s^2\,2s^2\,2p^5)$; $Q\,(1s^2\,2s^2\,2p^6\,3s^1)$; $R\,(1s^2\,2s^2\,2p^2)$

The element that would readily form a diatomic molecule is

(a) Q

(b) M

(c) R

(d) L

11 Consider two elements P and Q. If P has 2 and Q has 6 electrons in their outermost shell, then formula of compound is

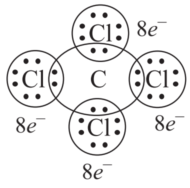
(a) PQ

(b) P_2Q

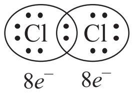
(c) P_2Q_3

(d) PQ_2

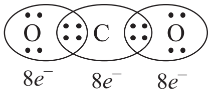
12 Which of the following structure are correct?



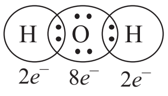
I



II



III



IV

Choose the correct option.

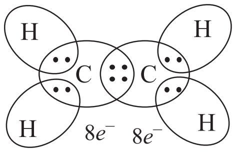
(a) I, II and IV

(b) II, III and IV

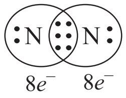
(c) II and III

(d) I, II, III and IV

13 Which of the following structures possesses triple bonds?



I



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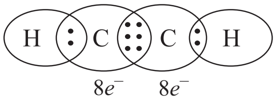


III

Choose the correct option.

(a) I, II and III

(b) Only III

(c) II and III

(d) Only I

14 According to Lewis and Kossel approach for the ammonium ion (NH_4^+), the one positive charge indicates

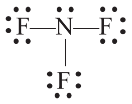
(a) loss of one electron from the group of neutral atoms

(b) gain of one electron to neutral atom

(c) neutrality

(d) All of the above

15 Which of the following Lewis representation of the molecules NF_3, O_3 and HNO_3 is correct?



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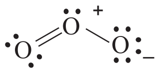
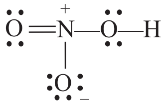


II



III

Choose the correct option.

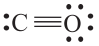
(a) Only I

(b) Only II

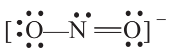
(c) Only III

(d) All of the above

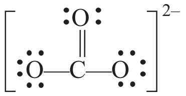
16 Lewis dot structure of CO, NO_2^- and CO_3^{2-} are I, II and III respectively



I



II



III

Which of the above structure(s) is/are wrong?

(a) Only I

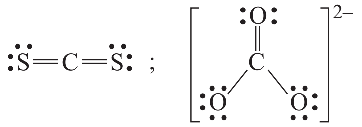
(b) Only II

(c) Only III

(d) All of the above

17 According to Lewis and Kossel approach, which of the following molecule has complete octet of the central atom?
(a) LiCl (b) BeH_2 (c) BCl_3 (d) CO_2

18 Consider the following molecules :



What is the formal charge on C in CS_2 and in CO_3^{2-} ?
(a) 0, –2 (b) 0, 0
(c) +2, – 2 (d) +1, – 1

19 Octet rule is not followed in
(a) NH_3 (b) CH_4 (c) CO_2 (d) NO

20 Which of the following has octet around central atom? ***JIPMER 2019***
(a) PF_5 (b) SF_6 (c) CCl_4 (d) BF_3

21 Ionic bonds will be formed more easily between elements with comparatively
(a) low ionisation enthalpy and high negative value of electron gain enthalpy
(b) high ionisation enthalpy and high negative value of electron gain enthalpy
(c) low ionisation enthalpy and low positive value of electron gain enthalpy
(d) high ionisation enthalpy and low positive value of electron gain enthalpy

22 The species in which bond is non-directional
(a) NCl_3 (b) RbCl (c) $BeCl_2$ (d) BCl_3

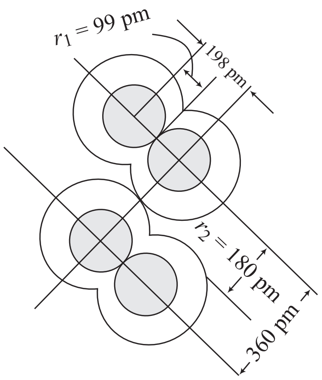
23 Ionic compounds in the crystalline state consist of orderly three-dimensional arrangements of cations and anions held together by
(a) coulombic interaction energies
(b) electron gain energies
(c) ionisation energies
(d) None of the above

TOPIC 2~ *Bond Parameters*

24 Bond length is defined as the equilibrium distance between the nuclei of two bonded atoms in a molecule. It is measured by spectroscopic X-ray diffraction and electron diffraction techniques. Bond length can be calculated in the case of
(a) covalent compounds only
(b) ionic compounds only
(c) Both covalent as well as ionic compounds
(d) None of the above

25 The correct order of increasing bond length of C—H, C—O, C—C and C═C is ***CBSE AIPMT 2011***
(a) C — H < C — O < C — C < C ═ C
(b) C — H < C ═ C < C — O < C — C
(c) C — C < C ═ C < C — O < C — H
(d) C — O < C — H < C — C < C ═ C

26 Consider the following figure :



In this figure, r_1 and r_2 represent respectively are
(a) covalent and van der Waals' radius
(b) van der Waals' and covalent radius
(c) covalent and covalent radius
(d) van der Waals' and van der Waals' radius

27 H—O—H bond angle in water is
(a) 104.5° (b) 109.5°
(c) 105.5° (d) 108.5°

28 In case of H_2O molecule, the enthalpy needed to break the two O — H bonds is not the same, i.e.

$$H_2O(g) \longrightarrow H(g) + OH(g); \Delta_a H_1^{S} = 502 \text{ kJ mol}^{-1}$$

$$OH(g) \longrightarrow H(g) + O(g); \Delta_a H_2^{S} = 427 \text{ kJ mol}^{-1}$$

What should be the mean bond enthalpy of O—H bonds in case of H_2O molecule?
(a) 75 kJ mol^{-1} (b) –75 kJ mol^{-1}
(c) 464.5 kJ mol^{-1} (d) 929 kJ mol^{-1}

29 Which of the following molecules have same bond order?

$$\underset{I}{H_2}, \underset{II}{Cl_2}, \underset{III}{CO}, \underset{IV}{Br_2}, \underset{V}{N_2}$$

Choose the correct option.
(a) I, II and IV have same bond order
(b) III and V have same bond order
(c) Both (a) and (b)
(d) None of the above

30 Which of the following is correct?

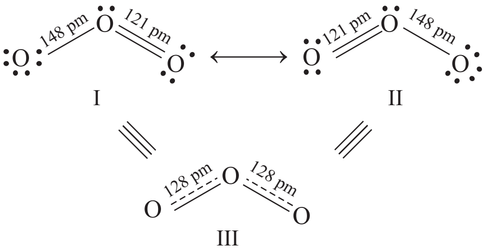
(a) Bond order $\propto \dfrac{1}{\text{bond length}} \propto \dfrac{1}{\text{bond enthalpy}} \propto$ stability

(b) Stability $\propto \dfrac{1}{\text{bond order}} \propto \dfrac{1}{\text{bond length}} \propto \dfrac{1}{\text{bond enthalpy}}$

(c) Stability $\propto$ bond order $\propto$ bond length $\propto$ bond enthalpy

(d) Stability $\propto$ bond order $\propto$ bond enthalpy $\propto \dfrac{1}{\text{bond length}}$

31



In the given resonating structures, which one is called resonance hybrid?

(a) Structure I (b) Structure II

(c) Structure III (d) Both structure I and II

32 The observed O — O bond length in ozone molecule is

(a) 121 pm (b) 148 pm

(c) 128 pm (d) None of these

33 Deviation of O — O bond length in ozone molecule from the normal bond length seems as

(a) single bond length increases while double bond length decreases

(b) single bond length decreases while double bond length increases

(c) single bond length increases while double bond length remains same

(d) single bond length remains same while double bond length increases

34 Whenever a single Lewis structure cannot describe a molecule accurately, a number of structures with almost similar energy, position of nuclei, bonding and non-bonding pairs of electrons are taken as the canonical structures of the hybrid which describes the molecule accurately. This concept is known as

(a) resonance (b) hybridisation

(c) inductive effect (d) None of these

35 Which of the following molecules can be represented in terms of resonance?

(a) O_3 (b) CO_3^{2-} (c) CO_2 (d) All of these

36 Resonance stabilises the molecule as the energy of the resonance hybrid is

(a) more than the energy of the single canonical structure

(b) less than the energy of the single canonical structure

(c) constant the energy of the single canonical structure

(d) None of the above

37 When covalent bond is formed between two similar atoms, the shared pair of electrons is equally attracted by the two atoms. As a result electron pair is situated exactly between the two identical nuclei. The bond so formed is called

(a) ionic bond (b) polar covalent bond

(c) non-polar covalent bond (d) None of these

38 In case of a heteronuclear molecule like HF, the shared electron pair between the two atoms gets displaced more towards fluorine since the electronegativity of fluorine is far greater than that of hydrogen. The resultant covalent bond is

(a) ionic bond (b) coordinate bond

(c) polar covalent bond (d) non-polar covalent bond

39 In case of polyatomic molecules, dipole moment

(a) only depends upon the individual dipole moments of bonds

(b) is vector sum of the dipole moments of various bonds

(c) is substraction of dipole moments of various bonds

(d) All of the above are correct

40 Dipole moment is usually designated by a Greek letter 'μ'

$$\mu = Q \times r$$

Here, Q and r represents

(a) Q = charge, r = distance of separation

(b) Q = heat, r = radius

(c) Q = charge, r = radius of cations

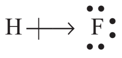
(d) Q = charge, r = radius of anions

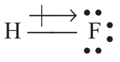
41 Dipole moment is usually expressed in Debye units (D). From the formula, the unit of dipole moment is Coulomb metre (Cm). The relation between both units of dipole moment is

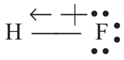
(a) 1 D = 1 Cm (b) $1\text{D} = 3.33564 \times 10^{-30}\,\text{Cm}$

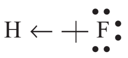
(c) $1\text{D} = 2.22564 \times 10^{-30}\,\text{Cm}$ (d) $1\text{D} = 1.11564 \times 10^{-30}\,\text{Cm}$

42 Dipole moment is a vector quantity and by convention it is depicted by a small arrow with tail on the negative centre and head pointing towards the positive centre. But in chemistry, presence of dipole moment is represented by the crossed arrow ($+\!\!\!\longrightarrow$) put on Lewis structure of the molecule. The cross is on positive end and arrow head is on negative end. From the above data, the dipole moment in HF molecule may be represented as

(a) 

(b) 

(c) 

(d) 

43 Which of the following molecule has net dipole moment zero?

(a) HF (b) H_2O

(c) BF_3 (d) $CHCl_3$

44 The decreasing order of dipole moments of the molecules HF, H_2O, BeF_2, NF_3 is
(a) $HF > H_2O > BeF_2 > NF_3$
(b) $H_2O > HF > NF_3 > BeF_2$
(c) $BeF_2 > NF_3 > HF > H_2O$
(d) $NF_3 > BeF_2 > H_2O > HF$

45 Consider the following compound,

$$NaCl, MgCl_2, AlCl_3$$

The correct increasing order of covalent character is
(a) $NaCl < MgCl_2 < AlCl_3$
(b) $MgCl_2 < NaCl < AlCl_3$
(c) $AlCl_3 < MgCl_2 < NaCl$
(d) $NaCl < AlCl_3 < MgCl_2$

46 Among CaH_2, BeH_2, BaH_2, the order of ionic character is ***NEET 2018***
(a) $BeH_2 < BaH_2 < CaH_2$ (b) $CaH_2 < BeH_2 < BaH_2$
(c) $BeH_2 < CaH_2 < BaH_2$ (d) $BaH_2 < BeH_2 < CaH_2$

TOPIC 3~ *VSEPR Theory*

47 Which one of the following species contains three bond pairs and one lone pair around the central atom? ***CBSE AIPMT 2012***
(a) H_2O (b) BF_3
(c) NH_2^- (d) PCl_3

48 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

49 Which one of the following species has plane triangular shape? ***CBSE AIPMT 2014***
(a) N_3 (b) NO_3^-
(c) NO_2^- (d) CO_2

50 Which of the following pairs of compounds is isoelectronic and isostructural? ***NEET 2017***
(a) $BeCl_2, XeF_2$ (b) TeI_2, XeF_2
(c) IBr_2^-, XeF_2 (d) IF_3, XeF_2

51 Which of the following pairs of ions are isoelectronic and isostructural? ***CBSE AIPMT 2015***
(a) CO_3^{2-}, SO_3^{2-}
(b) ClO_3^-, CO_3^{2-}
(c) SO_3^{2-}, NO_3^-
(d) ClO_3^-, SO_3^{2-}

52 The isoelectronic set of ions is ***JEE Main 2019***
(a) F^-, Li^+, Na^+ and Mg^{2+}
(b) N^{3-}, Li^+, Mg^{2+} and O^{2-}
(c) Li^+, Na^+, O^{2-} and F^-
(d) N^{3-}, O^{2-}, F^- and Na^+

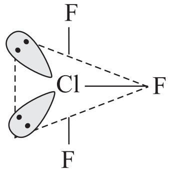
53 Which of the following is correct? ***JIPMER 2019***
(a) SO_3^{2} ⇒ Tetrahedral
(b) NO_2^- ⇒ Trigonal planar
(c) ClO_4^- ⇒ Tetrahedral
(d) NH_3 ⇒ Trigonal planar

54 Which of the molecules has trigonal bipyramidal geometry with bond angles 120° and 90°?
(a) SF_6 (b) PCl_5
(c) CH_4 (d) BF_3

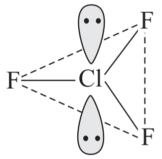
55 The species, having bond angles of 120° is ***NEET 2017***
(a) PH_3 (b) ClF_3
(c) NCl_3 (d) BCl_3

56 Which of the following shows correct molecule and shape ?
(a) AB_2E, bent shape
(b) AB_2E_2, bent shape
(c) AB_3E_2 T-shape
(d) All of the above

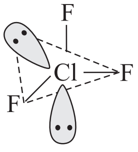
57 Which of the following structures is most stable?



