

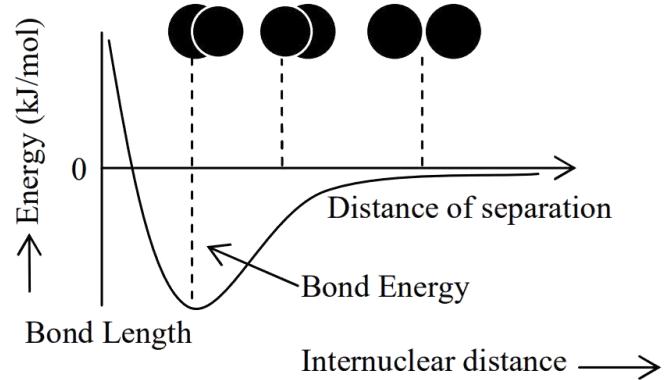
LECTURE NUMBER - 1

CHEMICAL BOND

The attractive force which holds various constituents (atoms, ions, etc.) together in different chemical species is called a chemical bond.

1. Tendency to acquire minimum energy:

- (a) When two atoms approach to each other- Nucleus of one atom attracts the electrons of another atom.
- (b) Two nuclei and electrons of both the atoms repel each other.
- (c) If net result is attraction, then the total energy of the system (molecule) decreases. A chemical bond is formed when the net energy of system is least
- (d) The amount of energy released during bond formation is known as 'Bond Energy'.
- (e) Bond formation is an exothermic process.

**2. Tendency to acquire noble gas configuration (Octet rule):**

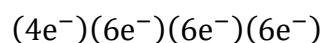
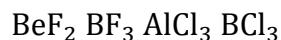
Atoms combine to complete an octet of electrons in their outer most shell. Hence all atoms have a tendency to acquire octet ($s^2 p^6$) configuration or to attain nearest noble gas configuration in their outermost orbit. This can be achieved by combining with other atom or ion.

EXCEPTIONS TO OCTET RULE**1. Transition metal ions**

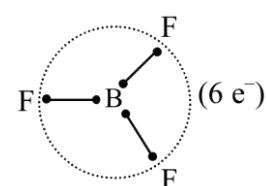
Cr^{3+}	Mn^{2+}	Fe^{2+}
[Ar]3 d ³	[Ar]3 d ⁵	[Ar]3 d ⁶
[2,8,11]	[2,8,13]	[2,8,14]

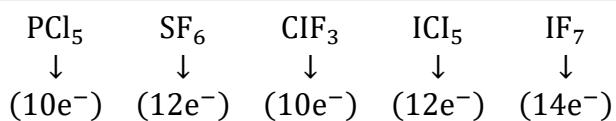
2. Pseudo inert gas configuration [$s^2 p^6 d^{10}$]

Zn^{2+}	Cd^{2+}
[Ar]3 d ¹⁰	[Kr]4 d ¹⁰

3. Contraction of octet (incomplete octet)

These compounds are hypovalent.

**4. Expansion of Octet (due to empty d-orbitals)**

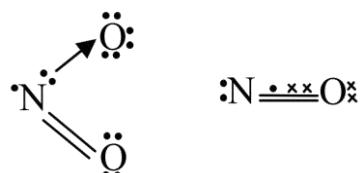


These compounds are hypervalent

5. Odd electron species

Species which contain odd number of electrons are called Odd electron species.

Ex. NO , NO_2 , ClO_2 etc.



6. Compounds of Noble gases

Noble gases which have already completed their octet (or duplet in case of He.) should not form compounds. However, their compounds like XeF_2 , XeF_6 & KrF_2 etc., have been actually prepared.

Que. Find the number of chemical specie(s) which does not follow octet rule.

BF_3 , PCl_5 , SF_4 , AlF_3 , CH_4 , SnCl_2 , NO_2

Sol. BF_3 , PCl_5 , SF_4 , SnCl_2 , NO_2

Classification of Bonds

(On the basis of bond energy)

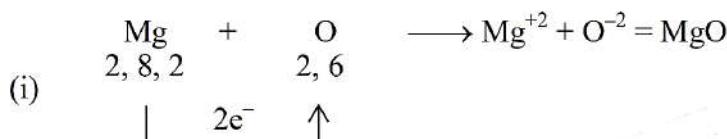
Types of Bonds

Chemical Bond	Force of attraction		
	Hydrogen Bond	Vander Waal's Bond	Other Interaction
1. Ionic Bond	1. Inter-molecular	1. Dipole – Dipole	1. Ion – Dipole
2. Covalent Bond	Hydrogen Bond	Interaction	Interaction
3. Co-ordinate Bond	2. intra-molecular	2. Dipole – Induced	2. Ion – Induced
4. Metallic Bond	Hydrogen Bond	Dipole Interaction	Dipole Interaction
		3. Instantaneous dipole – Induced dipole	
		Interaction	

ELECTROVALENT OR IONIC BOND

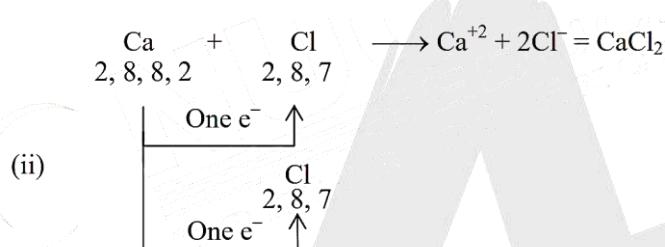
- (a)** The chemical bond formed between two or more atoms as a result of the complete transfer of one or more electrons from one atom to another is called as Ionic or electrovalent bond.
- (b)** Electropositive atom loses electron

- (c) Electronegative atom gains electron
 (d) Electrostatic force of attraction between cation and anion is called ionic bond or electrovalent bond.
 (e) Total number of electrons lost or gained is called electrovalency.

Ex.

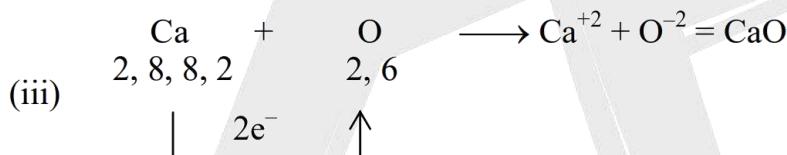
electrovalency of Mg = 2

electrovalency of O = 2



electrovalency of Ca = 2

electrovalency of Cl = 1

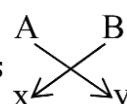
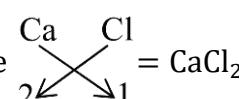


electrovalency of Ca = 2

electrovalency of O = 2

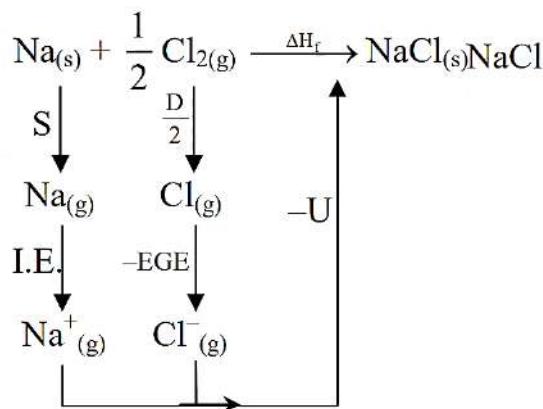
(f) A definite three dimensional structure is formed called crystal lattice.**(g)** The force of attraction is equal in all direction so ionic bond is non-directional.**(h)** Ionic compound do not have molecular formula. It has only empirical formula.**Ex.** NaCl is empirical formula of sodium chloride

Representation of formula of ionic compounds:

(a) Write the symbols of the ions side by side in such a way that positive ion is at the left and negative ion is at the right as A^+B^- **(b)** Write their electrovalencies in figure at the top of each symbol as $\text{A}^{+x}\text{B}^{-y}$ **(c)** Now apply criss-cross rule as  i.e. formula A_yB_x .Example : Calcium chloride  $= \text{CaCl}_2$

FORMATION OF IONIC COMPOUND- BORN HABER CYCLE

A whole series of energy changes are involved when one starts from the elements and finishes with an ionic crystal. These changes are shown in the Born-Haber cycle. Formation of NaCl (s) involves.



$$\text{thus, } S + \text{I.E.} + \frac{D}{2} - \text{EGE} - U = \Delta H_f$$

here, S = heat of sublimation of Na(s)

I.E. = ionisation enthalpy of Na(g)

D = bond dissociation energy of Cl₂(g)

EGE = electron gain enthalpy of Cl(g)

U = lattice energy

ΔH_f = heat of formation of NaCl(s)

FACTORS FAVOURING IONIC BONDING**(a) Ionisation energy :**

Lesser Ionization energy → Greater tendency to form cation.

Ex. Na > Mg > Al
Cs > Rb > K > Na > Li } Cation formation tendency

(b) Electron affinity:

Higher electron affinity → Greater tendency to form anion.

Ex. Cl > F > Br > I anion formation tendency

(c) Lattice energy :

Greater lattice energy

(d) Overall lowering of energy:

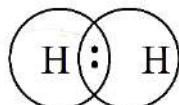
Energy must be released during bond formation.



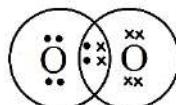
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COVALENT BOND

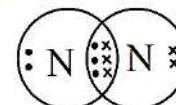
(a) A covalent bond is formed by the mutual sharing of electrons between two atoms to complete their octet. (Except H which completes its duplet)



$H - H$;
H₂ molecule



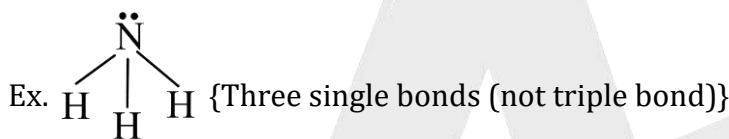
$\ddot{O} = \ddot{O}$;
O₂ molecule



$\ddot{N} \equiv \ddot{N}$
N₂ molecule

(b) The shared pair of electrons must have opposite spins, and are localised between two atoms concerned.

(c) On the basis of electrons being shared between two atoms the bonds are of three types –



H – H (Single bond), O = O (Double bond), N ≡ N [Triple bond (not three single bond)].

Classification of covalent bond:

1. Classification on the basis of number of covalent bond.

Single bond * Double bond * Triple bond

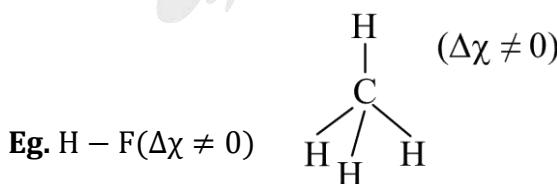
Note-1: Maximum number of covalent bond between two atoms is three

Note-2: Maximum number of σ and π bond between two atoms is 1 and 2 respectively.

Exception: $[Cl_4Re \equiv ReCl_4]^{-2}$

2. Classification on the basis of polarity of bond :

(a) **Polar bond**- Covalent bond in which the electronegativity difference between of combining atoms is non zero.



(b) **Non-polar bond** - Covalent bond in which the electronegativity difference is zero.

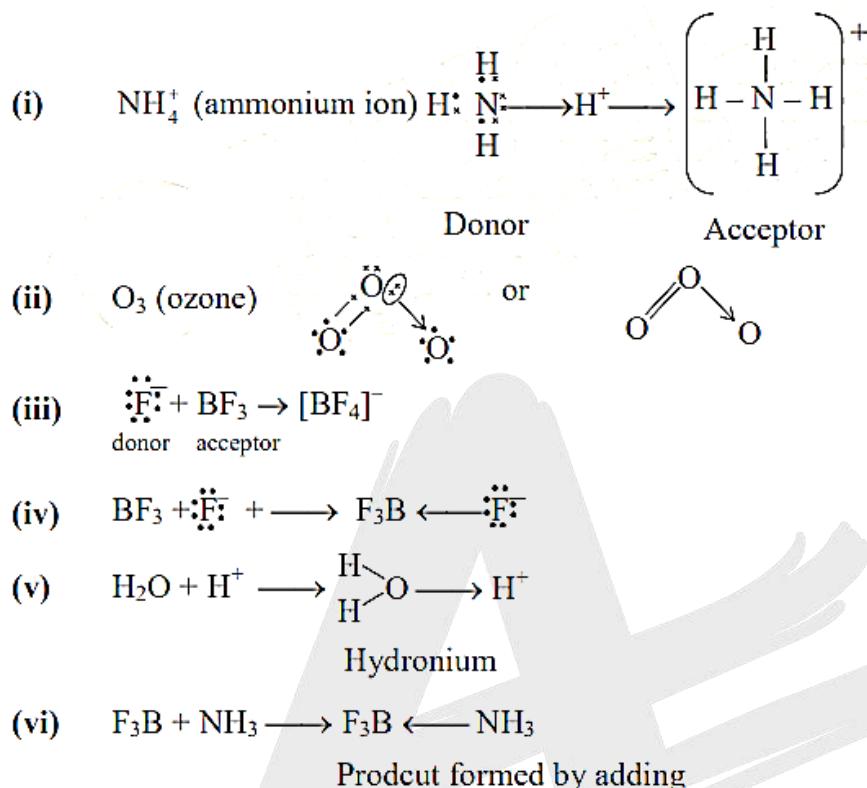
Eg. $H - H$ $O = O$
 $\Delta\chi = 0$ $\Delta\chi = 0$

3. Classification on the basis of overlapping (Discuss in VBT)

(a) Sigma (σ) bond (b) pi (π) bond

COORDINATE BOND (DATIVE BOND)

The bond formed between two atoms in which 'contribution of an electron pair is made by one of them while the sharing is done by both.



Note: Lewis base : Chemical species which can donate electron pair.

Ex. F^- , NH_3 , H_2O , CN^- , HN_3 , NO_2^- , $\text{N}(\text{CN}_3)_3$, SO_4^{2-}

Lewis acid: Chemical species which can accept an electron pair.

Ex. BF_3 , BCl_3 , PCl_3 , Fe^{+2} , H^+ , Me_3B , AlCl_3 , SiF_4 etc

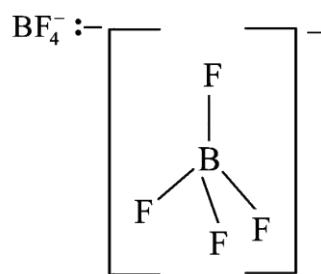
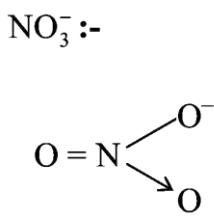
Other example

NO_3^- , N_3^- , HNO_3 , N_2O , HNC

Que. The species having co-ordinate bond from the following options is/are-

- (A) CO_3^{2-} (B) NO_3^- (C) NO_2^- (D) BF_4^-

Ans. (BD)



VALENCY

Valency: Combining capacity of an element is called valency.

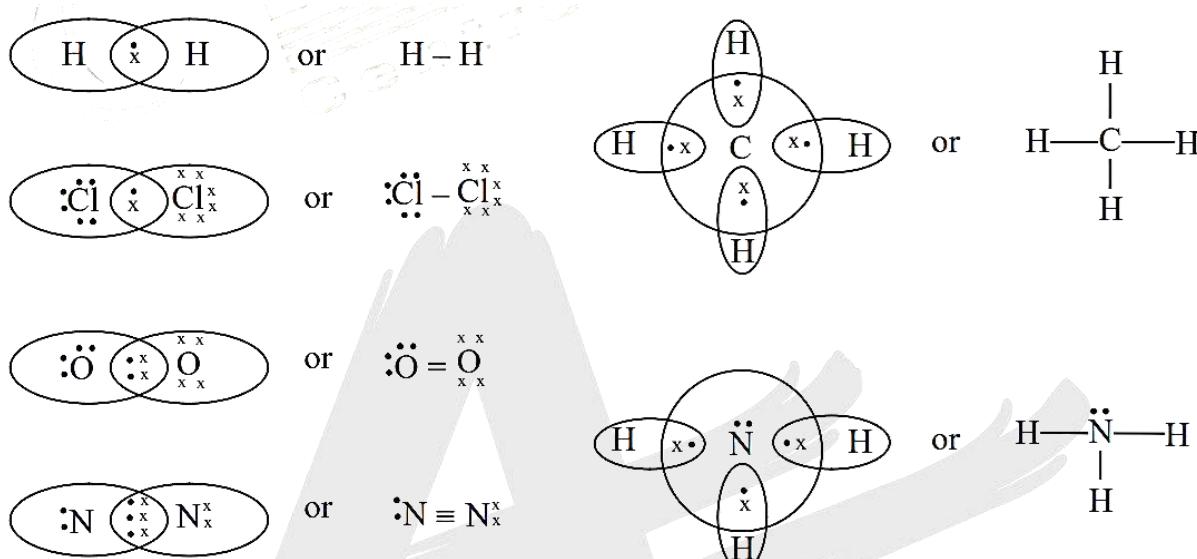
**ELECTROVALENCY**

It is defined as the number of electron gain or loss of an atom during ionic bond formation.

Ex. In NaCl the electrovalency of Na and Cl is 1 and 1 respectively.

COVALENCY: Capacity to form covalent bond is known as covalency

It is represented by (—) small line. means single bond; = means double bond; \equiv means triple bond.

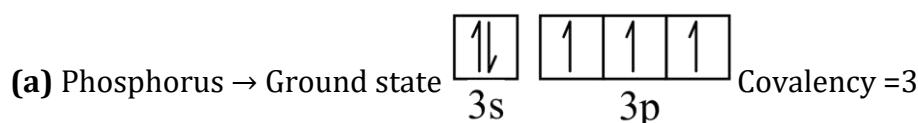
**FIXED COVALENCY**

Due to non-availability of vacant 'd' orbital in N, O, F therefore these elements does not shows variable covalency.

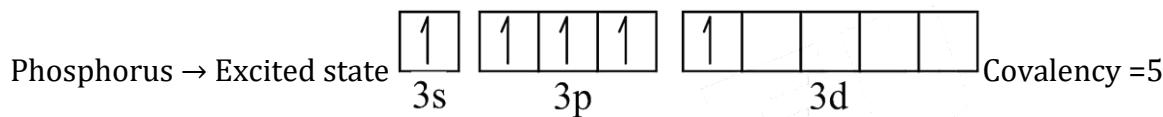
VARIABLE COVALENCY

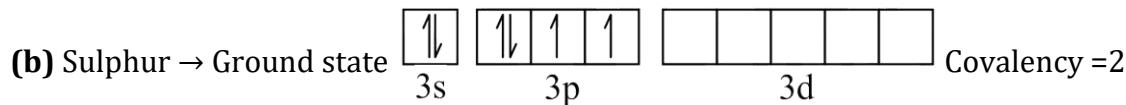
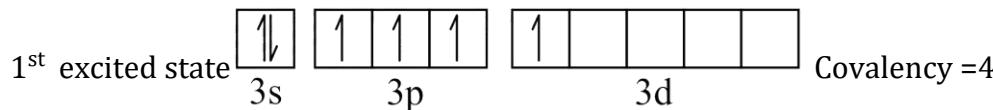
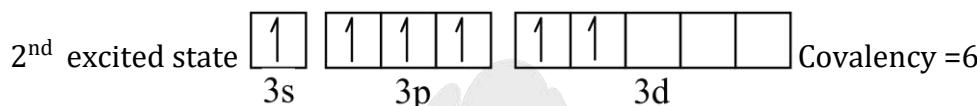
- Variable valencies are shown by those elements which have empty orbitals in outermost shell.
- Lone pair electrons gets excited in the subshell of the same shell to form the maximum number of unpaired electrons.
- The energy required for excitation of electrons is called promotion energy.
- Promotion rule - Excitation of electrons in the same orbit.

Example:-

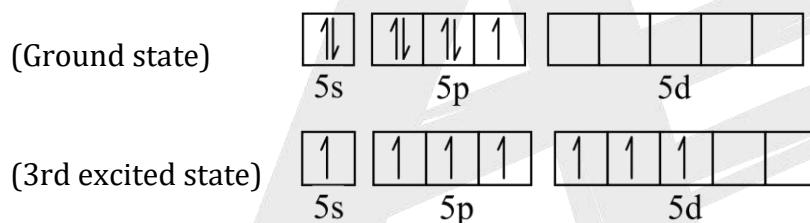


Ex: (PCl_3)



Ex: (PCl_5) Ex: (SF_2) Sulphur \rightarrow Excited stateEx: (SF_4) Ex: (SF_6)

So variable covalencies of S is 2,4 & 6.

(c) Iodine has three lone pair of electronsEx.: IF_7

So, it shows three excited states - Maximum number of unpaired electrons = 7 Variable Valencies are 1,3,5,7

Que. PCl_5 is formed but NCI_5 does not why?**Ans.** Due to non-availability of vacant 'd' orbital in N.**Que.** SF_4 is formed but OF_4 does not why?**Ans.** Same as above**Que.** Fluorine show only one covalency but other halogen can show variable covalency**Ans.** same as above**DO YOURSELF - 1**

1. Which of the following is an example of super octet molecule ?

- | | |
|--------------------|--------------------|
| (A) ClF_3 | (B) PCl_5 |
| (C) IF_7 | (D) All the three |
2. In which of the following species the bonds are non-directional ?
- | | |
|---------------------|--------------------|
| (A) NCl_3 | (B) RbCl |
| (C) BeCl_2 | (D) BCl_3 |



3. The maximum covalency is equal to -
(A) The number of unpaired p-electrons
(B) The number of paired d-electrons
(C) The number of unpaired s-and p-electrons
(D) The actual number of s-and p-electrons in the outermost shell
4. What is the number of lone pairs present in XeOF_4 ?
(A) 1 (B) 2 (C) 3 (D) 4
5. A covalent bond is possible between :
(A) Only similar atoms (B) Only dissimilar atoms
(C) Similar and dissimilar atoms (D) Similar molecules



LECTURE NUMBER - 3

OXIDATION NUMBER

- It is an imaginary or apparent charge gained by an element when it goes from its elemental free state to combined state in molecules ..
- It is calculated on basis of arbitrary set of rules.
- It is a relative charge in a particular bonded state.

Rules governing oxidation number:

The following rules are--helpful in calculating oxidation number of the elements in their different compounds. It is remember that the basis of these rule is the electronegativity of the element

- **Fluorine atom :** Fluorine is most electronegative atom (known). It always has oxidation number equal to, -1 in all its compounds.

- **Oxygen atom :** In general and as well as in its oxides, oxygen atom has oxidation number equal to -2 .

In case of :

(i) peroxide (e.g. H_2O_2 , Na_2O_2) is -1 .

(ii) super oxide (e.g. KO_2) is $-\frac{1}{2}$

(iii) ozonide (KO_3) is $-\frac{1}{3}$

(iv) oxygen fluoride OF_2 is +2 & in $\text{O}_2 \text{F}_2$ is +1

- **Hydrogen atom :** In general, H atom has oxidation number equal to +1 . But in metallic hydrides (e.g. NaH , KH) it is -1 .

- **Halogen atom :** In general, all halogen atom (Cl, Br, I) has oxidation number equal to-1. But if halogen atom is attached with more electronegative atom then halogen atom will show positive oxidation numbers.



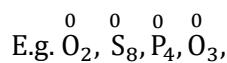
- **Metals :**

(a) Alkali metal (Li, Na, K, Rb, ..) always have oxidation number +1 .

(b) Alkaline earth metal (Be, Mg, Ca) always have oxidation number +2 . Note: Metal may have positive or zero oxidation number.

(c) Aluminium always have +3 oxidation number

(d) Oxidation number of an element in free state or in allotropic forms is always zero.



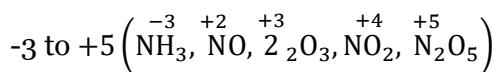
(e) Sum of the charges of elements in a molecule is zero.



(f) Sum of the charges of all elements in an ions is equal to the charge on the ion.

(g) If the group no. of an element in periodic table is n then its oxidation number may vary from n to n – 8 (but it is mainly applicable in p-block elements)

E.g. N-atom belongs to group- V in the periodic table therefore as per rule its oxidation number may vary from



- **Calculation of average oxidation number :**

Solved Examples :

Ex. Calculate oxidation number of underlined element $\text{Na}_2 \underline{\text{S}}_2\text{O}_3$:

Sol. Let oxidation number of S-atom is x. Now work accordingly with the rules given before.

$$(+1) \times 2 + (x) \times 2 + (-2) \times 3 = 0$$

$$x = +2$$

Ex. $\text{Na}_2\underline{\text{S}}_4\text{O}_6$:

Sol. Let oxidation number of S-atom is x

$$(+1) \times 2 + (x) \times 2 + (-2) \times 6 = 0$$

$$x = +2.5$$

- It's important to note here that $\text{Na}_2 \text{S}_2\text{O}_3$ have two S-atom and there are four S-atom in $\text{Na}_2 \text{S}_4\text{O}_6$ but sulphur atom in both the compound have +2 or +2.5 oxidation number, it is the average charge (Oxidation Number) Which reside on each sulphur atom therefore we should work to calculate the individual oxidation number of each sulphur atom in these compound.

Ex. Calculate the oxidation state of all the atoms in the following species :

- ClO^-
- NO_2^-
- NO_3^-
- CCl_4
- K_2CrO_4
- KMnO_4

Sol. (i) In ClO^- , the net charge on the species is -1 and therefore the sum of the oxidation states of Cl and O must be equal to -1 . Oxygen will have an oxidation state of -2 and if the oxidation state of Cl is assumed to be ' x ' then $x - 2$ should be equal to -1 . So x is +1
(ii) NO_2^- : $2 \times (-2) + x = -1$ (where ' x ' is oxidation state of N)

$$\therefore x = +3$$

$$(iii) \text{NO}_3^- : x + 3 \times (-2) = -1 \text{ (where ' x ' is oxidation state of N)}$$

$$x = +5$$



(iv) In CCl_4 , Cl has an oxidation state of -1

$$x + 4 \times (-1) = 0$$

$$\therefore x = +4$$

(where 'x' is oxidation state of C)

(v) K_2CrO_4 : K has O.S. of +1 and O has oxidation state of -2 and let Cr has oxidation state 'x' then,

$$2x + 1 + x + 4 \times (-2) = 0$$

$$\therefore x = +6$$

(vi) KMnO_4 : $+1 + x + 4 \times (-2) = 0$

$$\therefore x = +7$$

(where x is oxidation state of Mn).

Ex.2 Calculate the oxidation state in the following:

$$\text{NOF}_3 \quad x + (-2) + 3(-1) = 0$$

$$x = +5$$

$$\text{SF}_4 \quad x + 4(-1) = 0$$

$$x = +4$$

$$\text{H}_2\text{SO}_4 \quad 2(+1) + x + 4(-2) = 0$$

$$x = +6$$

$$\text{HNO}_3 \quad 1 + x + 3(-2) = 0$$

$$x = +5$$

$$\text{XeF}_5^+ \quad x + 5(-1) = +1$$

$$x = +6$$

$$\text{XeF}_5^- \quad x + 5(-1) = -1$$

$$x = +4$$

$$\text{XeO}_6^{4-} \quad x + 6(-2) = -4$$

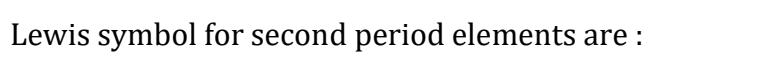
$$x = +8$$

LECTURE NUMBER - 4

LEWIS DOT STRUCTURES OR LEWIS SYMBOLS

Lewis introduced simple notations to represent valence election in an atom. These notations are called Lewis symbols or Lewis dot structure.