I



II



III

Choose the correct option.
(a) Only I
(b) Only II
(c) Only III
(d) All three have same stability

TOPIC 4 ~ Valence Bond Theory and Hybridisation

58 Lewis approach helps in writing the structure of molecules but it fails to explain
- (a) the formation of chemical bond
- (b) the reason for the difference in bond dissociation enthalpies and bond lengths in molecule like H_2, F_2 etc
- (c) the idea about the shapes of polyatomic molecules
- (d) All of the above

59 Valence bond theory (VBT) is based on the
- (a) knowledge of atomic orbitals and electronic configuration of elements
- (b) overlapping criteria and the hybridisation of atomic orbitals
- (c) the principles of variation and superposition
- (d) All of the above

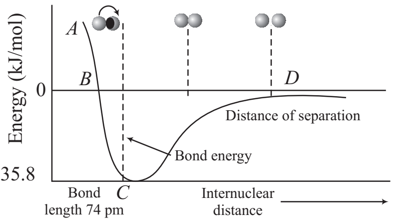
60 In which of the following pairs attractive force work?

$$\underset{\text{I}}{N_A - e_A},\ \underset{\text{II}}{N_A - e_B},\ \underset{\text{III}}{N_B - e_A},\ \underset{\text{IV}}{N_B - e_B},$$

$$\underset{\text{V}}{N_A - N_B},\ \underset{\text{VI}}{e_A - e_B}$$

Here, N_A and N_B represent two nuclei and e_A and e_B refer to electrons surrounding N_A and N_B nuclei.
- (a) I, II and VI
- (b) III, IV and V
- (c) I, II, III and IV
- (d) V and VI

61 Consider the following graph :

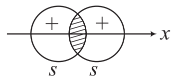


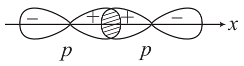
The above potential energy curve is given for the formation of H_2 molecule as a function of internuclear distance of H-atoms. At what point in the curve H_2 is found in the most stable state?
- (a) *A*
- (b) *B*
- (c) *C*
- (d) *D*

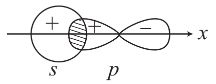
62 How much energy is required to dissociate one mole of H_2 molecule?
- (a) 435.8 kJ mol^{-1}
- (b) 435.8 J mol^{-1}
- (c) 345.8 kJ mol^{-1}
- (d) 345.8 J mol^{-1}

63 The formation of hydrogen molecule takes place when
- (a) the energy state is minimum
- (b) two hydrogen atomic orbitals undergo large extent of overlapping
- (c) Both (a) and (b)
- (d) None of the above

64 The molecule of hydrogen atom is formed due to the overlapping of orbitals of two hydrogen atoms. Which of the following types of overlapping takes place in the formation of H_2 molecule?

(a)


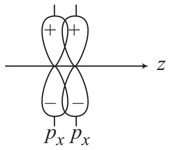
(b)


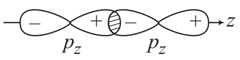
(c)


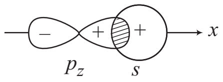
(d) All of these

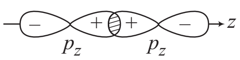
65 The valence bond theory explains the shape, the formation and directional properties of bonds in polyatomic molecules like CH_4, NH_3 and H_2O etc, in terms of
- (a) overlapping of atomic orbitals
- (b) hybridisation of atomic orbitals
- (c) Both (a) and (b)
- (d) None of the above

66 Which of the following does not represent positive overlap?

(a)


(b)


(c)


(d)


67 Which of the following species contains equal number of σ and π-bonds? **CBSE AIPMT 2015**
- (a) HCO_3^-
- (b) XeO_4
- (c) $(CN)_2$
- (d) $CH_2(CN)_2$

68 According to Pauling, the atomic orbitals combine to form new set of equivalent atomic orbitals known as
- (a) molecular orbitals
- (b) hybrid orbitals
- (c) pure orbitals
- (d) None of the above

69 The mixing of one *s* and one *p*- orbital resulting in the formation of two equivalent *sp*- hybrid orbitals. Which of the following orbitals are used for *sp*- hybridisation by convention?
- (a) *s* and p_x
- (b) *s* and p_y
- (c) *s* and p_z
- (d) None of these

70 Diagonal hybridisation is the another name of
- (a) sp^3- hybridisation
- (b) sp^2- hybridisation
- (c) *sp*- hybridisation
- (d) All of these

71 The two *sp*- hybrid points in the opposite direction along the *z*-axis with projecting lobes are of size (taking positive sign as overlapping end)
(a) more negative and less positive
(b) same positive and negative
(c) more positive and less negative
(d) Both (a) and (b)

72 Which of the two ions from the list given below that have the geometry that is explained by the same hybridisation of orbitals, NO_2^-, NO_3^-, NH_2^-, NH_4^+, SCN^-? **CBSE AIPMT 2011**
(a) NO_2^- and NH_2^- (b) NO_2^- and NO_3^-
(c) NH_4^+ and NO_3^- (d) SCN^- and NH_2^-

73 Considering the state of hybridisation of C-atoms, find out the molecule among the following which is linear? **CBSE AIPMT 2011**
(a) $CH_3 - CH_2 - CH_2 - CH_3$
(b) $CH_3 - CH = CH - CH_3$
(c) $CH_3 - C \equiv C - CH_3$
(d) $CH_2 = CH - CH_2 - C \equiv CH$

74 Maximum bond angle at nitrogen is present in which of the following? **CBSE AIPMT 2015**
(a) NO_2 (b) NO_2^- (c) NO_2^+ (d) NO_3^-

TOPIC 5~ *Molecular Orbital Theory*

75 The electron probability distribution around a group of nuclei in a molecule is given by
(a) atomic orbital
(b) molecular orbital
(c) only antibonding molecular orbital
(d) only bonding molecular orbital

76 'ψ' expressed as wave function can represent
(a) probability of an electron
(b) amplitude of the electron waves
(c) electron wave function
(d) Both (a) and (c)

77 Molecular orbitals which are one electron wave functions for molecules are difficult to obtain directly
(a) from the solution of Schrodinger wave equation
(b) from the linear combination of atomic orbitals
(c) Both (a) and (b)
(d) None of the above

78 $2s$ and $2p$ atomic orbitals combine to give how many molecular orbitals?
(a) 2 (b) 4 (c) 8 (d) 6

79 Which of the following method can be used for the formation of bonding in homonuclear diatomic hydrogen molecule?
(a) Non-linear combination of atomic orbitals
(b) Linear combination of atomic orbitals
(c) Linear combination of molecular orbitals
(d) None of the above

80 The number of nodal planes present in $\sigma^* s$ anti-bonding orbitals is
(a) 1 (b) 2 (c) 0 (d) 3

81 In the formation of bonding molecular orbital, the two electrons waves of the bonding atoms reinforce each other due to
(a) constructive interference (b) destructive interference
(c) Both (a) and (b) (d) None of these

82 In case of bonding molecular orbital, the electron density is located
(a) away from the space between nuclei of the bonded atom
(b) between the nuclei of the bonded atoms
(c) in the outer shell
(d) in the inner orbital

83 In case of antibonding molecular orbital the repulsion between the nuclei is high because
(a) presence of a nodal plane between the nuclei
(b) the electron density is very high
(c) the electron waves cancel each other
(d) All of the above

84 The electrons placed in antibonding molecular orbital destabilise the molecule. This is because
(a) mutual repulsion of electrons > attraction between electrons and nuclei
(b) the repulsion between the nuclei is high
(c) Both (a) and (b)
(d) None of the above

85 $2p_z$ orbital of one atom can not overlap with the $2p_x$ or $2p_y$ orbitals. Because
(a) they possesses same energy that is why p_z cannot overlap with p_x or p_y orbital
(b) the symmetry of p_x, p_y and p_z is same
(c) the energy of p_x, p_y and p_z is different
(d) symmetry of p_x, p_y and p_z is different

86 If internuclear axis is taken to be in *z*-direction then, which of the following orbital does form σ-bond? Choose the correct option.
(a) p_x-orbitals
(b) p_y-orbitals
(c) p_z-orbitals
(d) None of the above

87 According to molecular orbital theory, which of the following will not be a viable molecule? ***JEE Main 2018***

(a) He_2^{2+} (b) He_2^{+} (c) H_2^{-} (d) H_2^{2-}

88 Which of the following diatomic molecular species has only π-bonds according to molecular orbital theory? ***NEET (National) 2019***

(a) N_2 (b) C_2 (c) Be_2 (d) O_2

89 According to molecular orbital theory, which of the following is true with respect to Li_2^{+} and Li_2^{-}?

(a) Both are unstable

(b) Li_2^{+} is unstable and Li_2^{-} is stable

(c) Both are stable

(d) Li_2^{+} is stable and Li_2^{-} is unstable

90 The correct bond order in the following species is ***CBSE AIPMT 2015***

(a) $O_2^{2+} > O_2^{+} > O_2^{-}$ (b) $O_2^{2+} < O_2^{-} < O_2^{+}$

(c) $O_2^{+} > O_2^{-} < O_2^{2+}$ (d) $O_2^{-} < O_2^{+} > O_2^{2+}$

91 Which of the following has minimum bond length? ***CBSE AIPMT 2011***

(a) O_2 (b) O_2^{+} (c) O_2^{-} (d) O_2^{2-}

92 When O_2 is converted into O_2^{2+}, what will happen?

(a) Both paramagnetic character and bond order increase

(b) Bond order decreases

(c) Paramagnetic character increases

(d) Paramagnetic character decreases and bond order increases

93 Which of the following is paramagnetic? ***NEET (Odisha) 2019***

(a) N_2 (b) H_2 (c) Li_2 (d) O_2

94 Four diatomic species are listed below. Identify the correct order in which the bond order is increasing in them ***CBSE AIPMT 2012***

(a) $NO < O_2^{-} < C_2^{2-} < He_2^{+}$ (b) $O_2^{-} < NO < C_2^{2-} < He_2^{+}$

(c) $C_2^{2-} < He_2^{+} < O_2^{-} < NO$ (d) $He_2^{+} < O_2^{-} < NO < C_2^{2-}$

95 In which of the following processes, the bond order has increased and paramagnetic character has changed to diamagnetic? ***JEE Main 2019***

(a) $O_2 \rightarrow O_2^{+}$ (b) $N_2 \rightarrow N_2^{+}$

(c) $O_2 \rightarrow O_2^{2-}$ (d) $NO \rightarrow NO^{+}$

96 During change of O_2 to O_2^{-} ion, the electron adds on which one of the following orbitals? ***CBSE AIPMT 2012***

(a) $\overset{*}{\pi}$-orbital (b) π-orbital

(c) $\overset{*}{\sigma}$-orbital (d) σ-orbital

97 If the magnetic moment of a dioxygen species is 1.73 B.M, it may be ***JEE Main 2020***

(a) O_2, O_2^{-}, or O_2^{+} (b) O_2^{-} or O_2^{+}

(c) O_2 or O_2^{-} (d) O_2 or O_2^{+}

98 The pair of species with the same bond order is ***CBSE AIPMT 2014***

(a) O_2^{2-}, B_2 (b) O_2^{+}, NO^{+}

(c) NO, CO (d) N_2, O_2

99 Which one of the following pairs of species have the same bond order? ***NEET 2017***

(a) CO, NO (b) O_2, NO^{+}

(c) CN^{-}, CO (d) N_2, O_2^{-}

100 The bond order and the magnetic characteristics of CN^{-} are ***JEE Main 2020***

(a) 3, diamagnetic (b) $2\frac{1}{2}$, diamagnetic

(c) 3, paramagnetic (d) $2\frac{1}{2}$, diamagnetic

101 Consider the following species ***NEET 2018***

CN^{+}, CN^{-}, NO and CN

Which one of these will have the highest bond order?

(a) CN^{+} (b) CN^{-}

(c) NO (d) CN

TOPIC 6~ *Hydrogen Bonding*

102 Which of the following molecule does not show hydrogen bonding?

(a) HF (b) H_2O (c) NH_3 (d) H_2S

103 The boiling point of a substance increases with increase in

(a) intermolecular hydrogen bonding

(b) intramolecular hydrogen bonding

(c) molecular mass

(d) Both (a) and (c)

104 The magnitude of H-bonding depends on the physical state of the compound. It is maximum in the

(a) solid state

(b) liquid state

(c) gaseous state

(d) All of the above

SPECIAL TYPES QUESTIONS

I. Statement Based Questions

105 Which of the following statements is incorrect for writing the Lewis dot structure?.

(a) The total number of electrons required for writing the structure are obtained by adding the valence electrons of the combining atoms

(b) Knowing the chemical symbols of the combining atoms and having knowledge of the total skeletal structure of the compound, it is easy to distribute the number of electrons as bonding shared pairs between the atoms in proportions to the total bonds

(c) In general the least electropositive atom occupies the central position in the molecule/ion

(d) After accounting for the shared pairs of electrons for single bonds, the remaining electron pairs are either utilised for multiple bonding or remain as the lone pairs

106 Which of the following statement is incorrect?

(a) Lewis dot structures provide a picture of bonding in molecules and ions in terms of shared pair of electrons and octet rule

(b) Lowest energy structure is the one with highest formal charges on the atoms

(c) Octet rule is not applied in odd-electron molecules, molecules with expanded octet and incomplete octet of the central atom

(d) Energy required to completely separate one mole of a solid ionic compound into gaseous constituent ions is called lattice enthalpy

107 The important condition(s) for Lewis dot structure of covalent compounds is/are

(a) each bond is formed as a result of sharing of an electron pair between the atoms

(b) each combining atom contributes atleast one electron to the shared pair

(c) the combining atoms attain the outer shell noble gas configurations as a result of the sharing of electrons

(d) All of the above

108 Which of the following statements is incorrect?

(a) The formation of the positive and negative ions from the neutral atoms by losing and gaining electrons respectively

(b) The formation of positive and negative ions involve ionisation enthalpy and electron gain enthalpy respectively

(c) Ionisation enthalpy is always endothermic

(d) The formation of positive and negative ions involve electron gain enthalpy

109 Consider the following statements

I. Highly electronegative halogens and highly electropositive alkali metals are separated by noble gases.

II. Formation of negative ion from halogen atom and positive ion from alkali atom is associated with gain and loss of an electron.

III. Negative and positive ions are stabilised by electrostatic attraction.

Choose the correct statements.