Lewis symbols for atoms and monoatomic ions :



Number of dots around the symbol represents the number of valence electrons.

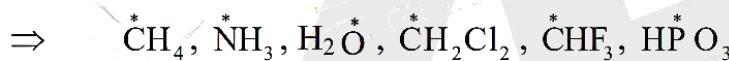


Lewis symbol for some anions are

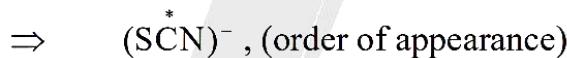
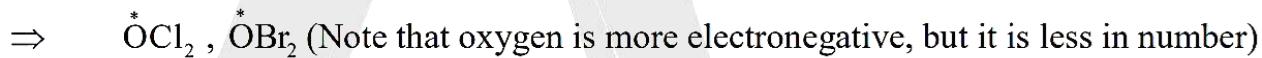


How to draw the Lewis electron dot/Bond line structure of inorganic covalent compounds:

1. (i) First of all, identify the central atom in the given species. Central atom in a given molecule/ion is usually that atom which is least electronegative.
- (ii) Hydrogen can't be central atom as its covalency is one.
- (iii) Sometimes the central atom is that atom which is less in number.
- (iv) Sometimes the central atom in the given molecule/ion can't be decided on the basis of electronegativity or number of atoms (less). In such cases, that atom is central atom which appears in central position of given formula of molecule/ion. To make it more clear, central atoms in the following species are starred (*).



(Note—that electronegativity of H is less than that of central atom).

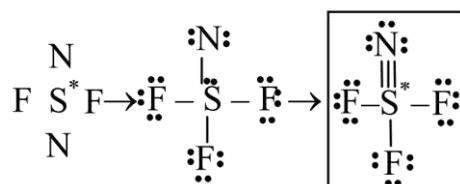


2. Surrounding atoms are the atoms which are directly bonded to central atom.
3. Arrange the surrounding atoms around the central atom and first form single bond between all surrounding atom with central atom.
4. Always make sure that octet of all the surrounding atoms is complete. It is not achieved by forming single bond, then try to make the double bond or triple bond between central atom and surrounding atom, as required to complete the octet of surrounding atoms.

e.g., CO₂



SNF₃





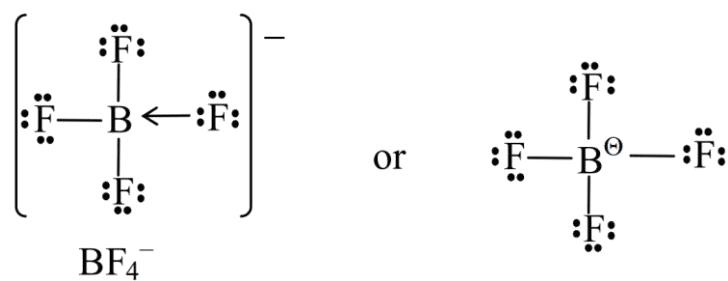
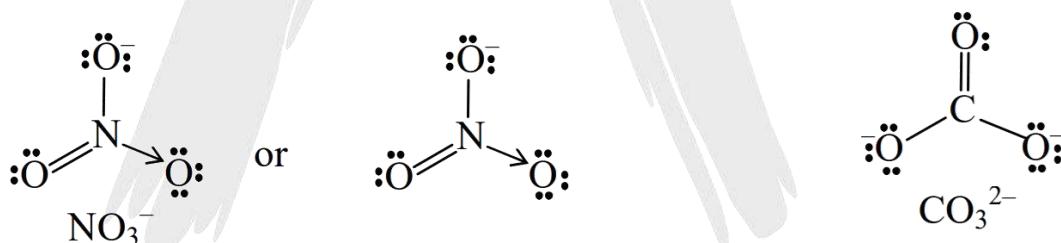
5. After the bond formation, represent the lone pair of electrons on central atom as well as on surrounding atoms.
6. Make sure that, in the structure you have made, the octet of the all surrounding atoms must be completed.
7. If the central atom belongs to second period, it can have < 8 (max.) electrons (i.e. < 4 bonds) but never greater than 8 electrons (i.e. > 4 bonds).
8. However, if the central atom belongs to third or lower period it can have > 8 electrons.
9. At last verify the covalency of central atom.

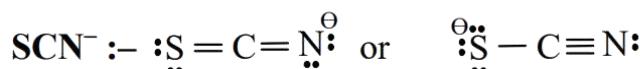
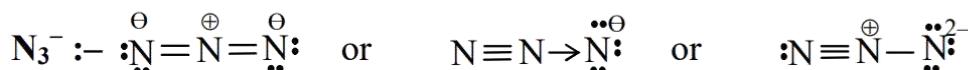
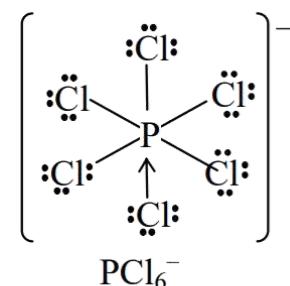
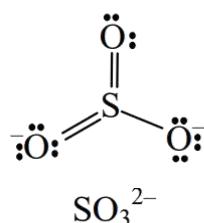
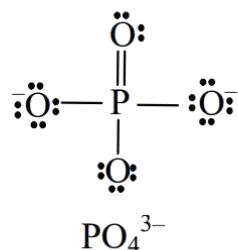
10. Lewis Structure of ions :

Distribute the negative charge on surrounding atom in such a way that octet of none of the surrounding atom is complete before the bond formation with central atom. If however, the octet of surrounding atom is complete by making it uninegatively charged (particularly in case of halogen which contains seven valence electron), then such surrounding atom will attach itself with central atom through a co-ordinate covalent bond.



But the above structures of NO_3^- is incorrect as the central nitrogen belongs to second period, it can never form five covalent bond i.e., it can't have more than 8 electrons, so its actual structure is :





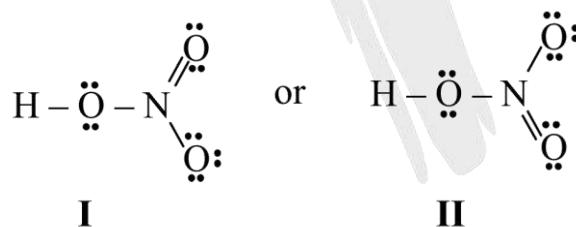
FORMAL CHARGE

Lewis dot structures, in general, do not represent the actual shapes of the molecules. In case of polyatomic ions, the net charge is possessed by the ion as a whole and not by a particular atom. It is, however, feasible to assign a formal charge on each atom.

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. It is expressed as :

Formal charge (F.C.) on an atom in a Lewis structure	$= \left(\text{Total number of valence electron in the free atom} \right) - \left(\text{Total number of non bonding (lone pair) electrons} \right) - \frac{1}{2} \left(\text{Total number of bonding(shared) electrons} \right)$
--	---

Ex. to calculate the formal charges on the various atoms of nitric acid (HNO_3) molecule which has been described by the following Lewis structures:



The H atom : It has one valence electron, zero lone pair (or zero nonbonding electrons), and forms one bond (two bonding electrons).

Substituting in Eq. (i), we write $FC = (1) - (0) - \frac{1}{2}(2) = 0$

The O atom bonded to H : It has six valence electrons, two lone pairs (or four nonbonding electrons), and form two bonds (or four bonding electrons).

Hence, we write $FC = (6) - (4) - \frac{1}{2}(4) = 0$



The N atom: It has five valence electrons, zero lone pair (or zero nonbonding electrons), and forms four bonds (or has eight bonding electrons).

$$\text{Thus, we write } FC = (5) - (0) - \frac{1}{2}(8) = +1$$

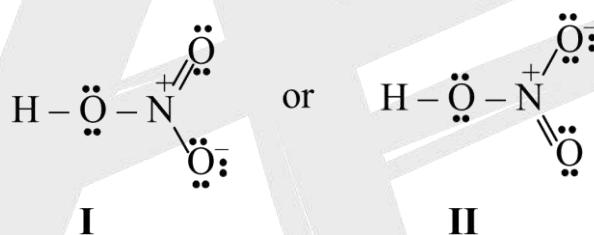
The end O atom in N = O : It has six valence electrons in the free state but in the Lewis structure (I or II), it has two lone pairs (or four nonbonding electrons) and forms two bonds (or has four bonding electrons).

$$\text{Thus, we can write } FC = (6) - (4) - \frac{1}{2}(4) = 0$$

The end O atom in N – O: It has six valence electrons in the free state but in the Lewis structure (I or II), it has three lone pairs or six nonbonding electrons and forms one bond (or has two bonding electrons).

$$\text{thus, we write } FC = (6) - (6) - \frac{1}{2}(2) = -1$$

We can now write the Lewis structures (I and II) for nitric acid molecule including the formal charges as:-

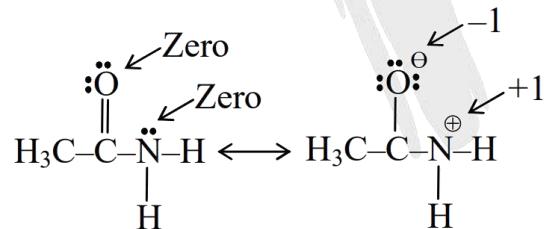


Molecule	Structure	Formal charge
O^3		$O(1) = 6 - 2 \frac{1}{2}(6) = +1$ $O(2) = 6 - 4 - \frac{1}{2}(4) = 0$ $O(3) = 6 - 6 - \frac{1}{2}(2) = -1$
SO_2		$S = 6 - 2 - \frac{1}{2} \times 6 = +1$ $O(1) = 6 - 6 - \frac{1}{2} \times 2 = -1$ $O(2) = 6 - 4 - \frac{1}{2} \times 4 = 0$

CO	$\ddot{\text{C}} \equiv \ddot{\text{O}}$	$C = 4 - 2 - \frac{1}{2} \times 6 = -1$ $O = 6 - 2 - \frac{1}{2} \times 6 = +1$
CN^θ	$\overline{\text{C}} \equiv \ddot{\text{N}}$	$C = 4 - 2 - \frac{1}{2} \times 6 = -1$ $N = 5 - 2 - \frac{1}{2} \times 6 = 0$
NH_4^+	$\left[\begin{array}{c} \text{H}^1 \\ \\ \text{N} \\ / \quad \backslash \\ \text{H}^2 \quad \text{H}^4 \\ \\ \text{H}^3 \end{array} \right]^+$	$N = 5 - 2 - \frac{1}{2}(8) = +1$ On each H = $1 - 0 - \frac{1}{2}(2) = 0$
NO_2^-	$\begin{array}{c} \text{I} & \text{N} & \text{(II)} \\ : \ddot{\text{O}} & \equiv & \ddot{\text{O}} : \\ & & \end{array}$	$N = 5 - 2 - \frac{1}{2}(6) = 0$ $O(I) = 6 - 4 - \frac{1}{2}(4) = 0$ $O(II) = 6 - 6 - \frac{1}{2}(2) = -1$

Formal charges help in the selection of the lowest energy structure from a number of possible Lewis structures for a given species. Generally the lowest energy structure is the one with the smallest formal charges on the atoms.

For example:



This structure is
Lower in energy

This structure is
Higher in energy

Formal charges are useful for helping decide which of the several possible Lewis structures is best.

1. A Lewis structure with small formal charges are preferable to large formal charges.
2. Lewis structure with negative formal charges on the more electronegative atom are preferable than Lewis structures with negative formal charges on the less electronegative atom.



3. Lewis structures with unlike charges close together are more likely than Lewis structure with opposite charges widely separated.
4. Lewis structures with like charges on adjacent atoms are very unlikely.

LECTURE NUMBER – 5

Hypovalent compound : The covalent compound in which central atom having less than 8 valence electron.

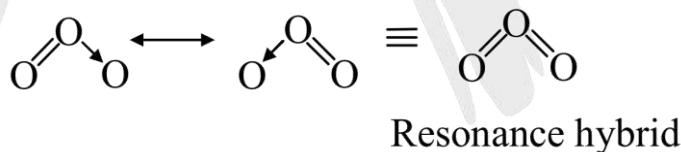
Ex. BF_3 , BeCl_2 etc.

Hypervalent compound : The covalent compound in which central atom having greater than 8 valence electron.

Ex. PC_5 , IF_7 , SF_6 etc.

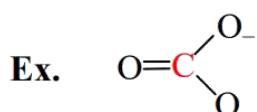
RESONANCE

- (a) The concept of resonance was introduced by Heisenberg (1920), and later developed by Pauling and Ingold, to explain the properties of certain molecules.
- (b) It has been found that the observed properties of certain compounds cannot be satisfactorily explained by writing a single lewis structure. The molecule is then supposed to have many structures, each of which can explain most of the properties of the molecule but none can explain all the properties of the molecules. The actual structure is in between of all these contributing structures and is called resonance hybrid and the different individual structures are called resonating structures or canonical forms. This phenomenon is called resonance.
- (c) Let us discuss resonance in ozone, according to its resonance structure it should have one single bond ($\text{O} - \text{O} = 1.48\text{\AA}$) but experiments show that both the bonds are same which can be proved by its resonance hybrid as shown below.