(a) Only I (b) Only III

(c) Both I and II (d) I, II and III

110 Which of the following is drawback of the octet theory?

I. It is clear that octet rule is based upon the chemical inertness of noble gases. However, some noble gases (for example xenon and krypton) also combine with oxygen and fluorine to form a number of compounds like XeF_2, KrF_2, $XeOF_2$ etc.

II. This theory does not account for the shape of molecules.

III. It does not explain the relative stability of the molecules being totally silent about the energy of a molecule.

Choose the correct statements

(a) Only I (b) Only II

(c) Only III (d) All of these

111 Consider the following statement

I. When a gas phase atom in its ground state gains an electron, the enthalpy change is called electron gain enthalpy.

II. The electron gain process is always exothermic.

III. The ionisation enthalpy process is always endothermic.

Choose the correct statements.

(a) I and II (b) Only II

(c) I and III (d) II and III

112 Which of the following is correct definition of bond angle?

(a) It is the angle between the orbitals containing bonding electron pairs around the central atom in a molecule/complex ion

(b) It is the degree which can be experimentally determined by spectroscopic methods

(c) It helps in determining the shape of a molecule/complex ion

(d) All of the above

113 NH_3 and NF_3, both the molecules have pyramidal shape with a lone pair of electrons on nitrogen atom. Why does the dipole moment of NH_3 is greater than that of NF_3?

(a) Because F is more electronegative than N-atom

(b) Because in NF_3 the orbital dipole is in the direction opposite to the resultant dipole moment of the three N—F bonds

(c) Because in NH_3 the orbital dipole is in the direction same to the resultant dipole moment of the three N—H bonds

(d) All of the above

114 Consider the following statements.

I. In the case of a covalent bond, the contribution from each atom is called the covalent radius of that atom.

II. The covalent radius is half of the distance between two similar atoms joined by a covalent bond in the same molecule.

III. The covalent radius is measured approximately as the radius of an atom core which is in contact with the core of an adjacent atom in a bonded situation.

Which of the above definitions is/are correct regarding the covalent bond?

(a) Only I (b) Only II

(c) Only III (d) I, II and III

115 Consider the following statements

I. The canonical forms have no real existence.

II. The molecule does not exist for a certain fraction of time in one canonical form and for other fractions of time in other canonical forms.

III. There is no such equilibrium between the canonical forms as we have between tautomeric forms (keto and enol) in tautomerism.

IV. The molecule such as has a single structure which is the resonance hybrid of the canonical forms and which cannot such as be depicted by a single Lewis structure.

Which of the above statements are correct?

(a) I and II (b) III and IV

(c) II and III (d) All of these

116 Bond length depends upon the size of atoms, hybridisation, resonance, bond order etc. In the following relations.

I. Bond length $\propto$ size of atoms

II. Bond length $\propto$ hybridisation (no. of hybrid orbitals)

III. Bond length $\propto$ bond order

Choose the correct option.

(a) I and II

(b) Only I

(c) I and III

(d) I, II and III

117 Which of the following statement is incorrect regarding Fajan's rule?

(a) It discussed the partial covalent character of ionic bonds

(b) Smaller the size of cation and larger the size of anion, the greater is the covalent character of an ionic bond

(c) Greater the charge on the cation, the greater the covalent character of the ionic bond

(d) For cations of same size and charge, the one with electronic configuration of noble gas is more polarising than the one with transition metals configuration

118 Which of the following statements is incorrect postulates of VSEPR theory?

(a) The shape of a molecule depends upon the number of valence shell electron pairs (bonded or non-bonded) around the central atom

(b) Pairs of electrons in the valence shell repel one another since their electron clouds are negatively charged

(c) These pairs of electrons tend to occupy such positions in space that minimise repulsion and thus maximise distance between them

(d) The valence shell is taken as a sphere with the electron pairs localising on the spherical surface at minimum distance from one another

119 Which of the following statements is incorrect regarding hybridisation?

(a) The number of hybrid orbitals is equal to the number of the atomic orbitals that get hybridised

(b) The hybridised orbitals are always equivalent in energy and shape

(c) The hybrid orbitals are less effective in forming stable bonds than the pure atomic orbitals

(d) These hybrid orbitals are directed in space in some preferred direction to have minimum repulsion between electron pairs and thus a stable arrangement. Therefore, the type of hybridisation indicates the geometry of the molecules

120 Consider the following statements

I. H_2O molecule has V-shape with two lone pairs of electrons.

II. SF_4 molecule has *see-saw* shape with one lone pair of electrons.

III. ClF_3 is T-shaped molecule with two lone pairs of electrons.

Which of the above statements are correct?

Choose the correct option.

(a) I and II

(b) II and III

(c) I and III

(d) All of the above

121 The correct statements among I to III are :

I. Valence bond theory cannot explain the colour exhibited by transition metal complexes.

II. Valence bond theory can predict quantitatively the magnetic properties of transition metal complexes.

III. Valence bond theory cannot distinguish ligands as weak and strong field ones. ***JEE Main 2019***

(a) II and III (b) I, II and III

(c) I and II (d) I and III

122 Consider the following statements

I. In F_2 molecule F—F σ-bond is formed by axial overlapping of two *p*-orbitals.

II. In O_2 molecule one σ-bond is formed by axial overlap of *p*-orbitals and one π-bond is formed by lateral overlap of *p*-orbitals.

III. In N_2 molecule one σ and two π-bonds, i.e. all the three bonds are formed by lateral overlap of *p*-orbitals.

Which of the above statements are incorrect?

(a) Only I

(b) Only II

(c) Only III

(d) All of the above

123 Consider the following statement

I. When O_2 is converted into O_2^{2+} bond order decreases.

II. O_2 molecule is paramagnetic because it contains two unpaired electrons in $\overset{*}{\pi}2p_x$ and $\overset{*}{\pi}2p_y$ molecular orbitals.

III. The bond length in NO is greater than in $N\overset{+}{O}$.

Choose the correct statements.

(a) Only I (b) I and II

(c) II and III (d) II and IV

124 Which of the following statements is incorrect regarding the conditions for the combination of atomic orbitals?

(a) The combining atomic orbitals must have the same or nearly the same energy

(b) The combining atomic orbitals must have the same symmetry about the molecular axis

(c) The combining atomic orbitals must overlap to the minimum extent

(d) Atomic orbitals having same or nearly the same energy will not combine if they do not have the same symmetry

125 When orbitals of two atoms come close to form bond, their overlap may be positive, negative or zero depending upon the sign (phase) and direction of orientation of amplitude of orbital wave function in space. The conditions for the positive overlap is

(a) orbitals forming bond should have same sign (phase) and orientation in space

(b) orbitals forming bond should have opposite sign and orientation in space

(c) opposite sign but same orientation in space

(d) All of the above

126 Which of the following is not an essential condition for hybridisation?

(a) The orbitals present in the valence shell of the atom are hybridised

(b) The orbitals undergoing hybridisation should have almost equal energy

(c) Promotion of electron is essential condition prior to hybridisation

(d) It is not necessary that only half-filled orbitals participate in hybridisation. In some cases, even filled orbitals of valence shell take part in hybridisation

127 Which of the following statements is correct?

(a) Sigma (σ) molecular orbitals are unsymmetrical around the bond axis

(b) π (pi) molecular orbitals are not unsymmetrical around the bond axis

(c) Sigma (σ) molecular orbitals are symmetrical around the bond axis

(d) Sigma (σ) and pi (π) molecular orbitals are symmetrical around the bond axis

128 Consider the following statements

I. The electrons in a molecule are present in various molecular orbitals as electrons of atoms are present in various atomic orbitals.

II. Atomic orbital is monocentric while molecular orbital is polycentric.

III. If internuclear axis is taken to be in *z*-direction, linear combination of $2p_z$-orbitals of two atoms produces $\sigma 2p_z$ and $\sigma^* 2p_z$.

Choose the correct statements.

(a) Both I and II (b) Both II and III

(c) Both I and III (d) I, II and III

129 Consider the following statements.

I. In the CH_4 molecule there are eight valence electrons available for bonding.

II. Sigma molecular orbitals are symmetrical around the bond axes.

III. The formation of positive and negative ions involve electron gain enthalpy.

IV. Hydrogen bonding is the characteristic features of all polar molecules.

Choose the correct statements.

(a) I and II (b) Only I (b) I and IV (d) I, II and IV

130 A bonding molecular orbital always possesses lower energy than either of the atomic orbitals that have overlapped to form it because

(a) electrons placed in a bonding molecular orbital tend to hold the nuclei together and stabilise a molecule

(b) electrons placed in a bonding molecular orbital repels each other

(c) the electron density in a bonding molecular orbital is located between the nuclei of the bonded atoms because of which the repulsion between the nuclei is very less

(d) Both (a) and (c)

131 If the intermolecular axis is taken to be in *z*-direction then, molecular orbitals obtained from $2p_x$ and $2p_y$ orbitals are not symmetrical around the bond axis because

(a) positive lobes are above the molecular plane and negative lobes are below the molecular plane
(b) negative lobes are above the plane and positive lobes are below the plane
(c) positive and negative lobes both are in same plane
(d) All of the above

132 Which of the following statement is correct?

(a) Magnitude of H-bonding is maximum in solid state and minimum in gaseous state
(b) Intermolecular hydrogen bond is formed between two different molecules of same or different compounds
(c) Intramolecular hydrogen bond is formed when hydrogen atom is in between the two highly electronegative atoms present with in the same molecule
(d) All of the above.

133 Choose the incorrect statement.

(a) Hydrogen bonding is the characteristic feature of non-polar molecules
(b) Hydrogen bonding may be present in non-polar molecules
(c) Hydrogen bonding is the characteristic feature of all polar molecules
(d) All of the above

II. Assertion and Reason

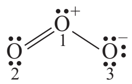
■ **Directions** (Q. Nos. 134-145) *In the following questions a statement of Assertion* (A) *followed by a statement of Reason* (R) *is given. Choose the correct answer out of the following choices.*

(a) Both A and R are correct; R is the correct explanation of A.
(b) Both A and R are correct; R is not the correct explanation of A.
(c) A is correct; R is incorrect.
(d) A is incorrect; R is correct.

134 **Assertion** (A) In case of polyatomic ions, the net charge is possessed by the ion as a whole and not by a particular atom.

Reason (R) The formal charge of an atom in a polyatomic molecule or ion may be defined as the difference between the number of valence electrons of that atom in an isolated or free state and the number of electrons assigned to that atom in the Lewis structure.

135 **Assertion** (A) The correct Lewis structure of O_3 may be drawn as :



Reason (R) In O_3, the formal charges on atom 1, 2 and 3 are +1, 0 and –1, respectively.

136 **Assertion** (A) Formal charges do not indicate real charge separation within the molecule.

Reason (R) Formal charges help in the selection of the lowest energy structure from a number of possible Lewis structures for a given species.

137 **Assertion** F—F bond has low bond dissociation energy.

Reason The fluorine has least reactivity.

138 **Assertion** (A) H_2SO_4 does not follow the octet rule.

Reason (R) In sulphur atom 3*d*- orbitals also available for bonding and hence, it has 12 electrons around itself in H_2SO_4.

139 **Assertion** (A) Sulphur forms many compounds in which the octet rule is obeyed.

Reason (R) Due to the absence of *d*-orbitals in sulphur, it follows the octet rule.

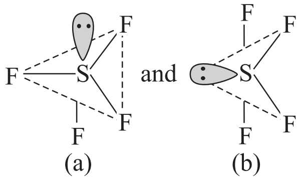
140 **Assertion** (A) NH_3 molecule is AB_3E type.

Reason (R) The geometry of NH_3 molecule is trigonal pyramidal.

141 **Assertion** (A) The structure of H_2O is similar to SO_2.

Reason (R) In both molecules (H_2O and SO_2), the central atom has one lone pair of electrons.

142 **Assertion** (A) SF_4 molecule has two type of structure.



in which structure (b) is more stable than (a).

Reason (R) *lp*-*bp* repulsions decide the greater stability of structure (b).

143 **Assertion** (A) BrF_5 and SF_6 both have same hybridisation.

Reason (R) BrF_5 is square pyramidal, while SF_6 molecule is octahedral.

144 **Assertion** (A) The total energy of two molecular orbitals, however, remains the same as that of two original atomic orbitals.

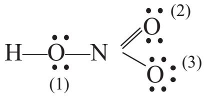
Reason (R) The energy of the antibonding orbital is raised above the energy of the parent atomic orbitals that have combined and the energy of the bonding orbital has been lowered than the parent orbitals.

145 **Assertion** (A) The combining atomic orbitals must have the same or nearly the same energy.

Reason (R) $1s$ orbital can combine with another $2s$ orbital but not with $1s$ orbital because the energy of $2s$ orbital is appreciably higher than that of $1s$ orbital. This is not true if the atoms are very different.

III. Matching Type Questions

146 In the following Lewis structure of HNO_3



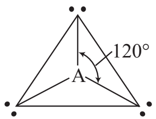
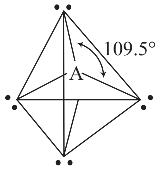
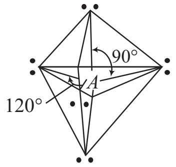
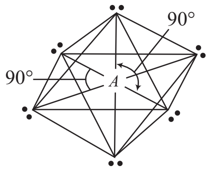
The formal charge on Column I, $O_{(1)}$, $O_{(2)}$ and $O_{(3)}$ are given in Column II. Match the following and choose the correct option from the codes given below.

	Column I	Column II
A.	$O_{(1)}$	1. Zero
B.	$O_{(2)}$	2. −1
C.	$O_{(3)}$	3. +1

Codes

	A	B	C		A	B	C
(a)	1	2	3	(b)	2	1	2
(c)	1	1	2	(d)	3	2	1

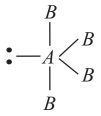
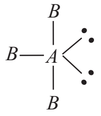
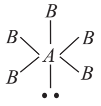
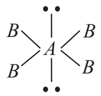
147 Match the following columns and choose the correct option from the codes given below :

	Column I	Column II
A.	 Trigonal planar	1. PCl_5
B.	 Tetrahedral	2. NH_4^+
C.	 Trigonal bipyramidal	3. SF_6
D.	 Octahedral	4. BF_3

Codes

	A	B	C	D		A	B	C	D
(a)	1	2	3	4	(b)	4	3	2	1
(c)	4	2	1	3	(d)	3	1	2	4

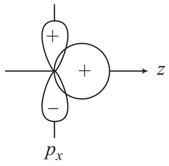
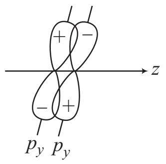
148 Match the following columns and choose the correct option from the codes given below.