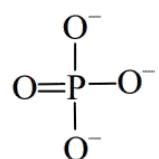


To calculate bond order in the polyatomic molecule or ion use following formula :

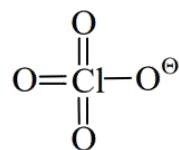
$$\text{Bond order} = \frac{\text{Total number of bonds in a molecule}}{\text{Resonating Structures}}$$



$\text{Bond order} = \frac{4}{3} = 1.33$



$\text{Bond order} = \frac{5}{4} = 1.25$

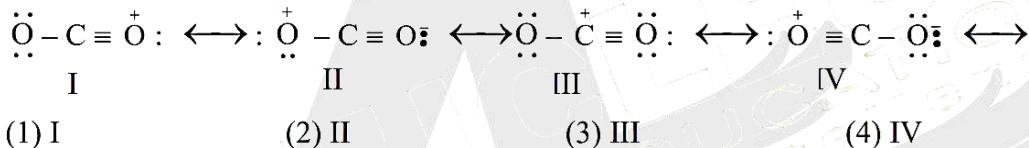


$\text{Bond order} = \frac{7}{4} = 1.75$

Q.1 Which of the following ions has resonating structures?

- (1) SO_4^{2-} (2) PO_4^{3-} (3) SO_3^{2-} (4) All of these

Q.2 Which of the following resonating structure is correct for CO_2 ?



Q.3 How many resonating structures can be drawn for NO_2 ?

- (1) Six (2) Four (3) Five (4) Two

Q.4 Which of the following is true for nitrate anion?

- (1) Formal charge on N is zero (2) Bond order of NO bond is $\frac{4}{3}$
 (3) Average formal charge on oxygen is $-\frac{1}{3}$ (4) There are 2π -bonds in the ion

Q.5 Discuss resonance and formal charge in N_3^- and N_2O ?

Q.6 Give the average formal charge and average bond order of X – O bond in the following oxy compounds?

- (a) SO_4^{2-} (b) SO_3^{2-} (c) NO_2^- (d) ClO_2^- (e) ClO_3^- (f) ClO_4^-
 (g) HCO_3^- (h) CO_3^- (i) HSO_3^- (j) PO_4^{3-}

LECTURE NUMBER - 6 & 7

VALENCE BOND THEORY

Valence bond theory was introduced by Heitler and London (1927) and developed further by Pauling and others. A discussion of the valence bond theory is based on the knowledge of atomic orbitals, electronic configurations of elements, the overlap criteria of atomic orbitals and the hybridization of atomic orbitals.

Formation of H_2 molecule : When two 'H'-atoms approaches towards each other for the formation of H_2 molecule. The following interactions takes place.

- (i) e-e repulsion
- (ii) e-p attraction
- (iii) p-p repulsion

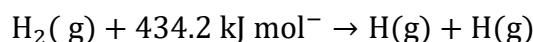
Experimentally, it has been found that the magnitude of attractive forces is more than the repulsive forces. As a result, when two atoms approach each other then potential energy decreases. Ultimately a stage is reached where the net force of attraction balances the force of repulsion and system acquires minimum energy.

At this stage two hydrogen atoms are said to be bonded together to form a stable molecule having the bond length of 74pm. Since the energy gets released when the bond is formed between two hydrogen atoms, the hydrogen molecule is more stable than that of isolated hydrogen atoms.

Bond Length : Internuclear distance at minimum potential energy is called bond length.

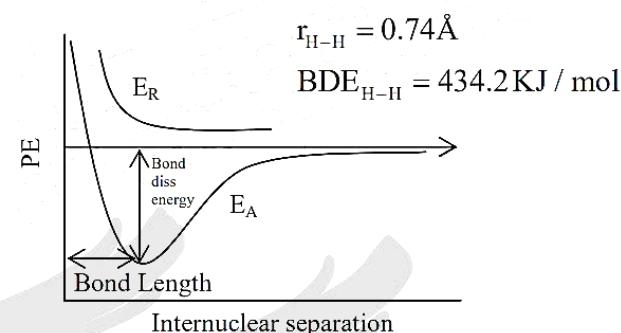
Bond Dissociation Energy : The amount of energy released when one mole of same type of bonds are formed is called B.D.E.

434.2 kJ/mol of energy is required to dissociate one mole of H_2 molecule.



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 the pairing of electrons. The extent of overlap decides the strength of a covalent bond. In general, greater the overlap the stronger is the bond formed between two atoms. Therefore, according to orbital



The potential energy curve for the formation of H_2 molecule as a function of internuclear distance of the H atoms. The minimum in the curve corresponds to the most stable state of H_2 .

overlap concept, the formation of a covalent bond between two atoms results by pairing of electrons, present in the valence shell having opposite spins.

Directional Properties of Bonds :

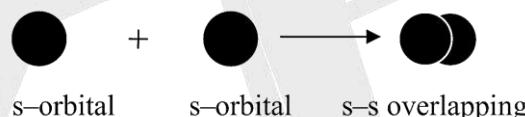
The valence bond theory explains the formation and directional properties of bonds in polyatomic molecules like CH_4 , NH_3 , and H_2O , etc. in terms of overlap and hybridisation of atomic orbitals.

Types of Overlapping and Nature of Covalent Bonds

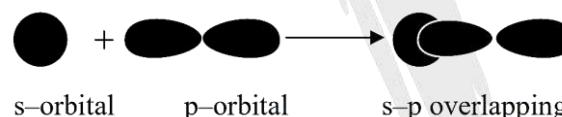
The covalent bond may be classified into following types depending upon the types of overlapping :-

- (i) sigma (σ) bond
- (ii) pi (π) bond
- (iii) delta (δ) bond

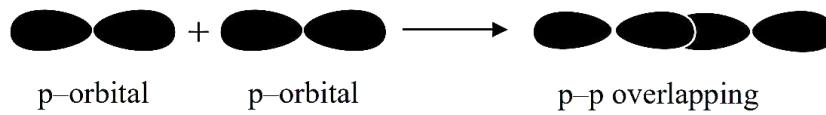
- (i) Sigma (σ) bond :** This type of covalent bond is formed by the end to-end (head on or axial) overlap of bonding orbitals along the internuclear axis. This can be formed by any one of the following types of combinations of atomic orbitals.
- s-s overlapping : In this case, there is overlap of two half filled s-orbitals along the internuclear axis as shown below :



- s-p overlapping : This type of overlap occurs between half filled s-orbital of one atom and half filled p-orbital of another atom.

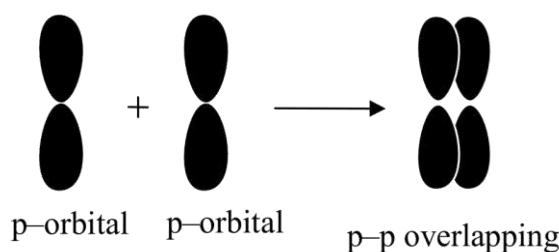
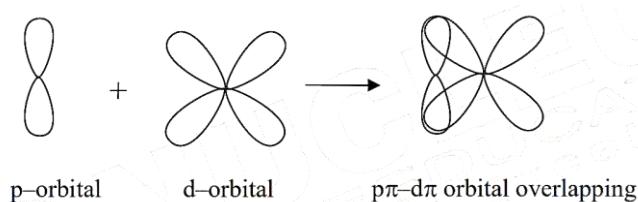
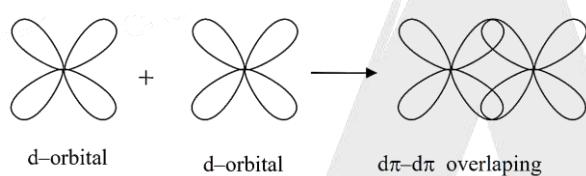


- p-p overlapping : This type of overlap takes place between half filled similar p-orbitals of the two approaching atoms.

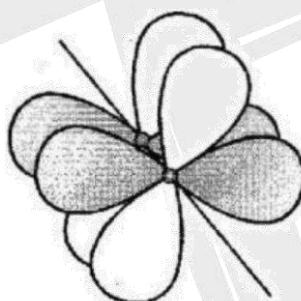


- (ii) pi (π) bond :** In the formation of π bond the atomic orbitals overlap in such a way that their axis remain parallel to each other and perpendicular to the internuclear axis. The orbitals formed due to sidewise overlapping consists of two saucer type charged clouds above and below the plane of the participating atoms.

- (a) $\mathbf{p}_{\pi} - \mathbf{p}_{\pi}$**

**(b) $p_{\pi} - d_{\pi}$** **(c) $d_{\pi} - d_{\pi}$** 

(iii) delta (δ) bond : are the covalent bonds where four lobes of d-orbital of one atom overlap with four lobes of the similar d-orbital of other atom. Except d_{z^2} all d orbitals form δ bond.



Q.1 In which molecule s - p overlapping occurs?

- (a) CH_4 (2) NH_3 (3) H_2O (4) All are wrong

Sol. (4) Because s - p overlapping occurs only in diatomic molecules.

Q.2 Predict the nature of bond

Orbitals	Internuclear axis	Bond
$s + s$	any axis	σ
$s + p_x$	x-axis	σ
$s + p_y$	y-axis	σ
$s + p_z$	z-axis	\times
$p_x + p_x$	x-axis	σ
$p_y + p_y$	y-axis	σ
$p_z + p_z$	z-axis	σ
$p_x - p_x$	y or z-axis	π
$p_y + p_y$	x or z axis	π
$p_z + p_z$	x or y axis	π



$d_{xy} + p_x$	y-axis	π
$d_{xy} + p_y$	x-axis	π
$d_{xy} + p_z$	anyaxis	\times
$d_{xy} + p_x$	x-axis	\times
$d_{xy} + p_y$	z-axis	\times
$d_{yz} + p_y$	z-axis	π
$d_{yz} + p_z$	y-axis	π
$d_{xz} + p_x$	z-axis	π
$d_{xz} + p_z$	x-axis	π

Strength of sigma and pi Bonds :

Basically the strength of a bond depends upon the extent of overlapping- In case of sigma bond, the overlapping of orbitals takes place to a larger extent. Hence, it is stronger as compared to the pi bond where the extent of overlapping occurs to a smaller extent. Further, it is important to note that pi bond between two atoms is formed in addition to a sigma bond. It is always present in the molecules containing multiple bond (double or triple bonds)

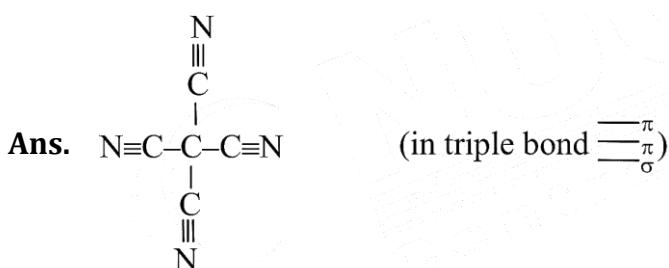
Advantages of VBT :

- It explains various bond characteristics e.g., bond length, bond strength.
- It explains the quantitative relationship between the extent of overlapping and bond dissociation energy.
- This theory accounts for shape and nature of bonding of the molecule whose covalency is not according to the number of half-filled orbitals present in the ground state.
- This theory redefined the stability of molecules e.g. BF_3 , $AlCl_3$, PCl_5 , SF_6 etc which are exception to octet rule.

Disadvantages of VBT :

- According to this theory three bond angle in CH_4 should be 90° , as these are formed by p-p overlapping, but actually it has six $109^\circ 28$ angles. In NH_3 & H_2O , angle should be 90° . This is in disagreement with the actual bond angles of 107° & 104.5° in NH_3 & H_2O molecules respectively.
- In order to explain the characteristic geometrical shapes of polyatomic molecules like CH_4 , NH_3 , H_2O etc. Pauling introduced the concept of hybridisation.

Ex.1 What are the total number of σ & π bonds in tetracyanomethane.



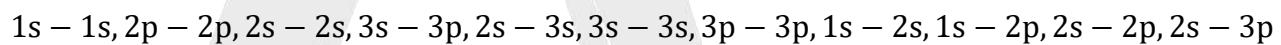
From the structure it is clear that it has 8σ and 8π bonds.

Comparison between Sigma and π bond

	σ bond	π bond	
1	Formed by axial overlapping	1	Formed by side by side overlapping
2	Involves s-s, s-p, p-p (axial) \& hybrid orbitals	2	Involve p-p, p-d & d-d orbital
3	Extent of overlapping is stronger	3	Extent of overlapping is less so weaker
4	Free rotation around σ bond is possible	4	Free rotation around π bond is not possible
5	Hybridized or unhybridized orbital forms σ bond	5	Hybridized orbital never forms π bond
6	Independent existence of σ -bond.	6	No independent existence.

Practice Set

Q.1 Give correct order of bond strength for σ bond.



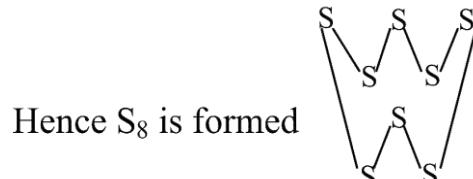
Sol. $1s - 1s > 1s - 2p > 1s - 2s > 2p - 2p > 2s - 2p > 2s - 2s > 2s - 3p > 2s - 3s > 3p - 3p > 3s - 3p > 3s - 3s$

Hint: If internuclear distance is incomparable than B.S. \propto Bond distance

If internuclear distance is comparable than B.S. \propto Extent of overlapping (directional of nature)

Q.2 O_2 exists but S_2 does not exist at room temperature? Why?

Sol. For S_2 , $3p\pi - 3p\pi$ bond is less effective.



Q.3 Compare bond strength.



Sol. $HF > HCl > HBr > HI$ $1s - 2p 1s - 3p 1s - 4p 1s - 5p$



Q.4 According to the valence bond theory, when a covalent bond is formed between two reacting atoms, the potential energy of the system becomes-

- (1) negative (2) positive (3) minimum (4) maximum

Q.5 The strongest covalent bond is formed by the overlap of-

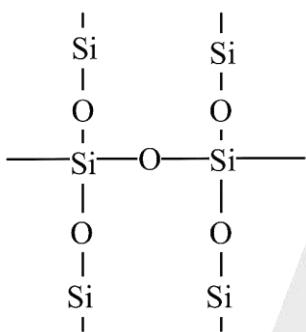
- (1) s and p orbitals (2) s and s orbitals (3) p and d orbitals (4) p and p collateral orbitals

Q.6 Explain

- (i) N_2 exist but P_2 does not (ii) CO_2 is gas but SiO_2 is covalent solid.

Sol. (i) For P_2 , $3p_\pi - 3p_\pi$ bonding is not effective.

(ii) In SiO_2 , Si does not have tendency to form π -bond so as the size increases the π bond formation tendency decreases. Due to large size of Si. Hence it forms 3D network structure.



Q.7 If x is the internuclear axis then which overlapping results π bond

- (1) $d_{xy} - d_{xy}$ (2) $p_x - p_y$ (3) $s - p_x$ (4) $p_x - p_x$

Ans. (1)

Sol. $p_x - p_y \rightarrow$ zero overlapping $s - p_x \rightarrow \sigma$ bond $p_x - p_x \rightarrow \sigma$ bond $d_{xy} - d_{xy} \rightarrow \pi$ bond

DO YOURSELF - 2

Q.1 A sigma bond is formed by the overlapping of :

- (A) s-s orbital alone (B) s and p orbitals alone
 (C) s-s, s-p or p-p orbitals along internuclear axis
 (D) p-p orbital along the sides

Q.2 Which of the following compound is formed in the second excitation state of sulphur atom?

- (A) SF_4 (B) SF_6 (C) SF_2 (D) None

Q.3 The strength of bonds by $2s - 2s$, $2p - 2p$ and $2p - 2s$ overlapping has the order:

- (A) $2s - 2s > 2p - 2p > 2s - 2p$ (B) $2s - 2s > 2p - 2s > 2p - 2p$
 (C) $2p - 2p > 2s - 2p > 2s - 2s$ (D) $2p - 2p > 2s - 2s > 2p - 2s$

Q.4 Fluorine molecule is formed by:

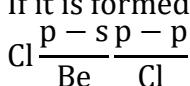
- (A) the axial p-p orbital overlap (B) the sideways p - p orbital overlap
 (C) the s-s orbital overlap (D) the s - p orbital overlap



LECTURE NO. - 8 & 9

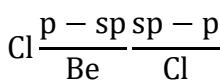
• HYBRIDISATION THEORY

- (a) It is introduced by Pauling and Slater, to explain equivalent nature of covalent bonds in a molecule. Consider an example of BeCl_2
If it is formed without hybridisation then -



both the $\text{Be} - \text{Cl}$ bonds should have different parameters and p-p bond strength $>$ s-p bond strength. But experimentally bond parameters of both the $\text{Be} - \text{Cl}$ bonds are same. This can be explained by the concept of hybridisation.

- (b) Hybridisation : Phenomenon of intermixing of atomic orbitals of same or nearly same energy and thus producing hybrid orbitals of same energy and same shape is called as hybridisation. Now after considering s-p hybridisation in BeCl_2



bond strength of both the bonds will be equal.

• Salient features of hybridisation: The main features of hybridisation are as under:

1. The number of hybrid orbitals is equal to the number of the atomic orbitals that get hybridised.
2. The hybridised orbitals are always equivalent in energy and shape.
3. The hybrid orbitals are more effective in forming stable bonds than the pure atomic orbitals.
4. 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.

• Important conditions for hybridization

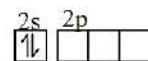
- (i) The orbitals present in the valence shell of the atom are hybridised.
- (ii) The orbitals undergoing hybridisation should have almost equal energy.
- (iii) Promotion of electron is not essential condition prior to hybridisation.
- (iv) It is not necessary that only half filled orbitals participate in hybridisation. In some cases, even filled orbitals of valence shell take part in hybridisation.

Types of hybridization

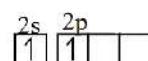
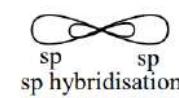
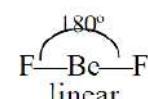
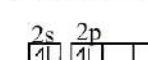
Hybrid Orbital	Hybridisation	Atomic orbital involved	Shape	Bond Angle
2	sp	$\text{sp}_x/\text{sp}_y/\text{sp}_z$	Linear	180°
3	sp^2	$\text{sp}_x\text{p}_y/\text{sp}_y\text{p}_z/\text{sp}_y\text{p}_z$	Trigonal planar	120°
4	sp^3	$\text{sp}_x\text{p}_y\text{p}_z$	Tetrahedral	$109^\circ 28'$
5	$\text{sp}^3 \text{d}$	$\text{sp}_x\text{p}_y\text{p}_z\text{d}_{z^2}$	Trigonal bipyramidal	$120^\circ, 90^\circ, 180^\circ$
7	$\text{sp}^3 \text{d}^2$	$\text{sp}_x\text{p}_y\text{p}_z\text{d}_{x^2-y^2}\text{d}_{z^2}$	Octahedral	90°
$7\text{sp}^3 \text{d}^3$	$\text{sp}_x\text{p}_y\text{p}_z\text{d}_{x^2-y^2}\text{d}_{z^2}\text{d}_{xy}$	Pentagonal bipyramidal	$72^\circ, 90^\circ, 180^\circ$	

**Ex.1** Hybridisation in BeCl_2

Be (ground state)



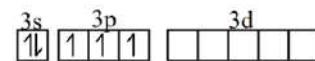
Be (excited state)

Be atom shares two electrons with F in BeF_2 

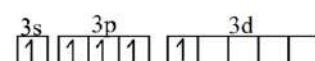
sp hybridisation

Ex.2 For example, PF_5 showing $\text{sp}^3 \text{d}$ hybridization

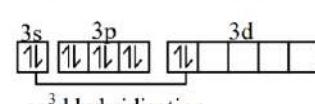
P (ground state)



P* (excited state)



P atom share five electron with five F

sp³d hybridisation

- Determination of hybridisation state -**

To predict hybridisation following formula may be used :

- Method-1 :**

No. of hybrid orbital = $\frac{1}{2}$ [Total number of valence e⁻ in the central atom + total number of monovalent atoms - charge on cation + charge on anion]

- Method-2 :**

Steric Number (S.N.) = Number of σ -bond around that atom + Number of lone pair on that atom.

Molecule	Method-1	Method-2	Hybridisation
NH_4^+	$\frac{1}{2}[5 + 4 - 1] = 4$	S.N. = 4 + 0 = 4	sp ³ hybridisation
SF_4	$\frac{1}{2}[6 + 4] = 5$	S.N. = 4 + 1 = 5	sp ³ d hybridisation
SO_4^{2-}	$\frac{1}{2}[6 + 2] = 4$	S.N. = 4 + 0 = 4	sp ³ hybridisation

- Method : 3**

In proper Lewis structure count the number of lone pairs and number of σ bonds with which that atom is directly connected to other atoms. The sum of lone pair and σ bonds gives the number of hybrid orbitals of that atom.

- Find hybridisation of following species :-

(i) $\text{CH}_2\text{Cl}_2\text{sp}^3$ $\rightarrow \sigma$ bonds = 4 sp³

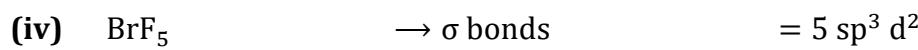
L.P. = 0

(ii) PF_5 $\rightarrow \sigma$ bonds = 5 sp³ d

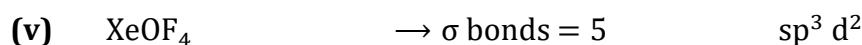
L.P. = 0

(iii) IC_2^\ominus $\rightarrow \sigma$ bonds = 2 sp³ d

L.P. = 3



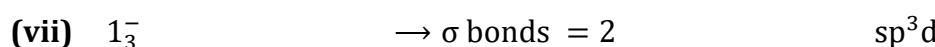
L.P. = 1



L.P. = 1



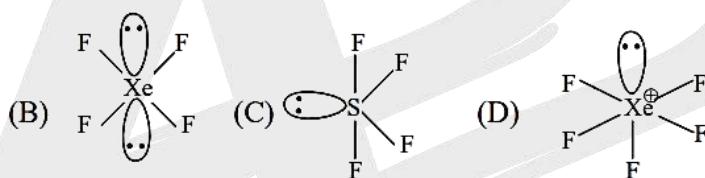
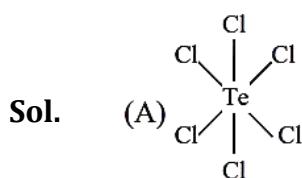
L.P. = 0



L.P. = 3

2. Which of the following molecule (s) is/are having $\text{sp}^3 \text{ d}^2$ hybridisation for their central atom.
 (A) TeCl_6 (B) XeF_4 (C) SF_4 (D) XeF_5^+

Ans. (A,B,D)



3. Which of the following orbital is not used in $\text{sp}^3 \text{ d}$ hybridisation to get square pyramidal geometry -



Ans. (B)

Sol. $\text{sp}^3 \text{ d}$ (TBP geometry) is made up of $(s + p_x + p_y + p_z + d_{x^2-y^2})$

4. Which of the following d orbital does not participate in $\text{sp}^3 \text{ d}^3$ hybridisation.



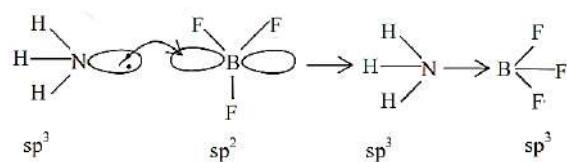
Ans. (D)

Sol. Atomic orbital involved in $\text{sp}^3 \text{ d}^3$

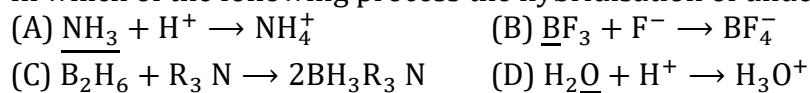
$s, p_x, p_y, p_z, d_{z^2}, d_{x^2-y^2}, d_{xy}$

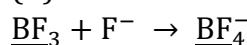
5. Find the change in hybridisation when NH_3 reacts with BF_3 .

Sol. Adduct formation



6. In which of the following process the hybridisation of underlined atom gets changed.



**Ans** (B)

sp²

sp³

Hybridisation of following species in specified state :

Species	Cationic part	Anionic part
PCl ₅ (s)	PCl ₄ ⁺ (sp ³)	PCl ₆ ⁻ (sp ³ d ²)
PBr ₅ (s)	PBr ₄ ⁺ (sp ³)	Br ⁻
XeF ₆ (s)	Xe F ₅ ⁺ (sp ³ d ²)	F ⁻
N ₂ O ₅ (s)	NO ₂ ⁺ (sp)	NO ₃ ⁻ (sp ²)
I ₂ Cl ₆ (liquid)	ICl ₂ ⁺ (sp ³)	ICl ₄ ⁻ (sp ³ d ²)
Cl ₂ O ₆ (s)	ClO ₂ ⁺ (sp ²)	ClO ₄ ⁻ (sp ³)
I ₂ (liquid)	I ₃ ⁺ (sp ³)	I ₃ ⁻ (sp ³ d)

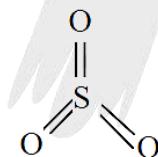
Q.7 What is the hybridisation of the anionic part of PCl₅ solid

(A) sp³(B) sp³ d(C) sp³ d²

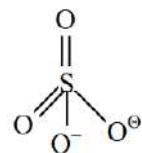
(D) none of these

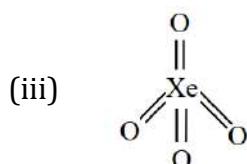
Ans. (C)**Sol.:** PCl_{5(s)} → PCl₄⁺ + PCl₆⁻**Sol. DETERMINATION OF π-BOND :**

Ex. (i)

Hybridisation = sp²2(p_π - d_π), 1(p_π - p_π)

(ii)

SO₄²⁻ Hybridisation = sp³
2(p_π - 3 d_π)



XeO_4 Hybridisation = sp^3
 $4(\text{p}_\pi - \text{d}_\pi)$

Q.1 Select the incorrect statements :

- (A) $\text{S}_2\text{O}_3^{2-}$ ion has $3 \text{d}_\pi - 2\text{p}_\pi$ bonding
- (B) ClO_3^- ion has three $3 \text{d}_\pi - 2\text{p}_\pi$ bonding
- (C) PO_4^{3-} ion has no lone pair
- (D) CO_3^{2-} ion has higher (C – O) bond length than that of HCOO^- ion

Ans. (B,C)

In ClO_3^- two $3 \text{d}_\pi - 2\text{p}_\pi$ bonds are present.

PO_4^{3-} has 11 lone pair

Q.2 From the following options most effective π -bond is –

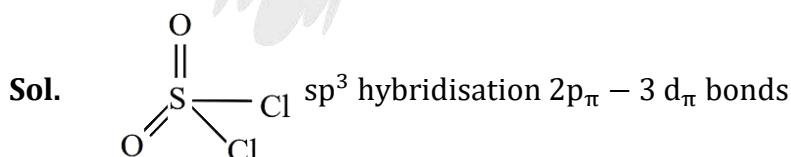
- (A) $3\text{p}_\pi - 2\text{p}_\pi$
- (B) $2\text{p}_\pi - 3\text{d}_\pi$
- (C) $3 \text{d}_\pi - 3 \text{d}_\pi$
- (D) $3\text{P}_\pi - 3\text{P}_\pi$

Ans. (B)

Q.3 How many $\text{p}_\pi - \text{d}_\pi$ bonds are present in the compound SO_2Cl_2 –

- (A) 0
- (B) 1
- (C) 2
- (D) 3

Ans. (3)



LECTURE NUMBER - 10

- **VALENCE SHELL ELECTRON PAIR REPULSION THEORY (VSEPR)**

- (a) Molecules having covalent bond have definite geometry as covalent bonding has directional characteristics. A simple theory was given for the molecular shape of the covalent molecules by Gillespie and Nyholm in 1957.