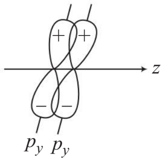
	Column I (Arrangements of electron pairs)	Column II (Shape)
A.	 Trigonal bipyramidal	1. Square planar
B.	 Trigonal bipyramidal	2. T-shaped
C.	 Octahedral	3. Square pyramidal
D.	 Octahedral	4. *See-saw*

Codes

	A	B	C	D
(a)	1	3	2	4
(b)	4	2	3	1
(c)	3	2	4	1
(d)	2	1	3	4

149 Match the following columns and choose the correct option from the codes given below.

	Column I (Representation)	Column II (Type)
A.		1. Positive overlap
B.		2. Zero overlap

Column I (Representation)	Column II (Type)
C. 	3. Negative overlap

Codes

	A	B	C
(a)	1	2	3
(b)	2	1	3
(c)	2	3	1
(d)	3	1	2

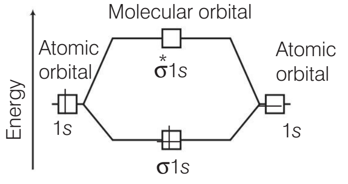
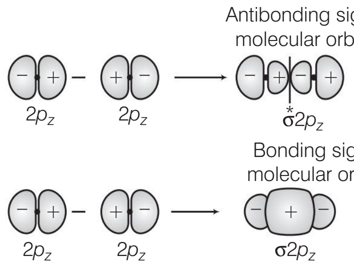
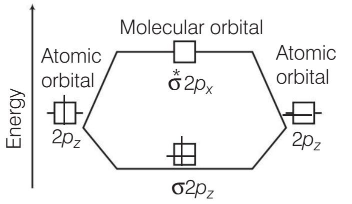
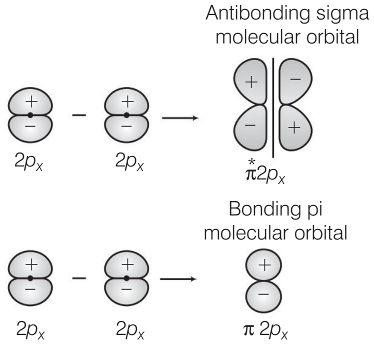
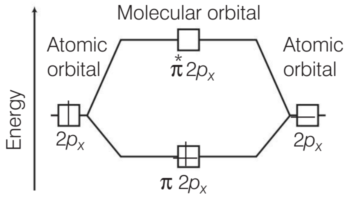
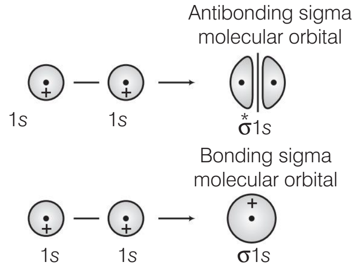
150 Match the species in Column I with the type of hybrid orbitals in Column II and choose the correct option from the codes given below.

Column I	Column II
A. SF_4	1. sp^3d^2
B. IF_5	2. sp
C. NO_2^+	3. sp^3d
D. NH_4^+	4. sp^3

Codes

	A	B	C	D		A	B	C	D
(a)	1	4	2	3	(b)	3	1	2	4
(c)	2	4	3	1	(d)	4	2	3	1

151 Match the following columns and choose the correct option from the codes given below.

Column I	Column II
A. 	1. 
B. 	2. 
C. 	3. 

Codes

	A	B	C		A	B	C		A	B	C		A	B	C
(a)	3	1	2	(b)	1	3	2	(c)	1	2	3	(d)	2	3	1

152 Match the following Columns and choose the correct option from the codes given below.

Column I		Column II	
A.	He_2	1.	Paramagnetic
B.	O_2	2.	Diamagnetic
C.	Li_2	3.	Does not exist
D.	C_2		

Codes

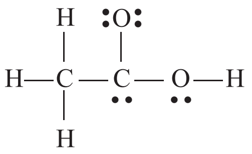
	A	B	C	D
(a)	1	2	3	1
(b)	1	1	2	3
(c)	3	1	2	2
(d)	3	3	1	2

NCERT & NCERT Exemplar

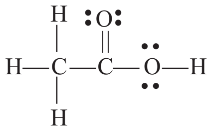
MULTIPLE CHOICE QUESTIONS

NCERT

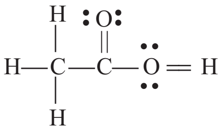
153 The skeletal structure of CH_3COOH as shown below is correct, but some of the bonds are shown incorrectly. Write the correct Lewis structure for acetic acid.



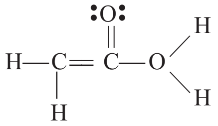
(a)



(b)



(c)



(d) None of these

154 The correct increasing order of ionic character in the molecules; LiF, K_2O, N_2, SO_2 and ClF_3 is

(a) $N_2 < ClF_3 < SO_2 < LiF < K_2O$

(b) $N_2 < SO_2 < ClF_3 < K_2O < LiF$

(c) $SO_2 < N_2 < ClF_3 < K_2O < LiF$

(d) $LiF < K_2O < ClF_3 < SO_2 < N_2$

155 Considering x-axis as the internuclear axis, which out of the following will not form a sigma bond?

(a) $1s$ and $1s$ (b) $1s$ and $2p_x$

(c) $2p_y$ and $2p_y$ (d) $1s$ and $2s$

NCERT Exemplar

156 The electronic configuration of the outermost shell of the most electronegative elements is

(a) $2s^2 2p^5$ (b) $3s^2 3p^5$ (c) $4s^2 4p^5$ (d) $5s^2 5p^5$

157 Amongst the following elements whose electronic configuration are given below, the one having the highest ionisation enthaply is

(a) [Ne] $3s^3 3p^1$ (b) [Ne]$3s^2 3p^3$

(c) [Ne]$3s^3 3p^2$ (d) [Ar]$3d^{10} 4s^2 4p^3$

158 If the electronic configuration of an element is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$, the four electrons involved in chemical bond formation will be

(a) $3p^6$ (b) $3p^6, 4s^2$ (c) $3p^6, 3d^2$ (d) $3d^2, 4s^2$

159 In PO_4^{3-} ion the average formal charge on the oxygen atom is

(a) + 1 (b) – 1 (c) – 0.75 (d) + 0.75

160 Polarity in a molecule and hence the dipole moment depends primarily on electronegativity of the constituent atoms and shape of a molecule. Which of the following has the highest dipole moment?

(a) CO_2 (b) HI (c) H_2O (d) SO_2

161 In NO_3^- ion, the number of bond pairs and lone pairs of electrons on nitrogen atom are

(a) 2, 2 (b) 3, 1 (c) 1, 3 (d) 4, 0

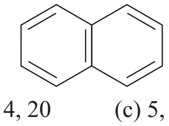
162 Which of the following species has tetrahedral geometry?

(a) BH_4^- (b) NH_2^- (c) CO_3^{2-} (d) H_3O^+

163 In which of the following molecule/ion all the bonds are not equal?

(a) XeF_4 (b) BF_4^- (c) C_2H_4 (d) SiF_4

164 Number of π- bonds and σ- bonds in the following structure is



(a) 6, 19 (b) 4, 20 (c) 5, 19 (d) 5, 20

165 Which of the following order of energies of molecular orbitals of N_2 is correct?

(a) $(\pi 2p_y) < (\sigma 2p_z) < (\pi^* 2p_x) \approx (\pi^* 2p_y)$

(b) $(\pi 2p_y) > (\sigma 2p_z) > (\pi^* 2p_x) \approx (\pi^* 2p_y)$

(c) $(\pi 2p_y) < (\sigma 2p_z) < (\pi^* 2p_x) \approx (\pi^* 2p_y)$

(d) $(\pi 2p_y) > (\sigma 2p_z) < (\pi^* 2p_x) \approx (\pi^* 2p_y)$

166 Which molecule/ion out of the following does not contain unpaired electrons?

(a) N_2^+ (b) O_2 (c) O_2^{2-} (d) B_2

167 Which of the following options represents the correct bond order?

(a) $O_2^- > O_2 > O_2^+$ (b) $O_2^- < O_2 < O_2^+$

(c) $O_2^- > O_2 < O_2^+$ (d) $O_2^- < O_2 > O_2^+$

168 Which of the following statement is not correct from the view point of molecular orbital theory?

(a) Be_2 is not a stable molecule

(b) He_2 is not stable but He_2^+ is expected to exist

(c) Bond strength of N_2 is maximum amongst the homonuclear diatomic molecules belonging to the second period

(d) The order of energies of molecular orbitals in N_2 molecule is $\sigma 2s < \overset{*}{\sigma} 2s < \sigma 2p_z < (\pi 2p_x \simeq \pi 2p_y) < (\pi^* 2p_x \simeq \pi^* 2p_y > \sigma^* 2p_z)$

169 Which of the following angle corresponds to sp^2 hybridisation?

(a) 90° (b) 120° (c) 180° (d) 109°

170 The types of hybrid orbitals of nitrogen in NO_2^+, NO_3^- and NH_4^+ respectively are expected to be

(a) sp, sp^3 and sp^2 (b) sp, sp^2 and sp^3

(c) sp^2, sp and sp^3 (d) sp^2, sp^3 and sp

171 Isostructural species are those which have the same shape and hybridisation. Among the given species identify the isostructural pairs.

(a) $[NF_3$ and $BF_3]$ (b) $[BF_4^-$ and $NH_4^+]$

(c) $[BCl_3$ and $BrCl_3]$ (d) $[NH_3$ and $NO_3^-]$

172 In which of the following substances will hydrogen bond be strongest?

(a) HCl (b) H_2O (c) HI (d) H_2S

173 Hydrogen bonds are formed in many compounds e.g., H_2O, HF, NH_3. The boiling point of such compounds depends to a extent on the strength of hydrogen bond and the number of hydrogen bonds. The correct decreasing order of the boiling points above compounds is

(a) $HF > H_2O > NH_3$ (b) $H_2O > HF > NH_3$

(c) $NH_3 > HF > H_2O$ (d) $NH_3 > H_2O > HF$

■ **Directions** (Q.Nos. 174-176) 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 in each question.

(a) A and R both are correct and R is the correct explanation of A

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

(c) A is true, but R is false

(d) A is false but R is true

174 **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.

175 **Assertion** (A) Though the central atom of both NH_3 and H_2O molecules are sp^3 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.

176 **Assertion** (A) Among the two O—H bonds in H_2O molecule, the energy required to break the first O—H bond and the other O—H bond is the same.

Reason (R) This is because the electronic environment around oxygen is the not same even after breakage of one O—H bond.

177 Match the species in Column I with the bond order in Column II and choose the correct option from the codes given below :

	Column I		Column II
A.	NO	1.	1.5
B.	CO	2.	2.0
C.	O_2^-	3.	2.5
D.	O_2	4.	3.0

Codes

	A	B	C	D		A	B	C	D
(a)	2	1	4	3	(b)	1	2	3	4
(c)	4	3	1	2	(d)	3	4	1	2

178 Match the the shape of molecules in Column I with the type of hybridisation in Column II and choose the correct option from the codes given below :

	Column I		Column II
A.	Tetrahedral	1.	sp^1
B.	Trigonal	2.	sp
C.	Linear	3.	sp^3

Codes

	A	B	C		A	B	C
(a)	2	1	3	(b)	1	2	3
(c)	3	1	2	(d)	1	3	2

Answers

Mastering NCERT with MCQs

1 (d)	2 (b)	3 (c)	4 (d)	5 (a)	6 (d)	7 (a)	8 (a)	9 (c)	10 (b)
11 (a)	12 (d)	13 (c)	14 (a)	15 (d)	16 (a)	17 (d)	18 (b)	19 (d)	20 (c)
21 (a)	22 (b)	23 (a)	24 (a)	25 (b)	26 (a)	27 (a)	28 (c)	29 (c)	30 (d)
31 (c)	32 (c)	33 (b)	34 (a)	35 (d)	36 (b)	37 (c)	38 (c)	39 (b)	40 (a)
41 (b)	42 (b)	43 (c)	44 (b)	45 (a)	46 (c)	47 (d)	48 (c)	49 (b)	50 (c)
51 (d)	52 (d)	53 (c)	54 (b)	55 (d)	56 (d)	57 (a)	58 (d)	59 (d)	60 (c)
61 (c)	62 (a)	63 (c)	64 (a)	65 (c)	66 (b)	67 (b)	68 (b)	69 (c)	70 (c)
71 (c)	72 (b)	73 (c)	74 (c)	75 (b)	76 (b)	77 (a)	78 (c)	79 (b)	80 (a)
81 (a)	82 (b)	83 (a)	84 (a)	85 (d)	86 (c)	87 (d)	88 (b)	89 (d)	90 (a)
91 (b)	92 (d)	93 (d)	94 (d)	95 (d)	96 (a)	97 (d)	98 (a)	99 (c)	100 (c)
101 (b)	102 (d)	103 (d)	104 (a)						

Special Types Questions

105 (c)	106 (b)	107 (d)	108 (d)	109 (d)	110 (d)	111 (c)	112 (d)	113 (d)	114 (d)
115 (d)	116 (a)	117 (d)	118 (d)	119 (c)	120 (d)	121 (d)	122 (c)	123 (c)	124 (c)
125 (a)	126 (c)	127 (c)	128 (d)	129 (a)	130 (a)	131 (a)	132 (d)	133 (d)	134 (a)
135 (a)	136 (b)	137 (c)	138 (a)	139 (c)	140 (b)	141 (c)	142 (a)	143 (b)	144 (b)
145 (c)	146 (c)	147 (c)	148 (b)	149 (c)	150 (b)	151 (a)	152 (c)		

NCERT & NCERT Exemplar Questions

153 (a)	154 (b)	155 (c)	156 (a)	157 (b)	158 (d)	159 (c)	160 (c)	161 (d)	162 (a)
163 (c)	164 (c)	165 (a)	166 (c)	167 (b)	168 (d)	169 (b)	170 (b)	171 (b)	172 (b)
173 (b)	174 (a)	175 (a)	176 (d)	177 (d)	178 (c)				

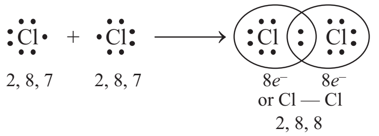
Hints & Explanations

2 (*b*) Kossel and Lewis approach was based on the inertness of noble gases, i.e. to complete the octet or achieve nearest inert gas configuration in outermost shell of each atom to achieve the stability.

5 (*a*) Outershell is known as valence shell and electrons present in it are called valence electrons.

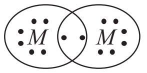
9 (*c*) The formation of chlorine molecule, (Cl_2), can be understood by Lewis-Langmuir theory. In this process, both chlorine atoms attain the outer shell octet of the nearest noble gas (i.e. argon).

Formation of Cl_2 molecule is as follows :



10 (*b*) The element that would readily form a diatomic molecule is M. By sharing of 1 electron each, both the atoms of M will get a completed octet.

It can be shown as follows :



11 (*a*) Valence electrons in $P = 2$

Valence electrons in $Q = 6$

$$P - 2e^- \longrightarrow P^{2+}$$

$$Q + 2e^- \longrightarrow Q^{2-}$$

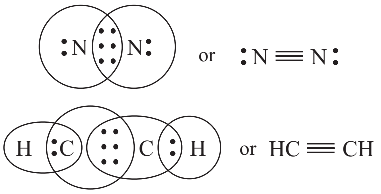
So, $$P^{2+} + Q^{2-} \longrightarrow PQ$$

Since, both show a valency of 2.
So, the formula for the compound will be PQ.

12 (*d*) All the given structures (I, II, III and IV) are correct.
- I. Represents Lewis dot structure of CCl_4.
- II. Represents Lewis dot structure of Cl_2.
- III. Represents Lewis dot structure of CO_2.
- IV. Represents Lewis dot structure of H_2O.

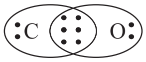
13 (*c*) Structures II and III possesses triple bond.

N_2 and C_2H_2 have triple bonds while C_2H_4 has a double bond. Structures are as follows :



16 (*a*) Lewis dot structure (I) of CO, is wrong.

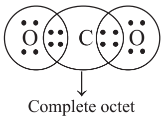
It may be correctly represented as :



or $:\!C\equiv O\!:$
(Correct)

17 (*d*) According to Lewis and Kossel approach, CO_2 molecule has complete octet of central atom

LiCl, BeH_2 and BCl_3 are the molecules with incomplete octet of central atom. Lewis structure of CO_2 can be represented as :



18 (*b*) Formal charge on C atom of CS_2

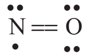
Formal charge on an atom in a Lewis structure

$$= \begin{bmatrix}\text{Total number of valence}\\ \text{electrons in the atom}\end{bmatrix} - \begin{bmatrix}\text{Total number of non -}\\ \text{bonding or lone pair } e^-\end{bmatrix} - \frac{1}{2}\begin{bmatrix}\text{Total number of bonding}\\ \text{(shared electrons)}\end{bmatrix}$$

$$= 4 - 0 - \frac{1}{2} \times 8 = 0$$

Similarly, formal charge on C atom of CO_3^{2-} is 0.

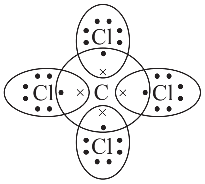
19 (*d*) Octet rule is not followed in NO. It is an odd molecule. The structural formula of NO is as follows :



20 (*c*) Carbon tetrachloride (CCl_4) has octet around central atom. The number of bonded electrons in other given compounds are as follows :

$$PF_5(10e^-),\ SF_6(12e^-),\ BF_3(6e^-)$$

Structural representation of CCl_4 is as follows :



22 (*b*) RbCl molecule bonds are non-directional because it is an electrovalent compounds.

Rest others are covalent compounds.

24 (*a*) Bond length is defined as the equilibrium distance between the nuclei of two bonded atoms in a molecule. It is measured by spectroscopic, X-ray diffraction and electron diffraction techniques.

So, bond length can be calculated in case of covalent compounds only.

Each atom of the bonded pair contributes to the bond length. In the case of a covalent bond, the contribution from each atom is called the covalent radius of that atom.

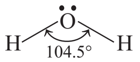
25 (*b*) The C—H is the shortest due to small size of both atoms and large electronegativity difference. The double bonds are shorter than single bonds. Hence, C=C bond is shorter than C—O and C—C. Due to electronegativity difference between C and O, the C—O bond length is shorter than C—C bond. Hence, the correct order is

$$C-H < C=C < C-O < C-C$$

26 (*a*) r_1 is covalent radius. It is half of the distance between two similar atoms joined by a covalent bond in the same molecule. r_2 is the van der Waals' radius. It represents the overall size of the atom which includes its valence shell in a non-bonded situation.

27 (*a*) H—O—H bond angle in water is 104.5°. Distribution of orbitals around the central atom in a molecule decides the bond angle.

It represented as shown below :



28 (*c*) In case of H_2O molecule, the enthalpy needed to break the two O—H bonds is not the same, i.e.

$$H_2O(g) \longrightarrow H(g) + OH(g);\quad \Delta_a H_1^s = 502 \text{ kJ mol}^{-1}$$

$$OH(g) \longrightarrow H(g) + O(g);\quad \Delta_a H_2^s = 427 \text{ kJ mol}^{-1}$$

The **mean or average bond enthalpy** of O—H bonds in case of H_2O molecule is obtained by dividing total bond dissociation enthalpy by the number of bonds broken as explained below in case of water molecule.

$$\text{Average bond enthalpy} = \frac{502 + 427}{2} = 464.5 \text{ kJ mol}^{-1}$$

29 (*c*) In CO (three shared electron pairs between C and O) the bond order is 3. For N_2, bond order is 3. H_2, Cl_2 and Br_2 have bond order 1.

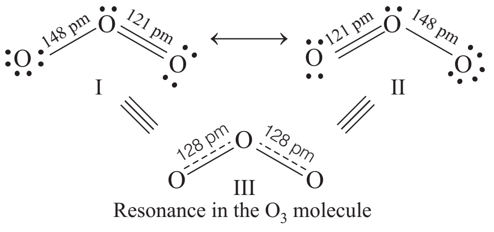
Hence, both (a) and (b) options are correct.

30 (*d*) A general correlation useful for understanding the stabilities of molecules is that, with increase in bond order, bond enthalpy increases and bond length decreases. Stability increases with increase in bond order and bond enthalpy.

Therefore, stability ∝ bond order ∝ bond enthalpy and stability increases with decrease in bond length.

$$\text{Therefore,}\quad \text{Stability} \propto \frac{1}{\text{bond length}}$$

31 (*c*) The ozone, O_3 molecule can be equally represented by the structures I and II shown below. In both structures, we have a O—O single bond



Resonance in the O_3 molecule

Structures I and II represents the two canonical forms while the structure III is the resonance hybrid.

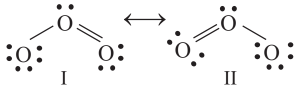
32 (*c*) The observed /calculated bond length is 128 pm due to resonance. Generally, the normal (expected) bond lengths of O — O (single) and O $=$ O (double) bond are 148 and 121 pm, respectively.

Thus, the O — O bonds in O_3 molecule are intermediate between a single and a double bond.

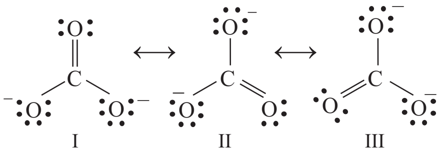
33 (*b*) Deviation of O—O bond length in ozone molecule from the normal bond length seems as single bond length decreases while double bond length increases from the normal bond length. It is due to resonance.

35 (*d*) All the given molecules can be represented in terms of resonance. These are shown below :

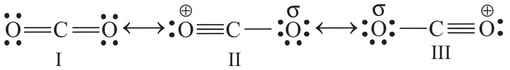
(a)



(b)

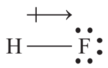


(c)



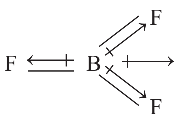
38 (*c*) In case of a heteronuclear molecule like HF, the shared electron pair between the two atoms gets displaced more towards fluorine since, the electronegativity of fluorine is far greater than that of hydrogen. The resultant covalent bond is a polar covalent bond. It is as follows :

42 (*b*) Dipole moment in HF molecule can be represented as :



This arrow symbolises the direction of the shift of electron density in the molecule. Note that the direction of crossed arrow is opposite to the conventional direction of dipole moment vector.

43 (*c*) In BF_3, the dipole moment is zero although the B — F bonds are oriented at an angle of 120° to one another, the three bond moments give a net sum of zero as the resultant of any two is equal and opposite to the third. Structure of BF_3 molecule is as follows :



44 (*b*) BeF_2 has zero dipole moment as it is symmetrical in nature. H_2O has maximum dipole moment as it possess two lone pair of electrons.

In case of NF_3, the direction of net dipole moment of three N—F bonds is opposite to that of the dipole moment of the lone pair. The dipole moment of HF is larger than NF_3 but smaller than H_2O.

The decreasing order of dipole moments of the molecules is as follows :

45 (*a*) The decreasing order of cation size is $Na^+ > Mg^{2+} > Al^{3+}$. Al^{3+} has maximum polarisation effect and Na^+ has least polarisation effect. So, the correct increasing order of covalent character is :

$$NaCl < MgCl_2 < AlCl_3$$

46 (*c*) According to Fajan's rule, compounds with small cation, large anion, more charge on cation or anion shows more covalent character. As the above conditions opposes, it shows ionic character. Since, the size of cation decreases in the following order :

$$Ba^{2+} > Ca^{2+} > Be^{2+}$$

Therefore, the correct order of ionic character will be

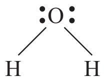
$$BeH_2 < CaH_2 < BaH_2.$$

Note BeH_2 *has some covalent character. It is because of the effect of polarisation. According to Fajan's rule, smaller the size of cation and more the charge on the cation, greater is its polarising power.*

Thus, BeH_2 has some covalent character also.

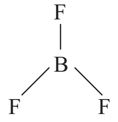
47 (*d*) PCl_3 contains three bond pairs and one lone pair around the central atom. Structural formula of all given compounds is as follows :

H_2O ⇒



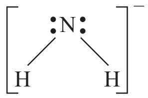
($2bp + 2lp$)

BF_3 ⇒



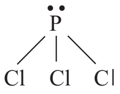
($3bp + 0lp$)

NH_2^- ⇒



($2bp + 2lp$)

PCl_3 ⇒

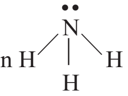


($3bp + 1lp$)

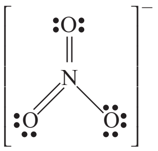
Thus, in PCl_3, the central atom P has three bond pairs and one lone pair.

48 (*c*) Repulsive effects result in deviations from idealised shapes and alterations in bond angles in the molecules. Presence of lone pair of electrons causes repulsion between lone pair-bond pair.

In $\mathrm{H}-\underset{\bullet\bullet}{\overset{\bullet\bullet}{\mathrm{O}}}-\mathrm{H}$, two lone pair of oxygen repel two bond pair of —OH.

In  one lone pair of nitrogen repel three bond pair of N—H

49 (*b*) Among the given species, NO_3^- has plane triangular shape. It is sp^2-hybridised with no lone pair of electrons on central atom N.



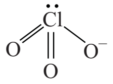
Whereas, N_3, NO_2^- and CO_2 are *sp*-hybridised with a linear shape as shown below :

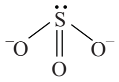
$$:\!N=\overset{+}{N}=N\!: \;;\; [O-\ddot{N}=O]^-, O=C=O$$

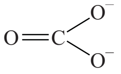
50 *(c)* IBr_2^- and XeF_2 compounds are isoelectronic and isostructural. All the given options are explanied in the following table :

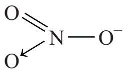
Compounds	Number of valence electrons	Geometry
$BeCl_2$	2 + 14 = 16	Linear
XeF_2	8 + 14 = 22	Linear
TeI_2	6 + 14 = 20	Bent or V-shape
IBr_2^-	7 + 14 + 1 = 22	Linear
IF_3	7 + 21 = 28	T-shape

51 (*d*) ClO_3^- ,and SO_3^{2-} ions are isoelectronic and isostructural. Structural formula of given options is as follows :









Number of electrons

$CO_3^{2-} = 4 + 18 + 2 = 24$; $SO_3^{2-} = 6 + 18 + 2 = 26$

$ClO_3^- = 7 + 18 + 1 = 26$; $NO_3^- = 5 + 18 + 1 = 24$

Hence, ClO_3^- and SO_3^{2-} are isoelectronic as both have same number of electrons and are isostructural as both are pyramidal in shape.

52 (*d*) The species with its atomic number and number of electrons are as follows :

Species (ions)	**At. no.** (*Z*)	**No. of electrons**
N^{3-}	7	7 + 3 = 10
O^{2-}	8	8 + 2 = 10
F^-	9	9 + 1 = 10
Na^+	11	11 – 1 = 10
Li^+	3	3 – 1 = 2
Mg^{2+}	12	12 – 2 = 10

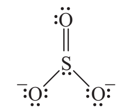
Thus, option (d) contains isoelectronic set of ions.

53 (*c*) Option (c) is correct.

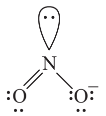
ClO_4^- is tetrahedral.

Other options are incorrect. Corrected form are as follows :

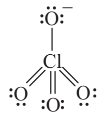
The structure with hybridisation of given compounds are as follows :



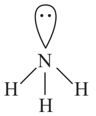
Sulphite ion (SO_3^{2-})
sp^2-trigonal planar



Nitrite ion (NO_2^-)
sp^2-bent

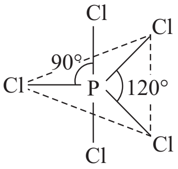


Perchlorate ion (ClO_4^-)
sp^3-tetrahedral



Ammonia (NH_3)
sp^3-pyramidal

54 (*b*) PCl_5 has trigonal bipyramidal geometry with bond angles 120° and 90°. Structure is as follows :

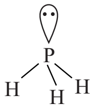
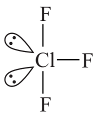
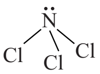
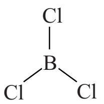


It shows sp^3d-hybridisation.

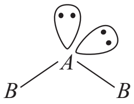
55 (*d*) The species having bond angles of 120° is BCl_3.