(b) This theory predicts the shape of the molecule by considering the most stable configuration of the bond angles in the molecule. This theory states

(i) Electron pairs in the valence shell of the central atom of a molecule, whether bonding or lone pairs are regarded as occupying localized orbitals. These orbitals arrange themselves to minimize the mutual electronic repulsions.

(ii) The magnitude of the different types of electronic repulsions follows the order given below:

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

(iii) The electronic repulsion between two pairs of electrons will be minimum if they are as far apart as possible.

• SHAPES OF MOLECULES BASE ON VSEPR THEORY

Total no. of hybrid orbital	No. of b.p. (bond pairs)	No. of unshared pair i.e. l_p	General formula	Type of hybridisation	Stereo chemical formula/str.	Shape	Exam.
2	2	0	AB_2	sp		Linear	$BeCl_2$
3	3	0	AB_3	sp^2		Trigonal planar	BF_3
3	2	1	AB_2	sp^2		V or Bent or angular	SO_2
4	4	0	AB_4	sp^3		Tetrahedron	CH_4
4	3	1	AB_3	sp^3		Trigonal pyramidal	NH_3 CH^-_3
4	2	2	AB_2	sp^3		V or Bent or angular	H_2O SF_2
4	1	3	AB	sp^3		linear	ClO^-
5	5	0	AB_5	sp^3d		Trigonal bipyramidal	PCl_5
5	3	2	AB_3	sp^3d		T-shaped	CIF_3
5	2	3	AB_2	sp^3d		Linear	IF_2^-
6	6	0	AB_6	sp^3d^2		Octahedral	SF_6 IF_6^+
6	5	1	AB_5	sp^3d^2		Square pyramidal	XeF_5^+
6	4	2	AB_4	sp^3d^2		Square planar	XeF_4
7	7	0	AB_7	sp^3d^3		Pentagonal bipyramidal	IF_7
7	6	1	AB_6	sp^3d^3		Distorted octahedral	XeF_6 IF_6^-
7	5	2	AB_5	sp^3d^3		Pentagonal planar	XeF_5^-



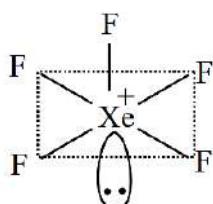
Practice Set

Q.1 Which of the following species / molecule is not planar

- (A) XeF_5^- (B) XeF_5^+ (C) XeF_4 (D) NO_2Cl

Ans. (B)

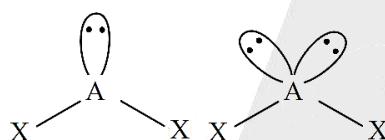
$\text{XeF}_5^+ \Rightarrow$ It is square pyramidal which is non planar.



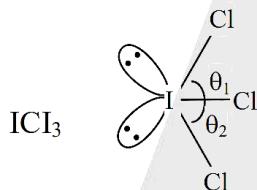
Q.2 The 'BENT' molecular geometry can be obtained from which of the following electron geometry

- (A) sp^3d (B) sp^3 (C) sp^3d^2 (D) sp^2

Ans. (B,D) sp^2 and sp^3 having bent molecular geometry i.e. $\text{sp}^2:-\text{sp}^3:-$



Q.3 Find the number of exact 90° angles in ICl_3 Ans. (0)



Both are less than 90° angles to L.P. - B.P. repulsion.

Q.4 Choose the correct option in which all compounds are having same electron geometry of their central atom :-

- | | | | |
|------------------------------|---------------------|---------------------------------|-------------------------------|
| (I) XeO_2F_2 | (II) BrF_3 | (III) SiF_2Cl_2 | (IV) XeO_3F_2 |
| (A) I and II only | (B) II and III only | (C) I, II and III only | (D) I, II and IV only |

Ans. (D)

Molecule	e ⁻ geometry
XeO_2F_2	Trigonal bipyramidal
BrF_3	Trigonal bipyramidal
SiF_2Cl_2	Tetrahedral
XeO_3F_2	Trigonal bipyramidal



Q.5 In trigonal bipyramidal electronic geometry we get the following repulsion at 90°,

$$\text{l.p.} - \text{l.p.} = 0,$$

$$\text{l.p.} - \text{b.p.} = 4$$

$$\text{b.p.} - \text{b.p.} = 2,$$

which type of molecule is satisfying the above conditions.

(A) AB_5

(B) $\text{AB}_4 \text{L}$

(C) $\text{AB}_3 \text{L}_2$

(D) $\text{AB}_2 \text{L}_3$

(A= central atom, B = bond atom, L = lone pair)

Ans. (C)

Q.6 Which of the following is isoelectronic and isostructural with H_3O^+

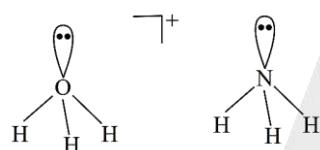
(A) H_2F

(B) BH_4^-

(C) NH_3

(D) All of these

Ans. (C)



Both species have same structure and same number of electrons i.e. 10

Q.7 Which of the following has/have $\text{sp}^3 \text{d}$ hybridisation and linear structure

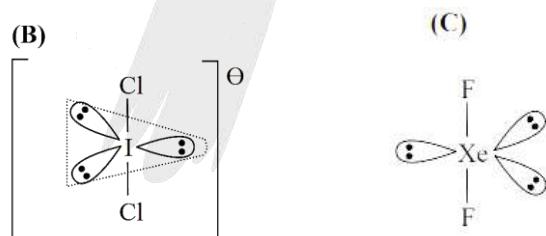
(A) ClF_3

(B) ICl_2^-

(C) XeF_2

(D) XeF_4

Ans. (B,C)



Q.8 Which of the following molecule(s)/ion(s) is/are NOT non-linear -

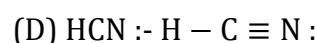
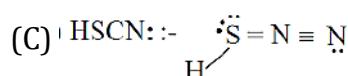
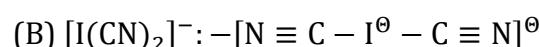
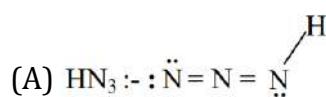
(A) HN_3

(B) $[\text{I}(\text{CN})_2]^-$

(C) HSCN

(D) HCN

Ans. (B, D)

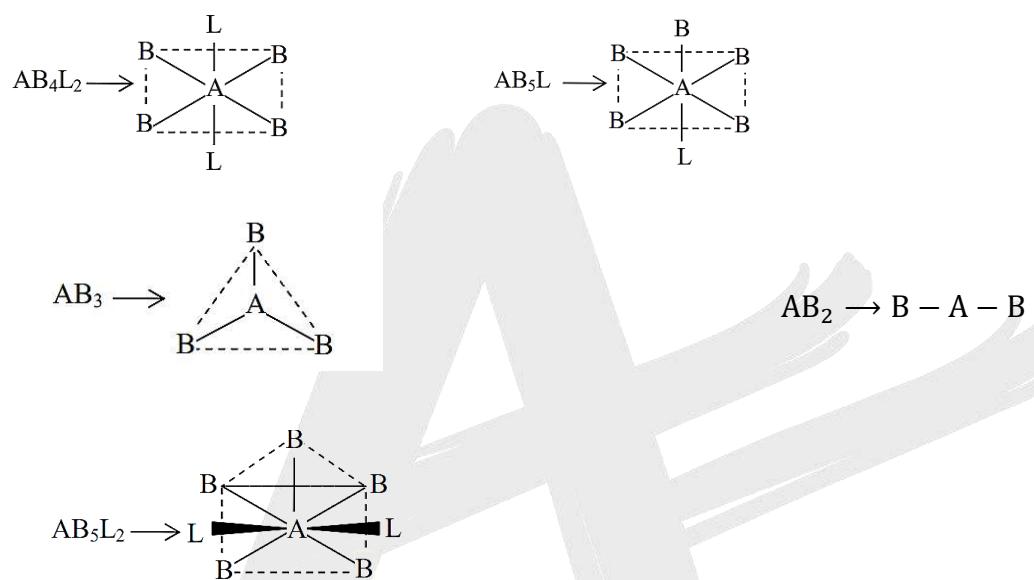


Q.9 In which of the following 4 'B' atoms are in same plane?

- (A) AB_4 (B) $\text{AB}_4 \text{ L}$ (C) $\text{AB}_4 \text{ L}_2$ (D) AB_5
 (E) $\text{AB}_5 \text{ L}$ (F) $\text{AB}_5 \text{ L}_2$ (G) AB_3 (H) AB_2

Sol. $\text{AB}_4 \rightarrow$ Tetrahedral
 $\text{AB}_4 \text{ L} \rightarrow$ See saw structure }
 $\text{AB}_5 \rightarrow$ Trigonal bipyramidal }

4' B atoms are not in same plane



Q.10 Which of the following specie has maximum number of lone pair -

- (A) SiF_6^{2-} (B) XeF_6 (C) PCl_6^- (D) SF_6

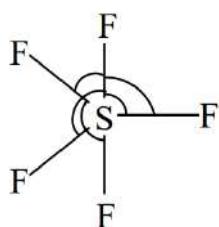
Ans. (B)
ion/molecule

total number of lone pair

SiF_6^{2-}	18
XeF_6	19
PCl_6^-	18
SF_6	18

Q.11 Find the maximum number of identical angles in $[\text{SF}_5]^+$ which are all less than 180° .

Ans. (6)



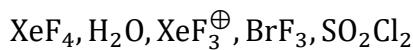


Q.12 Shape of NH_3 is very similar to –

- (A) CH_4 (B) CH_3^- (C) BH_3 (D) CH_3^+

Ans. (B) Both have the same state of hybridization sp^3 with one lone pair of e^- each.

Q.13 Find the number of molecule which are planar.



Ans. (4)

XeF_4 – square planar

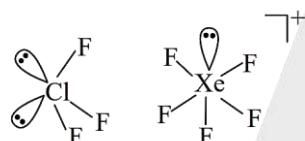
H_2O – V-shaped

XeF_3^\oplus – T-shaped

BrF_3 – T-shaped

Q.14 Find the ratio of lone pairs on the central atom of ClF_3 and XeF_5^\oplus

Ans. (2)



$$\text{ratio of lone pairs on the central atom} = 2$$

Q.15 Find the number of angles which are less than 90° in perfect pentagonal bipyramidal geometry.

Ans. (5)

PBP contain five 90° angles which are present at equatorial position.

Q.16 Which of the following has pyramidal shape-

- (A) XeO_3 (B) XeF_4 (C) XeF_2 (D) XeF_6

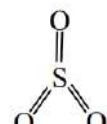
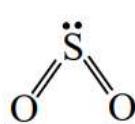
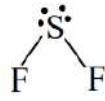
Ans. (A) Due to presence of lone pair of electron.

Q.17 Find number of planer species out of



Ans. (3)

Sol. Planar species are





Q.18 Which of the following molecule have see-saw shape

- (A) CH_4 (B) SF_4 (C) XeF_4 (D) CCl_4

Ans. (B)

Sol. (1) CH_4 – Tetrahedral

(2) SF_4 - See saw

(3) XeF_4 - Square planar

(4) CCl_4 – Tetrahedral

Q.19 Which of the following molecule is linear and central atom is sp^3d hybridised -

- (A) XeF_2 (B) CO_2 (C) SO_2 (D) HCN

Ans. (1)

Sol. XeF_2 sp^3d linear

CO_2 sp linear

SF_4 sp^3d See saw

NH_3 sp^3

Pyramidal

Q.20 Which of the following is expected to be planar where B is univalent bonded atom & E is lone pair on central atom –

- (A) AB_4E (B) AB_5E (C) AB_3E (D) AB_2E

Q.21 Which of the following is expected to be planar where B is univalent bonded atom & E is lone pair on central atom –

- (A) AB_4E (B) AB_5E (C) AB_3E (D) AB_2E

Ans. (4)

Sol. AB_5

Square pyramidal

AB_4E See saw

AB_3E Pyramidal

AB_2E V-shape

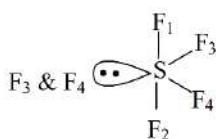
Q.22 Find the maximum number of identical bond angle in SF_4 is-

- (A) 2 (B) 3 (C) 4 (D) 6



Ans. (3)

Sol. Total four bond angles are identical, two formed by F_1 , with $F_3 \& F_4$ and two are formed by F_2 with

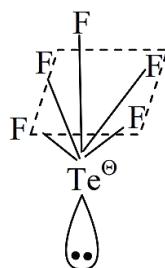


Q.23 In Which of the following there is no bonds at right angle -

- (A) ICl_4^- (B) PCl_6^- (C) PCl_5 (D) TeF_5^-

Ans. (4)

Sol. TeF_5^\ominus is square pyramidal in which all bond angles are less than 90° .



Q.24 Which of the following molecule/ion is non-linear

- (A) HCN (B) I_3^- (C) I_3^+ (D) CO_2

Q.25 Which of the following molecule/ion is non-linear

- (A) HCN (B) I_3^- (C) I_3^+ (D) CO_2



DO YOUR SELF - 3

Q.1 The pair of species with similar shape is

- (A) $\text{PCl}_3, \text{NH}_3$ (B) CF_4, SF_4 (C) $\text{PbCl}_2, \text{CO}_2$ (D) PF_5, IF_5

Q.2 The shape of sulphate ion is -

- (A) hexagonal (B) square planar (C) trigonal bipyramidal (D) tetrahedral

Q.3 What is not true for SiH_4 molecule

- (A) Tetrahedral hybridization (B) 109° angle
 (C) 4σ bond (D) 4-lone pair of electrons

Q.4 The structure of Br_3^- involves hybridisation of the type -

- (A) $\text{sp}^3 \text{d}$ (B) $\text{sp}^3 \text{d}^2$ (C) $\text{sp}^3 \text{d}$ (D) $\text{d}^2 \text{sp}^3$

Q.5 The structure of ICl_2^- is -

- (A) Trigonal planar (B) Octahedral (C) Square planar (D) Linear

LECTURE NO. -11

BOND PARAMETERS

- (I) Bond Angle (II) Bond Length (Bond distance) (III) Bond Energy

(I) Bond angle:

Angle between two adjacent bond in any species is called the Bond angle. The following factors affect bond angle.