It is sp^2-hybridised and central atom does not have any lone pair of electrons.

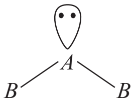
All the given species with their structure is shown in following table :

Chemical formula	Species	Bond angle
PH_3	 (Pyramidal)	93.5°
ClF_3	 (T-shaped)	90°
NCl_3	 (Pyramidal)	107.8°
BCl_3	 (Trigonal planar)	120°

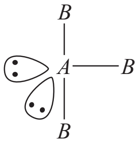
56 (*d*) Structures of AB_2E, AB_2E_2 and AB_3E_2 type molecules are as follows :



Bent shape (AB_2E)



Bent shape (AB_2E_2)



T-shaped (AB_3E_2)

Clearly from the above structures, AB_2E_2 and AB_2E has bent structure while AB_3E_2 has T-shaped.

57 (*a*) Structure I is the most stable geometry because both the lone pairs are present at equatorial position.

Due to which repulsion is minimum in molecule as compared to the repulsion in other molecules where lone pair is at axial position.

60 (*c*) In I, II, III and IV pairs, attractive force work.

Attractive forces arise between

(i) nucleus of one atom and its own electron that is $N_A - e_A$ and $N_B - e_B$.

(ii) nucleus of one atom and electron of other atom, i.e. $N_A - e_B$ and $N_B - e_A$.

Similarly, repulsive forces arise between

(i) electrons of two atoms like $e_A - e_B$.

(ii) nuclei of two atoms $N_A - N_B$.

Attractive forces tend to bring the two atoms close to each other whereas repulsive forces tend to push them apart.

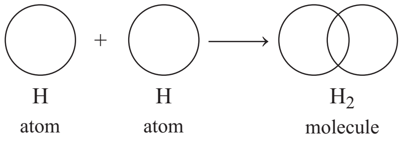
61 (*c*) At *C* point in the curve, H_2 is found in the most stable state due to minimum energy as the energy get released when bond is formed between two hydrogen atoms.

62 (*a*) Energy gets released when bond is formed between two hydrogen atoms, the H_2 molecule is more stable than isolated H atoms. The energy so released is called bond enthalpy which corresponds to minimum in the potential energy curve for the formation of H_2 molecule. Conversely 435.8 kJ energy is required to dissociate 1 mole of H_2 molecule.

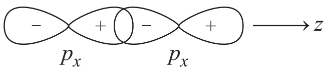
63 (*c*) In the formation of hydrogen molecule, there is a minimum energy state when two hydrogen atoms are so near that their atomic orbitals undergo partial interpenetration.

This partial merging of atomic orbitals is called overlapping of atomic orbitals which results in the pairing of electrons. The extent of overlap decides the strength of a covalent bond. In general, greater the overlap, stronger is the bond formed between two atoms.

64 (*a*) H-atom has only *s*-orbital. Therefore, *s-s* overlapping takes place in the formation of H_2 molecule. It is as follows :



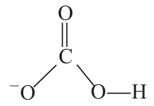
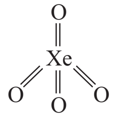
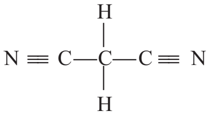
66 (*b*) Option (b) does not represent positive overlap. It is an out of phase overlap.



Thus, it shows negative overlap.

67 (*b*) XeO_4 contain equal number of σ and π-bonds.

Number of σ and π-bonds present in species are as follows :

	Structure	σ and π-bonds
(a)		σ- bond-4 π- bond-1
(b)		σ- bond-4 π- bond-4
(c)	$N \equiv C—C \equiv N$	σ- bond-3 π- bond-4
(d)	 $N \equiv C—\underset{H}{\overset{H}{C}}—C \equiv N$	σ- bond-6 π- bond-4

68 (*b*) According to Pauling, the atomic orbitals combine to form new set of equivalent orbitals known as **hybrid orbitals**. Unlike pure orbitals, the hybrid orbitals are used in the bond formation.

69 (*c*) *sp* - hybridisation involves the mixing of one *s* and one *p*-orbital resulting in the formation of two equivalent *sp*-hybrid orbitals. The suitable orbitals for *sp*-hybridisation are *s* and p_z, if the hybrid orbitals lie along the *z*-axis.

70 (*c*) The *sp*-hybridisation is also called diagonal hybridisation because it possess linear geometry.

71 (*c*) The two *sp*-hybrid points in the opposite direction along the *z*-axis with projecting more positive lobes and less negativc lobes, which provides more effective overlapping resulting in the formation of stronger bonds.

72 (*b*) NO_2^- and NO_3^- both have same hybridisation, i.e. sp^2 hybridisation and other given orbitals is as follows :

NH_2^- – sp^3-hybridisation

NH_4^+ – sp^3-hybridisation

SCN^- – *sp*-hybridisation

73 (*c*) $H_3C—\underset{\substack{\uparrow \\ sp}}{C} \equiv \underset{\substack{\uparrow \\ sp}}{C}—CH_3$ is linear due to *sp*-hybridisation of the two symmetric carbon.

74 (*c*) Maximum bond angle at nitrogen is present in NO_2^+. Bond angle along with hybridisation is given in following table :

Species	Hybridisation	Bond angle
NO_2	*sp*	less than 120°
NO_2^-	sp^2	115.4°
NO_2^+	*sp* (linear)	180°
NO_3^-	sp^2	120°

77 (*a*) Molecular orbitals which are one electron wave functions for molecules are difficult to obtain directly from the solution of Schrodinger wave electron. Schrodinger wave equation cannot be solved for any system containing more than one electron. To overcome this problem, an approximate method known as linear combination of atomic orbitals (LCAO) has been adopted.

78 (*c*) 2*s* and 2*p* atomic orbitals combine to give eight molecular orbitals. From 2*s* orbitals, $\sigma 2s$ and $\sigma^* 2s$ can be formed. From 2*p* orbital, $\sigma 2p_z, \sigma^* 2p_z, \pi 2p_x, \pi^* 2p_x$, $\pi 2p_y$ and $\pi^* 2p_y$ molecular orbitals can be formed.

79 (*b*) Linear combination of atomic orbital (LCAO) method can be used for the homonuclear diatomic hydrogen molecule consisting of two atoms *A* and *B*. Each hydrogen atom in the ground state has one electron in 1*s*-orbital. The atomic orbitals of these atoms may be represented by the wave functions ψ_A and ψ_B.

80 (*a*) In an anti-bonding molecular orbital, most of the electron density is located away from the space between the nuclei, as a result of which there is a nodal plane (i.e a plane at which the electron density is zero) between the nuclei.

84 (*a*) The electrons placed in the antibonding molecular orbital destabilise the molecule. This is because the mutual repulsion of the electrons in this orbital is more than the attraction between the electrons and the nuclei, which causes a net increase in energy.

86 (*c*) If intermolecular axis is taken to be in *z*-direction then, p_z orbital form σ-bond. p_x and p_y form π-bond.

88 (*b*) According to MO theory, C_2 is the diatomic molecular species that has only π-bonds.

The molecular orbital configuration of C_2 is

$$C_2 (Z = 12) \Rightarrow \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2.$$

Double bond in C_2 consists of both π-bonds because of the presence of last (valence) four electrons in two π-molecular orbitals.

The configuration of N_2, Be_2 and O_2 are as follows:

$$N_2 (Z = 14) - \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2, \sigma 2p_z^2 \text{ (1 σ and 2π-bonds)}$$

$$Be_2 (Z = 8) - \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2 \text{ (σ bonds only)}$$

$$O_2 (Z = 16) - \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma^* 2p_z^2, \pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^1 = \pi^* 2p_z^1 \text{ (σ, π and 1π*-bond)}$$

89 (*d*) Considering molecular orbital theory (MOT) :

The electronic configuration of

$$Li_2^+ (Z = 5) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^1$$

$$\text{Bond order (BO)} = \frac{N_b - N_a}{2} = \frac{3-2}{2} = \frac{1}{2}$$

The electronic configuration of

$$Li_2^- (Z = 7) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^1$$

$$\text{Bond order (BO)} = \frac{N_b - N_a}{2} = \frac{4-3}{2} = \frac{1}{2}$$

For the species having the same value of BO, the species having lesser number of antibonding electrons $[N_a]$ will be more stable.

Here, N_a of Li_2^+ (2) < N_a of Li_2^- (3).

So, their order of stability will be $Li_2^+ > Li_2^-$.

90 (*a*) Bond order of O_2^{2+}, O_2^+ and O_2^- are as follows :

$$O_2^{2+} = \sigma 1s^2 \overset{*}{\sigma} 1s^2 \; \sigma 2s^2 \overset{*}{\sigma} 2s^2 \sigma 2p_z^2 \; (\pi 2p_x^2 = \pi 2p_y^2)(\overset{*}{\pi} 2p_x^0 = \overset{*}{\pi} 2p_y^0)$$

$$\text{Bond order} = \frac{10-4}{2} = \frac{6}{2} = 3$$

$$O_2^{+} = \sigma 1s^2 \overset{*}{\sigma} 1s^2 \; \sigma 2s^2 \overset{*}{\sigma} 2s^2 \sigma 2p_z^2 \; (\pi 2p_x^2 = \pi 2p_y^2)(\overset{*}{\pi} 2p_x^1 = \overset{*}{\pi} 2p_y^0)$$

$$\text{Bond order} = \frac{10-5}{2} = \frac{5}{2} = 2.5$$

$$O_2^{-} = \sigma 1s^2 \overset{*}{\sigma} 1s^2 \; \sigma 2s^2 \overset{*}{\sigma} 2s^2 \sigma 2p_z^2 \; (\pi 2p_x^2 = \pi 2p_y^2)(\overset{*}{\pi} 2p_x^2 = \overset{*}{\pi} 2p_y^1)$$

$$\text{Bond order} = \frac{10-7}{2} = \frac{3}{2} = 1.5$$

So, the correct sequence of bond order is

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

91 (*b*) $O_2 (8 + 8 = 16) = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2, \overset{*}{\pi} 2p_x^1 \approx \overset{*}{\pi} 2p_y^1$

$$\text{Bond order} = \frac{10-6}{2} = 2$$

Similarly, O_2^+ $(8 + 8 - 1 = 15)$,

$$BO = \frac{10-5}{2} = 2.5$$

$\Rightarrow \quad O_2^- (8 + 8 + 1 = 17), \; BO = \frac{10-7}{2} = 1.5$

$\Rightarrow \quad O_2^{2-} (8 + 8 + 2 = 18), \; BO = \frac{10-8}{2} = 1$

$$\therefore \quad \text{Bond order} \propto \frac{1}{\text{bond length}}$$

Thus, O_2^+ has minimum bond length as its bond order is maximum.

92 (*d*) When O_2 is converted into O_2^{2+}, the paramagnetic character decreases and the bond order increases. To get O_2^{2+}, electron is removed from $\pi^* 2p_x$ and $\pi^* 2p_y$. As a result, diamagnetic species is obtain. As two electrons are removed from antibonding orbital, so bond order increases.

93 (*d*) Molecular orbital configuration of given molecules are as follows:

(a) $N_2 (Z = 14) - \sigma 1s^2, \sigma * 1s^2, \sigma 2s^2, \sigma * 2s^2, \pi 2p_x^2 \approx \pi 2p_y^2, \sigma 2p_z^2$

It is a diamagnetic molecule due to absence of unpaired electron.

(b) $H_2 (Z = 2) - 1\sigma^2$

It is a diamagnetic molecule.

(c) $Li_2 (Z = 6) - \sigma 1s^2, \sigma * 1s^2, \sigma 2s^2$

It is a diamagnetic molecule.

(d) $O_2 (Z = 16) - \sigma 1s^2, \sigma * 1s^2, \sigma 2s^2, \sigma * 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2, \pi * 2p_x^1 \approx \pi * 2p_y^1$

It is a paramagnetic molecule due to presence of unpaired electrons in each orbital of degenerate levels. Thus, option (d) is correct.

94 (*d*) Bond order $= \dfrac{N_b - N_a}{2}$

In NO, total number of electrons $= 7 + 8 = 15$

$\therefore$ Configuration of NO

$$= KK^*, \sigma(2s^2), \overset{*}{\sigma}(2s^2), \sigma(2p_z^2), \pi(2p_x^2) \approx \pi(2p_y^2), \overset{*}{\pi}(2p_x^1)$$

$\therefore$ Bond order $= \dfrac{8-3}{2} = \dfrac{5}{2} = 2.5$

In O_2^-, total number of electrons $= 16 + 1 = 17$

$\therefore$ Configuration of $O_2^- = KK^*, \sigma(2s^2), \overset{*}{\sigma}(2s^2), \sigma(2p_z^2), \pi(2p_x^2) \approx \pi(2p_y^2), \overset{*}{\pi}(2p_x^2) \approx \overset{*}{\pi}(2p_y^1)$

$\therefore$ Bond order $= \dfrac{8-5}{2} = \dfrac{3}{2} = 1.5$

In C_2^{2-}, total number of electrons $= 12 + 2 = 14$

$\therefore$ Configuration of $C_2^{2-} = K\overset{*}{K}, \sigma(2s^2), \overset{*}{\sigma}(2s^2), \sigma(2p_z^2) \pi(2p_z^2) \approx \pi(2p_y^2)$

$\therefore$ Bond order $= \dfrac{8-2}{2} = \dfrac{6}{2} = 3$

In He_2^+, total number of electrons $= 4 - 1 = 3$

$\therefore$ Configuration of $He_2^+ = \sigma(1s^2), \overset{*}{\sigma}(1s^1)$

$\therefore$ Bond order $= \dfrac{2-1}{2} = \dfrac{1}{2} = 0.5$

Hence, correct order of bond order is

$$He_2^+ < O_2^- < NO < C_2^{2-}$$

95 (d)

Species	Valence MOs	Bond Order $\left(\dfrac{N_b - N_a}{2}\right)$	Paramagnetic/Diamagnetic Nature
$NO(15e^-)$	$[8e^-]\ \pi 2p_x^2 = \pi 2p_y^2 \sigma 2p_z^2$ $\pi * 2p_x^1 = \pi * 2p_y^0 \sigma * 2pz^0$	$\dfrac{6-1}{2} = 2.5$	Paramagnetic
$-e^-$			
$NO^+ (14e^-)$	$[8e^-]\ \pi 2p_x^2 = \pi 2p_y^2 \sigma 2p_z^2$ $\pi * 2p_x^0 = \pi * 2p_y^0 \sigma * 2p_z^0$	$\dfrac{6-0}{2} = 3$	Diamagnetic
$N_2(14e^-)$	$[8e^-] \pi 2p_x^2 = \pi 2p_y^2 \sigma 2 p_z^2$ $\pi * 2p_x^0 = \pi * 2p_y^0, \sigma 2p_z^0$	$\dfrac{6-0}{2} = 3$	Diamagnetic
$-e^-$			
$N_2^+ (13e^-)$	$[8e^-] \pi 2p_x^2 = \pi 2p_y^2 \sigma\ 2p_{z1}$ $\pi * 2p_x^0 = \pi * 2p_y^0 \sigma * 2pz_0$	$\dfrac{5-0}{2} = 2.5$	Paramagnetic
$O_2(16e^-)$	$[8e^-] \sigma 2p_z^2 \pi 2p_x^2 = \pi 2p_y^2$ $\pi * 2p_x^1 = \pi * 2p_y^1 \sigma * 2p_z^0$	$\dfrac{6-2}{2} = 2$	Paramagnetic
$-e^-$			
$O_2^+ (15e^-)$	$[8e^-] \sigma 2p_z^2 \pi 2p_x^2 = \pi 2p_y^2$ $\pi * 2p_x^1 = \pi * 2p_y^0 \sigma * 2p_z^0$	$\dfrac{6-1}{2} = 2.5$	Paramagnetic
$+2e^-$			
$O_2^{2-} (18e^-)$	$[8e^-] \sigma 2p_z^2 \pi 2p_x^2 = \pi 2p_y^2$ $\pi * 2p_x^2 = \pi * 2p_y^2 \sigma * 2p_z^0$	$\dfrac{6-4}{2} = 1$	Diamagnetic

So, only in the conversion of $NO \rightarrow NO^+$, the bond order has increased $(2.5 \rightarrow 3)$ and paramagnetic character has changed to diamagnetic.

96 (*a*) During change of O_2 to O_2^-, the electron adds on π^*-orbital. The electronic configuration of O_2 (total $e^- = 16$) is

$$\sigma(1s^2), \overset{*}{\sigma}(1s^2), \sigma(2s^2), \overset{*}{\sigma}(2s^2), \sigma(2p_z^2)$$

$$\pi(2p_x^2) \approx \pi(2p_y^2), \overset{*}{\pi}(2p_x^1) \approx \overset{*}{\pi}(2p_y^1)$$

and configuration of O_2^-, (total $e^- = 17$)

$$\sigma(1s^2), \overset{*}{\sigma}(1s^2), \sigma(2s^2), \overset{*}{\sigma}(2s^2), \overset{*}{\sigma}(2p_z^2), \pi(2p_x^2)$$

$$\approx \pi(2p_y^2), \overset{*}{\pi}(2p_x^2) \approx \overset{*}{\pi}(2p_y^1)$$

Thus, electron goes in the $\overset{*}{\pi}$-orbital.

97 (*b*)

	Species and number of electrons	Molecular orbital electronic configuration	Number of unpaired electrons (*n*) and magnetic moment
1.	O_2-16 electrons	$\sigma 1s$ $\overset{*}{\sigma} 1s$ $\sigma 2s$ $\overset{*}{\sigma} 2s$ $\sigma 2p_Z$ $\pi 2p_X = \pi 2p_Y$ $\overset{*}{\pi} 2p_X = \overset{*}{\pi} 2p_Y$ $\overset{*}{\sigma} 2p_Z$ [⇅] [⇅] [⇅] [⇅] [⇅] [⇅⎮⇅] [↑⎮↑] [ ]	$n = 2, \mu = \sqrt{n(n+2)}$ $\mu = \sqrt{2 \times 4}$ BM = 2.82 BM
2.	O_2^+-15 electrons	[⇅] [⇅] [⇅] [⇅] [⇅] [⇅⎮⇅] [↑⎮] [ ]	$n = 1$, $\mu = \sqrt{1 \times 3} = 1.73$ BM
3.	O_2^--17 electrons	[⇅] [⇅] [⇅] [⇅] [⇅] [⇅⎮⇅] [⇅⎮↑] [ ]	$n = 1, \mu = 1.73$ BM

98 (*a*) Electronic configuration of O_2^{2-} $(8 + 8 + 2 = 18)$

$$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2,$$

$$\overset{*}{\pi} 2p_x^2 \approx \overset{*}{\pi} 2p_y^2$$

$$\text{Bond order (BO)} = \frac{N_b - N_a}{2} = \frac{10-8}{2} = 1$$

$$B_2 (5 + 5 = 10) = \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2\ \overset{*}{\sigma} 2s^2, \pi 2p_x^1 \approx \pi 2p_y^1$$

$$BO = \frac{6-4}{2} = 1$$

Thus, O_2^{2-} and B_2 have the same bond order.

99 *(c)* Both CN^- and CO pair have equal number of electrons. So, their bond order will be same.

Number of electrons in all species is given below :

Species	Number of electrons
CO	6 + 8 = 14
NO	7 + 8 = 15
O_2	8 + 8 = 16
NO^+	7 + 8 − 1 = 14
CN^-	6 + 7 + 1 = 14
O_2^-	8 + 8 + 1 = 17

100 (*a*) CN^- has 14 electrons (6 from C, 7 from N and 1 for negative charge).

Its MO configuration must be similar to

$$N_2 : \sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \pi 2p_x^2\ \pi 2p_y^2\ \sigma 2p_z^2$$

$$\therefore \text{ Bond order} = \frac{10-4}{2} = 3$$

As there is no unpaired electron in CN^-, thus it is diamagnetic.

101 (*b*) The formula of bond order is given as :

$$BO = \frac{\begin{bmatrix}\text{No. of electrons} \\ \text{in bonding}\end{bmatrix} - \begin{bmatrix}\text{No. of electrons} \\ \text{in antibonding}\end{bmatrix}}{2}$$

Energy level pattern for molecular orbitals of different molecules depend upon their central atom.

(a) **CN^+** Central atom is C.

[Total number of electrons =12]

$$\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, (\pi 2p_x^2 \approx \pi 2p_y^2)$$

$$BO = \frac{8-4}{2} = 2$$

(b) CN^- Central atom is C.

[Total number of electrons = 14]

$$\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, (\pi 2p_x{}^2 \approx \pi 2p_y{}^2)\ \sigma 2p_z^2$$

$$BO = \frac{10-4}{2} = 3$$

(c) NO Central atom is N. (Total number of electrons = 15)

$$\therefore \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2,$$

$$(\pi 2p_x^2 \simeq \pi 2p_y^2), \sigma 2p_z^2, (\pi^* 2p_x^1 \approx \pi^* 2p_y^1)$$

$$BO = \frac{10-5}{2} = 2.5$$

(d) **CN** Central atom is C. [Total number of electrons = 13]

$$\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, (\pi 2p_x^2 \approx \pi 2p_y^2), \sigma 2p_z^1$$

$$BO = \frac{9-4}{2} = 2.5$$

Therefore, option (b) is correct.

102 (*d*) H_2S does not show hydrogen bonding, that's why it exists as a gas, other given molecules such as HF, H_2O and NH_3 show hydrogen bonding.

103 (*d*) The boiling point of a substance increases with increase in intermolecular hydrogen bonding and molecular mass. Association of molecules takes place due to intermolecular hydrogen bonding which increases the boiling point of a substance.

105 (*c*) Statement (c) is incorrect. It's correct form is as follows :

In general, the least electronegative atom occupies the central position in the molecule/ion.

Rest other statements are correct.

106 (*b*) Statement (b) is incorrect. It's correct form is as follows :

The lowest energy structure is the one with the smallest formal charges on the atoms.

The formal charge is a factor based on pure covalent view of bonding in which electron pairs are shared equally by neighbouring atoms.

Rest other statements are correct.

108 (*d*) Statement (d) is incorrect. It's correct form is as follows :

The formation of positive ion involve ionisation enthalpy whereas the formation of negative ion involve electron gain enthalpy.

It is shown as follows :

$$M(g) \longrightarrow M^+(g) + e^- \text{ [removal of electron]}$$

This involves ionisation enthalpy

$$X(g) + e^- \longrightarrow X^-(g) \text{ [addition of electron]}$$

This involves electron gain enthalpy.

Rest other statements are correct.

111 (*c*) Statements I and III are correct while statement II is incorrect. It's correct form is as follows :

The electron gain process can be exothermic or endothermic.

116 (*a*) Statements I and II are correct while the statement III is incorrect. It's correct form is as follows :

Bond length is directly proportional to size of atoms and hybridisation but it is inversely proportional to bond order.

$$\text{Bond length} \propto \frac{1}{\text{bond order}}$$

117 (*d*) Statement (d) is incorrect. It's correct form is as follows :

For cations of the same size and charge, the one with electronic configuration $(n-1)\,d^n ns^0$, typical of transition metals is more polarising than the one with a noble gas configuration, ns^2np^6.

Rest other statements are correct.

118 (*d*) Statement (d) is incorrect.

It's correct form is as follows :

Valence shell is taken as a sphere with the electron pairs localising on the spherical surface at maximum distance from one another.

Rest other statements are correct.

119 (*c*) Statement (c) is incorrect.

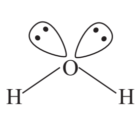
It's correct form is as follows :

The hybrid orbitals are more effective in forming stable bonds than the pure atomic orbitals.

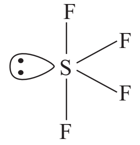
Rest other statements are correct.

120 (*d*) All the given statements are correct regarding the given structure.

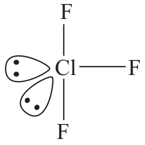
These are shown below :



Bent shape
H_2O



sea-saw shape
SF_4



T-shaped
ClF_3

121 (*d*) Among the given statements, correct statements are I and III only. Valence bond theory (VBT) cannot explain the colour exhibited by transition metal complexes. This theory cannot distinguish ligands as weak and strong field ones.

122 (*c*) Statement III is incorrect.

It's correct form is as follows :

In N_2 molecule, one σ-bond is formed by axial overlapping of *p*-orbitals and 2π bonds are formed by lateral overlapping of *p*-orbitals.

Rest other statements are correct.

123 (*c*) Statements II and III are correct while statement I is incorrect. It's correct form is as follows :

When O_2 is converted into O_2^{2+} bond order increases.

124 (*c*) Statement (c) is incorrect.

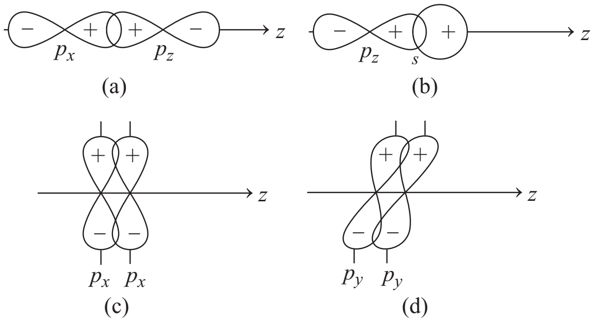
It's correct form is as follows :

The combining atomic orbitals must overlap to the maximum extent.

Rest other statements are correct.

125 (*a*) Orbitals forming bond should have same sign (phase) and orientation in space. This is called positive overlap. Various overlaps of *s* and *p*- orbitals are depicted below :

Positive or in phase overlap



(a) (b) (c) (d)

126 (*c*) Option (c) is not the essential condition for hybridisation are as follows :

Promotion of electron is not essential condition prior to hybridisation.

127 (*c*) Statement (c) is correct while the other statements are incorrect.

Corrected form are as follows :

Molecular orbitals of diatomic molecules are designated as σ (sigma), π(pi), δ (delta) etc.

In this nomenclature, the sigma (σ) molecular orbitals are symmetrical around the bond-axis while pi (π) molecular orbitals are not symmetrical, e.g. the linear combination of 1*s* orbitals centred on two nuclei produces two molecular orbitals which are symmetrical around the bond axis.

129 (*a*) Statements I, II are correct whereas statements III and IV are incorrect. Corrected form are as follows :

III. The formation of positive ions involve ionisation enthalpy and negative ions involve electron gain enthalpy.

IV. Hydrogen bonding is the characteristic feature of those polar molecules which contain a covalent bond between H and any electronegative atoms among F, O, N.

130 (*a*) A bonding molecular orbital always possesses lower energy than either of the atomic orbitals that have overlapped to form it because electron placed in a bonding molecular orbital tend to hold the nuclei together and stabilise a molecule.

Thus, statement (a) is correct.

133 (*d*) All the given statements are incorrect.

Corrected statements are as follows :

Hydrogen bonding is the characteristic feature of those polar molecules only which contain a covalent bond between H and any of the electronegative elements among F, O, N.

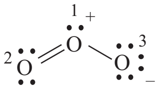
134 (*a*) In case of polyatomic ions, the net charge is possessed by the ion as a whole and not by a particular atom and the

$$\begin{bmatrix}\text{Formal}\\ \text{charge on}\\ \text{atom}\end{bmatrix} = \begin{bmatrix}\text{Total valence}\\ \text{electrons in}\\ \text{free atom}\end{bmatrix} - \begin{bmatrix}\text{Total non - bonding}\\ \text{electrons (lone pair)}\end{bmatrix}$$

$$-\frac{1}{2}[\text{Total shared electrons}]$$

Thus, both A and R are correct; R is the correct explanation of A.

135 (*a*) The Lewis structure of O_3 is as follows :

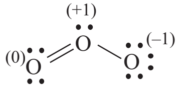


Formal charge on $O_1 = 6-2-\frac{1}{2}(6)=+1$

Formal charge on $O_2 = 6-4-\frac{1}{2}(4)=0$

Formal charge on $O_3 = 6-6-\frac{1}{2}\times 2=-1$

Hence, correct representation of O_3 is



Thus, both A and R are correct; R is the correct explanation of A.

136 (*b*) Formal charge help in the selection of lowest energy structure from a number of possible structures for a given species. Formal charge do not indicate real charge separation within the molecule.

Thus, both A and R are correct but R is not the correct explanation of A.

137 (*c*) Fluorine is highly reactive because F—F bond has low bond dissociation energy.
Thus, A is correct but R is incorrect.

138 (*a*) Due to presence of vacant *d*-orbital on S-atom, it can expand its octet as in the case of H_2SO_4 .