(a) State of Hybridization :

With the change in state of hybridization relative percentage of s-character changes and with increasing percentage of s-character, the bond angle increase.

State of hybridization %	s-character	Bond angle
Sp	50	180°
sp^2	33.33	120°
sp^3	25	109°28'

If state of hybridization of central atom is same and all the surrounding atoms are identical and identically attached as well, the bond angle remains the same (as predicted by its hybridization state) no matter what the central atom and what surrounding atoms are.

For example, bond angles in CF_4 , CCl_4 , CBr_4 is same i.e. 109°28'

(b) Presence of lone pair :

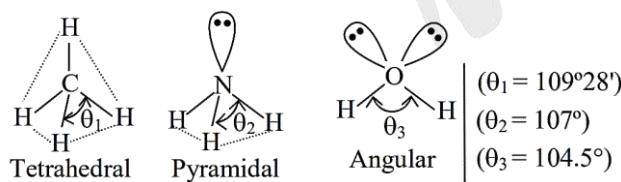
Since the lone pair occupies more space around central atom, so the space available for bond pairs is less and hence bond angle decreases.

The extent of repulsive interaction follows the order

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

Example :

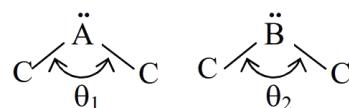
The bond angle of CH_4 , NH_3 , H_2O .



As there is no lone pair of electron on carbon in CH_4 molecule, so all the HCC bond angles are H_2O , the lone pairs occupy more space around central atom, thus bond angle in CH_4 is maximum and in H_2O it is minimum. Hence, $\theta_1 > \theta_2 > \theta_3$

(c) Electronegativity of central atom :

Let us consider the molecule $\ddot{\text{A}}_2$ and $\ddot{\text{B}}\text{C}_2$ in which electronegativity of A > B



State of hybridisation of A and B = sp^2

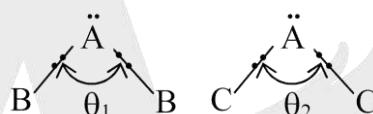
Due to greater electronegativity of A than B, the bond pair of electron in AC_2 is more closer to A than B in BC_2 . Due to decrease in distance between bond pairs in AC_2 , bp – bp repulsion is more than that in BC_2 .

So the bond angle order is $\theta_1 > \theta_2$

(d) Electronegativity of surrounding atom :

Let us consider two molecules $\ddot{A}B_2$ and $\ddot{A}C_2$ in both A is sp^2 hybridised and electronegativity of B > C. Due to greater electronegativity of B than that of C, the shared electron pair is attracted towards B, so the repulsion between bp-bp in AB_2 is less than that in AC_2 .

Hence $\theta_1 < \theta_2$.



(e) Size of surrounding atom:

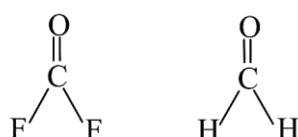
Let us consider the two molecules OCl_2 and $OBBr_2$ where O-atom is sp^3 hybrid and Br atom is larger than Cl-atom, so Br will occupy more space around central atom than Cl-atom, hence bond angle in $OBBr_2$ is more than that in OCl_2 .

Moreover, it has been experimentally found that the bond angle in $OBBr_2$ is 112° and in OCl_2 it is 111° , the bond angle is more than even the normal tetrahedral angle ($109^\circ 28'$). This may be due to steric repulsion of two Cl-atom in OCl_2 and two Br-atoms in $OBBr_2$ and some effect of back bonding.

(f) Multiple bond orbital repel other orbitals more strongly than single bond orbitals.

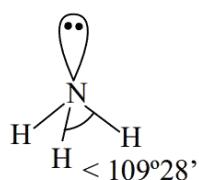
The multiple bond orbital possess extra electron density and naturally exert stronger repulsion on neighboring electron pair than a single bond does. Thus a double bond containing four electrons exerts a greater repulsive effect on other sigma bonds present in the molecule and result in a smaller bond angle.

Ex.

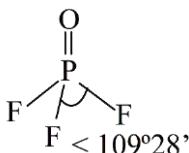


Fluorine is more electronegative than hydrogen.

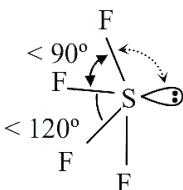
$\therefore F - \hat{C} - F < H - \hat{C} - H$

**Ex.**

$\text{lb-bp} > \text{bp-bp}$ (repulsion)
shape - pyramidal

Ex.

$\text{D.B-S.B} > \text{S.B-S.B}$
shape - pyramidal

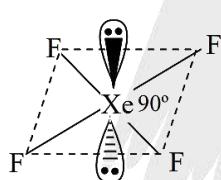
Ex.

$$\text{F}_{\text{ax}} - \hat{\text{S}} - \text{F}_{\text{eq}} < 90^\circ$$

$$\text{F}_{\text{ax}} - \hat{\text{S}} - \text{F}_{\text{eq}} < 180^\circ$$

$$\text{F}_{\text{ax}} - \hat{\text{S}} - \text{F}_{\text{eq}} < 120^\circ$$

$\text{lp} - \text{bp} > \text{bp} - \text{bp}$ (repulsion)

Ex.

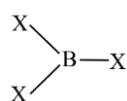
Both lone pair cancel out their effect

shape = square planar

Ex.

Compare the bond angle in the following

(a) $\text{BF}_3, \text{BCl}_3, \text{BBr}_3, \text{BI}_3$ ($\text{X} - \hat{\text{B}} - \text{X}$)



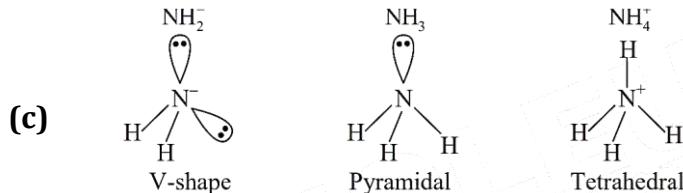
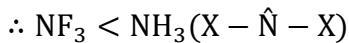
having perfect geometry therefore there is no effect of electronegativity of surrounding



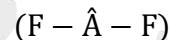
atom.



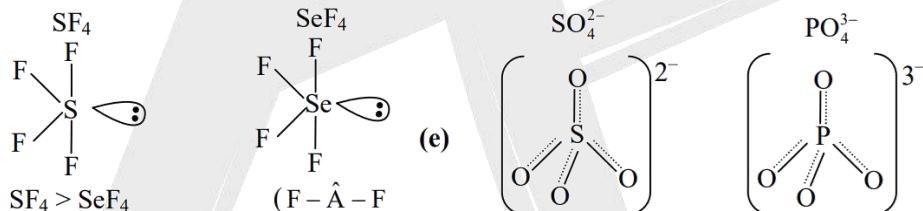
solution: Fluorine is more electronegative than hydrogen therefore electron cloud is more shifted towards surrounding atom in NF_3 than NH_3 .



In all the above species N is sp^3 hybridized and all the attach surrounding atoms are identical in all species.



(d) In both cases central atom is sp^3 d hybridized and surrounding atoms are same therefore greater the electro negativity of central atom greater will be the bond angle.



Due to equivalent resonance both having perfect geometry therefore all the bond angle is same.

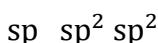
Ex. Ether $\text{R}-\ddot{\text{O}}-\text{R}$ and water $\text{H}-\ddot{\text{O}}-\text{H}$ have same hybridization of oxygen. What angle would you expect for them -

Ans. In H_2O bond angle is less than $109^\circ 28'$ due to lone pair and bond pair repulsion. But in ether, due to strong mutual repulsion between two alkyl groups bond angle becomes greater than $109^\circ 28'$

Ex. Compare the bond angle in following:

- | | |
|---|---|
| (i) $\text{CO}_2, \text{SO}_2, \text{SO}_3$ | (ii) $\text{SiH}_4, \text{SiF}_4, \text{SiCl}_4$ |
| (iii) $\text{SO}_4^{2-}, \text{CO}_3^{2-}, \text{NO}_3^-$ | (iv) $\text{COF}_2, \text{COCl}_2, \text{COBr}_2, \text{COI}_2$ |
| (v) $\text{OF}_2, \text{Cl}_2\text{O}, \text{Br}_2\text{O}$ | |

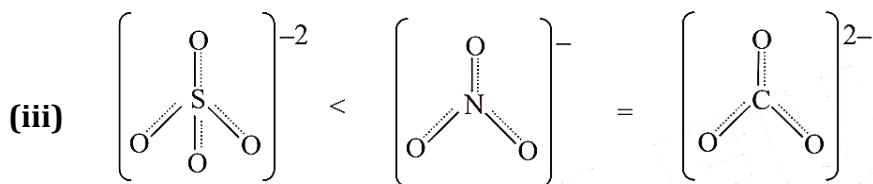
Ans. (i) $\text{CO}_2 \quad \text{SO}_2 \quad \text{SO}_3$





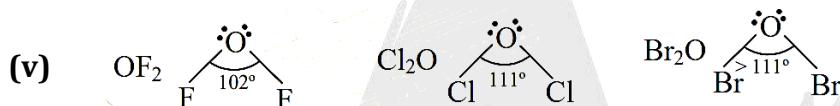
In SO_2 molecule, due to presence of lone pair, bond angle decreases.

(ii) $\text{SiH}_4 = \text{SiF}_4 = \text{SiCl}_4$



(iv) $\text{COF}_2 < \text{COCl}_2 < \text{COBr}_2 < \text{COI}_2$

The steric crowding of the larger halogen atoms contributes in the increasing bond angles.



Bond pairs of electrons are more closer to the fluorine atoms (because of high electronegativity of fluorine). So the $\ell p - \ell p$ repulsion is more than $bp - bp$. Thus the $\text{F} - \text{O} - \text{F}$ bond angle decreases to 102° from 109.5° .

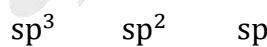
In Cl_2O , the bond angle $\text{Cl} - \text{O} - \text{Cl}$ increases to $\approx 111^\circ$ due to $bp - bp$ repulsion and repulsion between larger Cl atoms.

Note: The steric crowding of the larger atoms/group of atoms also contributes in the increasing bond angles.

Q.1 Compare bond angle.

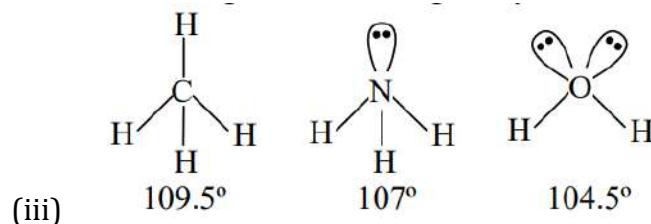
- (i) $\text{CH}_4, \text{BF}_3, \text{BeCl}_2$
- (iii) $\text{CH}_4, \text{NH}_3, \text{H}_2\text{O}$
- (iv) $\text{OF}_2, \text{OC}_2, \text{OBr}_2, \text{OI}_2$

Sol. (i) $\text{CH}_4 < \text{BF}_3 < \text{BeCl}_2$



(ii) $\text{NC}_3 > \text{PC}_3 > \text{AsC}_3 > \text{SbC}_3$

Bond angle \propto Electronegativity of central atom.



Number of lone pair increase bond angle decreases.



Size of surrounding atom \propto Bond angle.

Q.2 Which of the following bond angle order is incorrect -

- (A) $\text{BF}_3 = \text{BCl}_3$ (B) $\text{CH}_4 = \text{CC}_4$ (C) $\text{NH}_3 = \text{NF}_3$ (D) $\text{CO}_3^{2-} = \text{NO}_3^-$

Ans. (C)

Sol. Bond angle $\text{NH}_3 > \text{NF}_3$

Q.3 Which of the following is incorrect order of X – P – X bond angle. (X = halogen atom)

- (A) $\text{PBr}_3 > \text{PCl}_3 > \text{PF}_3$ (B) $\text{OPBr}_3 > \text{OPCl}_3 > \text{OPE}_3$
 (C) $\text{PBr}_4^+ > \text{PCl}_4^+ > \text{PF}_4^+$ (D) $\text{PCl}_4^+ > \text{PCl}_3$

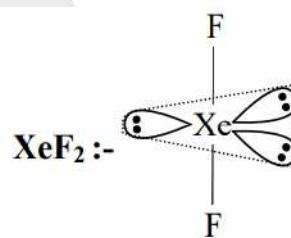
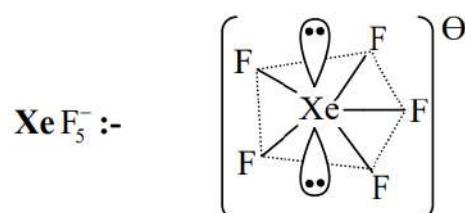
Q.4 Which of the following bond angle order is correct

- (A) $\text{PH}_3 > \text{PH}_4^+$ (B) $\text{NH}_4^+ > \text{PH}_4^+$
 (C) $\text{H}_2\text{O} > \text{H}_3\text{O}^+$ (D) $\text{OF}_2 < \text{H}_2\text{O}$

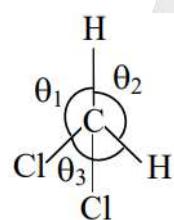
Q.5 In which of the following molecule(s) presence of 1.p. does not affect the idealized bond angle according to hybridisation :-

- (A) XeF_5^- (B) XeF_2
 (C) XeF_5^+ (D) SF_4

Ans. (A, B)



Sol.