Thus, both A and R are correct. R is the correct explanation of A.

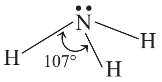
139 (*c*) Sulphur has vacant *d*-orbital so it can expand its octet.

In general, it forms many compounds which obey octet rule.

Thus, A is correct and R is incorrect.

140 (*b*) The NH_3 molecule has sp^3-hybridisation with one lone pair of electrons, i.e. it is AB_3E type molecule.

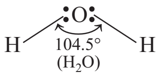
NH_3 possesses a one lone pair. Due to the repulsion between *lp-bp* (which is more than *bp-bp* repulsion), the angle between bond pairs is reduced to 107° from 109.5°.



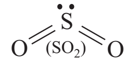
Thus, both A and R are correct; R is not the correct explanation of A.

141 (*c*) H_2O has two lone pairs of electrons on oxygen atom. while SO_2 has one lone pair of electron.

Both possess bent shape as shown below :



Due to *lp*-*lp* repulsion, it has bent shape.



Due to *lp*-*bp* repulsion it has bent shape.

Thus, A is correct but R is incorrect.

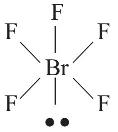
142 (*a*) In (a), the lone pair is present at axial position, so there are three *lp*-*bp* repulsions at 90°. In (b) the lone pair is at equatorial position and there are two *lp*-*bp* repulsions. Hence, arrangement (b) is more stable.

The shape shown in (b) is described as a distorted tetrahedron, a folded square or a *see-saw.*

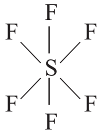
Thus, both A and R are correct; R is the correct explanation of A.

143 (*b*) Both BrF_5 and SF_6 both have sp^3d^2 hybridisation but the shape of molecules is different. BrF_5 is square pyramidal and SF_6 is octahedral.

It is as follows :



Square pyramidal



Octahedral

Thus, both A and R are correct; R is not the correct explanation of A.

144 (*b*) According to assumptions of MOT, the atomic orbitals which undergo LCAO must have the comparable energy because each specific orbital have its own specific energy depending upon various quantum number and their sum.

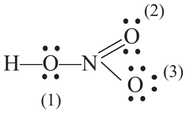
Thus, both A and R are correct, R is not the correct explanation of A.

145 (*c*) The linear combination of atomic orbitals to form molecular orbitals takes place, if the combining atomic orbitals must have the same or nearly the same energy.

1*s* orbital can not combine with another 2*s* orbital but with 1*s*-orbitals because the energy of 2*s* orbitals is appreciably higher than that of 1*s* orbital. This is not true, if the atoms are very different.

Thus, A is correct; R is incorrect.

146 (*c*) In the given molecule,



A. For $O_{(1)}$

Formal charge $= 6 - \frac{1}{2}(4) - 4 = 0$

B. For $O_{(2)}$

Formal charge $= 6 - \frac{1}{2}(4) - 4 = 0$

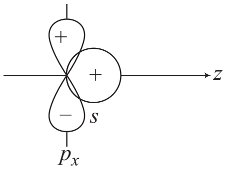
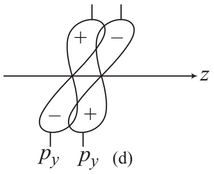
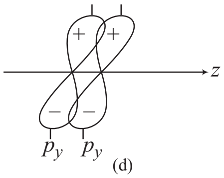
C. For $O_{(3)}$

Formal charge $= 6 - \frac{1}{2}(2) - 6 = -1$

Thus, the correct match is :

$$A \rightarrow 1, B \rightarrow 1, C \rightarrow 2$$

149 (*c*) The correct match is $A \rightarrow 2, B \rightarrow 3, C \rightarrow 1$

A.		Zero overlap (Out of phase due to different orientation or direction of approach)
B.		Negative overlap (Orbitals forming bond have different sign and orientation)
C.		Positive overlap (Orbitals forming bond have same sign and orientation in space)

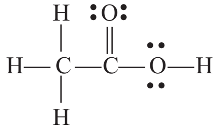
152 (*c*) C_2, Li_2 are diamagnetic.

O_2 is paramagnetic, He_2 does not exist.

Hence, correct match is

$$A \rightarrow 3, B \rightarrow 1, C \rightarrow 2, D \rightarrow 2$$

153 (*a*) Option (a) is the correct Lewis structure for acetic acid is,



Options (b) and (c) are not correct.

154 (*b*) Ionic character ∝ lattice energy

$\propto \frac{1}{\text{size of ion}} \propto$ charge on ion.

A non-polar molecule like N_2 has almost negligible ionic character. Hence, the correct increasing order of ionic character is :

$$N_2 < SO_2 < ClF_3 < K_2O < LiF$$

155 (*c*) $2p_y$ and $2p_y$ will not form a σ-bond. Because on taking *x*-axis as the internuclear axis, $2p_y$ and $2p_y$ orbitals overlap sideway (lateral overlapping) resulting in the formation of a π-bond.

156 (*a*) The electronic configuration of the most electronegative element is : $2s^2 2p^5$ (fluorine)

157 (*b*) The electronic configuration of options (b) and (d) have exactly half-filled $3p$ orbitals (b) represents phosphorus and (c) represents arsenic but (b) is smaller in size than (d).

Hence, (b) has highest ionisation enthalpy among the given options.

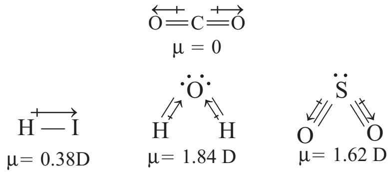
158 (*d*) The given electronic configuration shows that the element is titanium ($Z = 22$). It belongs to *d*-block of the periodic table. In transition elements, i.e. *d*-block elements, electrons of *ns* and $(n-1)\,d$- subshell take part in bond formation. Hence, $3d^2, 4s^2$ contain 4 electrons which will be involved in chemical bond formation.

159 (*c*) In PO_4^{3-} ion, formal charge on each O-atom of P—O bond, i.e. average formal charge

$$= \frac{\text{total charge}}{\text{number of O-atoms}} = -\frac{3}{4} = -0.75$$

160 (*c*) Among HI, SO_2 and H_2O, dipole moment is highest for H_2O as in it the central atom contains 2 lone pairs and also due to maximum electronegativity difference between H and O-atoms.

CO_2 being symmetrical has zero dipole moment.

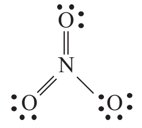


161 (*d*) In N-atom, number of valence electrons = 5

Due to the presence of one negative charge, number of valence electrons = 5 + 1 = 6. In NO_3^- ion, one O-atom forms two bond (= bond) and two O-atom shared with two electrons of N-atom.

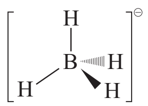
Thus, 3 O-atoms shared with 8 electrons of N-atom.

∴ Number of bond pairs (or shared pairs) = 4
Number of lone pairs = 0



162 (*a*) BH_4^s has tetrahedral geometry.

It's structure is



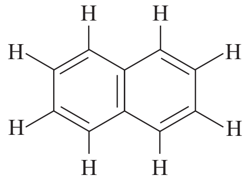
The geometry of other options are as follows :

$NH_2^- =$ V-shape, $CO_3^{2-} =$ Triangular planar,

$H_3O^+ =$ Pyramidal

163 (*c*) In C_2H_4 (ethene), all bonds are not equal. The molecule consist of one double bond and two single bonds. Double bond is shorter than single bond. Whereas all other bonds are equal.

164 (*c*) The given compound will have the correct structure as :



(Naphthalene)

There are 5 π-bonds and 8 C — H + 11C — Cσ-bonds, i.e. 19 σ-bond are present in the above molecule.

165 (*a*) The correct increasing order of energies of molecular orbitals of N_2 is given below :

$$\sigma 1s < \overset{*}{\sigma} 1s < \sigma 2s < \overset{*}{\sigma} 2s < (\pi 2p_x \approx \pi 2p_y) < \sigma 2p_z < (\overset{*}{\pi} 2p_x \approx \overset{*}{\pi} 2p_y) < \overset{*}{\pi} 2p_z$$

166 (*c*) O_2^{2-} does not contain unpaired electrons.

It is as follows :

$$O_2^{2-} = 18 \text{ electrons -} \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2, \overset{*}{\pi} 2p_x^2 \approx \overset{*}{\pi} 2p_y^2$$

Thus, O_2^{2-} has no unpaired electrons.

The electronic configuration of the other given molecules are as follows :

(a) $N_2^+ = 13 \text{ electrons -} \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \pi 2p_x^2 = \pi 2p_y^2, \sigma 2p_z^1$

It has one unpaired electron

(b) $O_2 = 16 \text{ electrons -} \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2, \overset{*}{\pi} 2p_x^1 \approx \overset{*}{\pi} 2p_y^1$

O_2 has two unpaired electrons.

(c) $B_2 = 10 \text{ electrons -} \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \pi 2p_x^1 \approx \pi 2p_y^1$

Thus, B_2 has two unpaired electrons.

167 (*b*) Electronic configuration of O_2 (16 electrons)

$$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2, \overset{*}{\pi} 2p_x^1 \approx \overset{*}{\pi} 2p_y^1$$

$$\text{Bond order} = \frac{1}{2}(N_b - N_a) = \frac{1}{2}(10 - 6) = 2$$

Electronic configuration of O_2^+ (15 electrons)

$$= \sigma 1s^2, \overset{*}{\sigma} 1s^2, \sigma 2s^2, \overset{*}{\sigma} 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2, \overset{*}{\pi} 2p_x^1 \approx \overset{*}{\pi} 2p_y^0$$

$$\text{Bond order} = \frac{1}{2}(N_b - N_a) = \frac{1}{2}(10-5) = 2.5$$

Electronic configuration of O_2^- (17 electrons)

$$= \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2,$$
$$\overset{*}{\pi} 2p_x^2 \approx \pi^* 2p_y^1$$

$$\text{Bond order} = \frac{1}{2}(N_b - N_a) = \frac{1}{2}(10-7) = 1.5$$

Thus, the order of bond order is

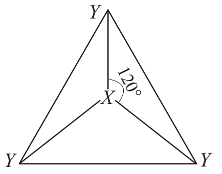
$$O_2^- < O_2 < O_2^+$$

168 (*d*) Option (d) is incorrect regarding molecular orbital theory.

The correct order of energies of molecular orbitals in N_2 molecule is

$$\sigma 2s < \sigma^* 2s < \sigma 2p_z (\pi 2p_x \simeq \pi 2p_y) < \sigma 2p_z$$
$$< (\pi^* 2p_x \approx \pi^* 2p_y < \sigma^* 2p_z)$$

169 (*b*) For sp^2- hybridisation 120° is the bond angle and the geometry is generally triangular planar.



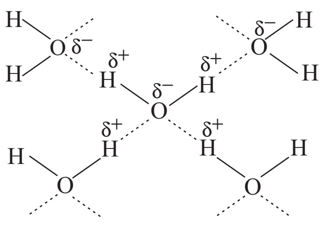
170 (*b*) The type of hybrid orbitals of nitrogen in NO_2^+, NO_3^- and NH_4^+ respectively are sp, sp^2 and sp^3 respectively.

171 (*b*) BF_4^- and NH_4^+ both are isostructural pairs. Both are tetrahedral and sp^3-hybridised. Explanations of other are as follows :

(a) NF_3 is pyramidal whereas BF_3 is planar triangular.
(b) BCl_3 is triangular planar whereas $BrCl_3$ is T-shaped.
(c) NH_3 is pyramidal whereas NO_3^- is triangular planar.

172 (*b*) H_2O will form strongest hydrogen bond.

Only H_2O forms hydrogen bonds. One H_2O molecule forms four H-bonds.



HCl, HI and H_2S do not form H-bonds due to presence of less electronegative and large size of Cl, I and S-atoms.

173 (*b*) Strength of H-bond is in the order

$$\overset{\delta^+}{H} \ldots \overset{\delta^-}{F} > \overset{\delta^+}{H} \ldots\ldots \overset{\delta^-}{O} > \overset{\delta^+}{H} \ldots\ldots \overset{\delta^-}{N}$$

But each H_2O molecule is linked to four other H_2O molecules through H-bonds, whereas each HF molecule is linked only to two other HF molecules.

Hence, correct decreasing order of boiling points is

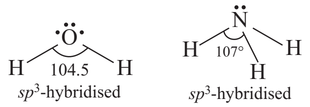
$$H_2O > HF > NH_3.$$

174 (*a*) A and R both are correct and R is the correct explanation of A.

$$\underset{(2,\,8,\,1)}{Na} + \underset{(2,\,8,\,7)}{Cl} \longrightarrow \underset{\substack{(2,\,8)\\(2,\,8,\,8)}}{NaCl}$$

Hence, both Na^+ and Cl^- have complete octet, hence NaCl is stable.

175 (*a*)



Thus, both A and R are correct and R is the correct explanation of A.

176 (*d*) The bond enthalpies of the two O—H bonds in H—O—H are not equal.

This is because electronic environment around O is not same after breakage os one O—H bond.

Thus, A is incorrect but R is correct.

177 (*d*) A. → 3; B. → 4; C. → 1; D. → 2

A. $NO\ (7+8=15) = \sigma 1s^2, \sigma^* 1s^2; \sigma 2s^2, \sigma^* 2s^2,$
$$\sigma 2p_z^2, \pi 2p_x^2 \approx \pi 2p_y^2, \pi^* 2p_x^1$$

$$\text{Bond order} = \frac{1}{2}(N_b - N_a) = \frac{10-5}{2} = 2.5$$

B. $CO\ (6+8=14) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2,$
$$\sigma 2p_z^2, \pi 2p_x^2 \approx \pi^* 2p_y^2$$

$$\text{Bond order} = \frac{10-4}{2} = 3.0$$

C. $O_2^- (8+8+1=17) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2,$
$$\sigma 2p_z^2, \pi 2\pi_x^2 \approx \pi 2p_y^2, \pi^* 2p_x^2 \approx \pi^* 2p_x^1$$

$$\text{Bond order} = \frac{10-7}{2} = 1.5$$

D. $O_2 (8+8=16) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2,$
$$\pi 2p_y^2, \pi^* 2p_x^1 \simeq \pi^* 2p_y^1$$

$$\text{Bond order} = \frac{10-6}{2} = 2.0$$