For the above figure.

- (A) $\theta_1 = \theta_2 = \theta_3$ (B) $\theta_3 > \theta_1 > \theta_2$
 (C) $\theta_3 < \theta_2 < \theta_1$ (D) None of these

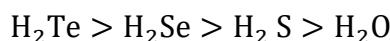
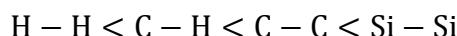
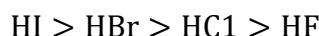
Sol. Due to large size of Cl atoms, repulsion increase, hence bond angle increase. Correct option is (B).



(II) Bond Length :- The average distance between the nucleus of two atoms is known as bond length.

Factors affecting bond length

- (a) Size of atoms: As size of atom increases bond length increases



- (b) Effect of bond order or number of bonds: As number of bonds or bond order increases bond length decreases.



Bond length 154pm 134pm 120pm

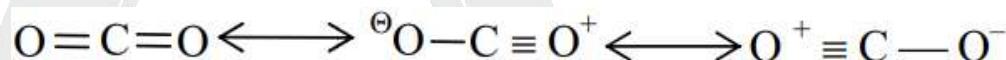
- (c) Effect of Resonance (due to resonance bond length is affected) eg. In Benzene :



We know that $\text{C}-\text{C}$ bond length is 154 pm and $\text{C}=\text{C}$ bond length is 134pm but in benzene the $\text{C}-\text{C}$ bond length is between single & double bond due to resonance which is equal to 139pm.

eg. Bond length of $\text{C}-\text{O}$ in CO_2 is 115pm due to resonance.

Resonance occurs in CO_2 as follows-

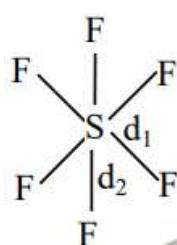


- (d) Effect of Electronegativity difference :

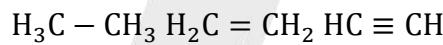
Generally as electronegativity difference of bonded atom increases bond length decreases.

- (f) Effect of Hybridisation : In hybrid orbitals bond length decreases as the s-character increases.

Example :-	Compound	Hybridisation	Bond length
s-character increases ↓	$\begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} - \begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array}$	$\text{sp}^3 - \text{sp}^3$	1.54 Å
	$\begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} - \begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} =$	$\text{sp}^3 - \text{sp}^2$	1.51 Å
	$\begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} - \begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} \equiv$	$\text{sp}^3 - \text{sp}$	1.47 Å
	$= \begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} - \begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} =$	$\text{sp}^2 - \text{sp}^2$	1.48 Å
	$= \begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} - \begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} \equiv$	$\text{sp}^2 - \text{sp}$	1.43 Å
	$\equiv \begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} - \begin{array}{c} \diagup \\ \text{C} \\ \diagdown \end{array} \equiv$	$\text{sp} - \text{sp}$	1.38 Å

Ex. SF₆

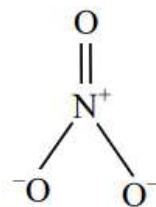
All hybrid orbital of 'S' having equal length

Ex. Compare the bond length in the following as given,(a) C₂H₆ C₂H₄ C₂H₂

BO: 1 BO: 2 BO: 3

$$\therefore \text{C}_2\text{H}_6 > \text{C}_2\text{H}_4 > \text{C}_2\text{H}_2 \quad (\text{C}-\text{C})$$
Note: BO ↑ BL ↓(b) NO₂⁻

BO = 1.5

$$\therefore \text{NO}_2^- < \text{NO}_3^- \text{ (B.L.)}$$
NO₃⁻

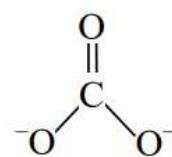
BO = 1.33

(c) CO

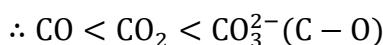
CO₂CO₃²⁻



$$\text{BO} = 3 \quad \text{BO} = 2$$



$$\text{BO} = 1.33$$



Ex. Find the maximum number of equal angle in CH_4 and NH_3

Ans. 6 and 3

Ex. Find the maximum number of 90° angle in SF_4 , SF_6 , PC_5 and IF_5

Ans. 0,12,6,0 respectively

Q.2 If number of identical bond length in CH_4 is 'x' and number of identical bond angles in CH_4 is 'y'. Find value of $\frac{y-x}{y+x}$.

Ans. 0.2

$$\text{Sol. } \frac{y-x}{y+x} = \frac{6-4}{6+4} = 0.2$$

(III) Bond Energy (BE) :- Bond energy may be defined as-

- (a)** Bond formation energy:- Energy released, when one mole of same type of bonds are formed, is known as bond formation energy or bond energy.
- (b)** Bond dissociation energy:- Energy required to dissociate one mole of same types of bond is known as bond dissociation energy.

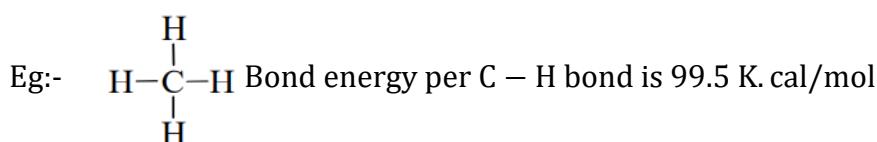
Case-I: In diatomic molecule:

Bond energy = bond dissociation energy

Eg: $-\text{N}_2 > \text{O}_2 > \text{H}_2 > \text{F}_2$

Case-II For polyatomic molecule

Bond energy = Bond dissociation energy (D)



Theoretical values of bond dissociation energy (D) of individual C – H bonds CH_4 are given below-

$$D(\text{CH}_3 - \text{H}) = 102 \text{ K} \cdot \text{Ca/mol}$$

$$D(\text{CH}_2 - \text{H}) = 105 \text{ K} \cdot \text{Cal/mol}$$

$$D(\text{CH} - \text{H}) = 108 \text{ K} \cdot \text{Cal/mol}$$

$$D(\text{C} - \text{H}) = 83 \text{ K} \cdot \text{Cal/mol}$$



Hence bond energy E per C-H bond in methane = $\frac{398}{4} = 99.5$ K. Cal/mol Bond dissociation energy

(D) is related to the state of hybridisation.

Que. Compare the bond energy in the following

(a) F₂, Cl₂, Br₂ and I₂

Ans. Cl₂ > Br₂ > F₂ > I₂ Bond energy order (Experimental facts)

Que. Compare the bond energy in the following:

(a) C – C, Si – Si

(b) N – N, P – P

(c) O – O, S – S

Ans. (a) C – C

(b) P – P

(c) S – S

LECTURE NUMBER -13

DIPOLE MOMENT : (IONIC NATURE IN COVALENT BOND)

Due to difference in electronegativity a covalent bond acquires a partial polar character. The two charged ends of the polar bond behave as electric dipoles and degree of polarity is expressed in term of dipole moment.

Dipole moment is defined as the product of the magnitude of charge on any one of the atoms and the distance between them

$$\mu = q \times d$$

q = charge on any one of the atom which is in the order of 10^{-10} esu or 10^{-19} coulomb and d = distance between charged atoms is in the order of 10^{-8} cm.

10^{-18} esu cm = 1 debye (unit of dipole moment)

In S.I. system

$$1\text{esu} = \frac{1.6 \times 10^{-19}}{4.8 \times 10^{-10}} = 3.33 \times 10^{-10}\text{C}$$

$$1\text{ cm} = 10^{-2}\text{ m}$$

$$1\text{D} = 10^{-18} \times 3.33 \times 10^{-10} \times 10^{-2}\text{ cm}$$

$$1\text{D} = 3.33 \times 10^{-30}\text{ cm}$$

Any covalent bond which has a certain degree of polarity will have a corresponding dipole moment.

The polarity of molecule on the whole is the vector sum of the individual dipole moment.

Dipole moment can be determined experimentally and its value can give an idea of the polar character of a molecule. It is a vector quantity, as it has a direction as well as magnitude. The direction of dipole is towards negative centre. It is represented by an arrow pointing from positive centre towards the negative centre (\rightarrow)

The resultant dipole moment depends upon magnitude of bond moments and the angles between the bonds and given by parallelogram law as:

$$\mu_{\text{resultant}} = \sqrt{\mu_1^2 + \mu_2^2 + 2\mu_1\mu_2 \cos \theta}$$

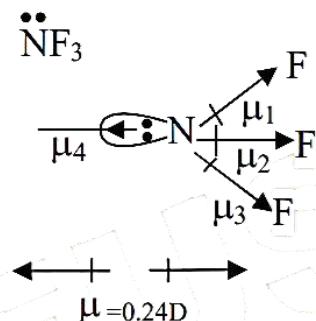
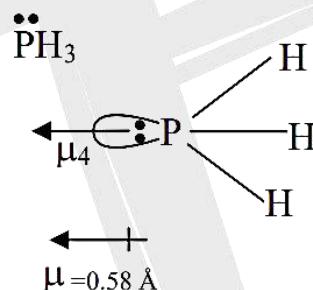
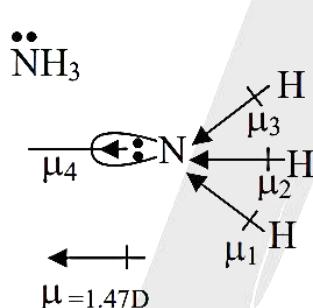
In a bond H – X, the hydrogen atom is the positive end of dipole where X is an atom more electronegative than H.

In a bond C – X, the carbon atom is the positive end of the dipole where X is an atom other than carbon. However, in the C – H bonds of hydrocarbons, the value and directions of the dipole are not constant and depends upon the state of hybridization of the carbon.

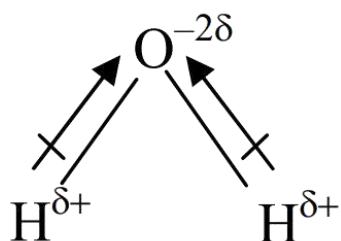
Characteristics of Dipole Moment:

1. For diatomic molecule $\mu = e \times d$
2. In polyatomic molecule with angle θ , resultant dipole moment is the vector summation of the vector moments.
3. **Polyatomic molecules:** A poly atomic molecules is made up of more than two atoms joined by polar covalent bonds and their dipole moment will be the vector sum of dipole moment of different bonds which depends on spatial orientation of bond.

For example:



4. Dipole moment is a vector quantity. Therefore individual dipole moments should be added vectorially to get net dipole moment.
 5. Symmetrical molecule without lone pair of electrons has $\mu = 0$. e.g. $\text{CO}_2, \text{BeF}_2, \text{BF}_3, \text{CCl}_4$, etc.
- (XI) Dipole moment of H_2O is 1.85 D which is resultant μ of two O – H bonds.



Application of dipole moment :

(A) To determine polarity and geometry of molecule-

If $\mu = 0$ compound is non polar and symmetrical



eg. CO_2 , BF_3 , CCl_4 , CH_4 , BeF_2 etc.

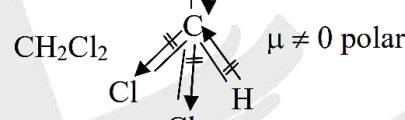
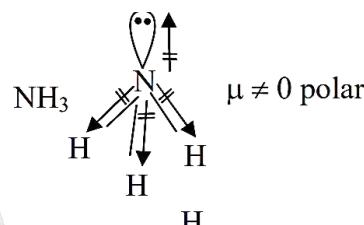
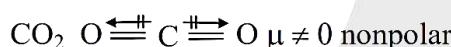
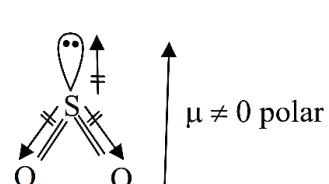
If $\mu \neq 0$ compound will be polar and unsymmetrical.

H_2O , SO_2 , NH_3 , Cl_2O , CH_3Cl , CHCl_3 etc.

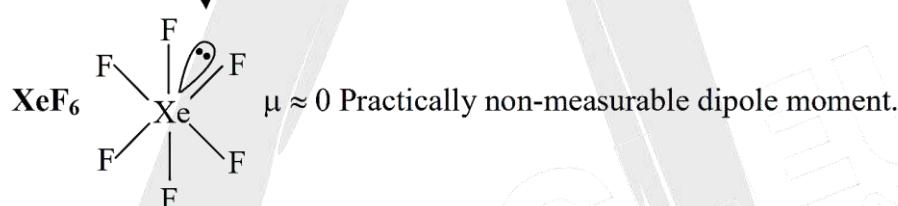
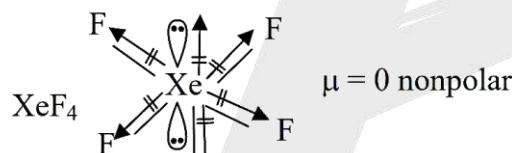
Ex 1. Which of the following bond is most polar -

- (A) O – H (B) P – H (C) C – F (D) S – Cl

Sol. (C) Due to maximum electronegativity difference.



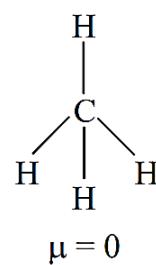
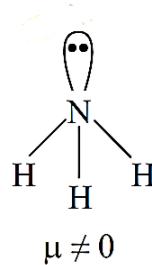
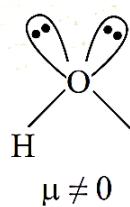
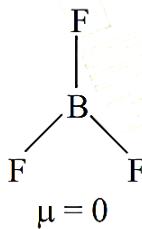
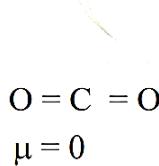
Ex.

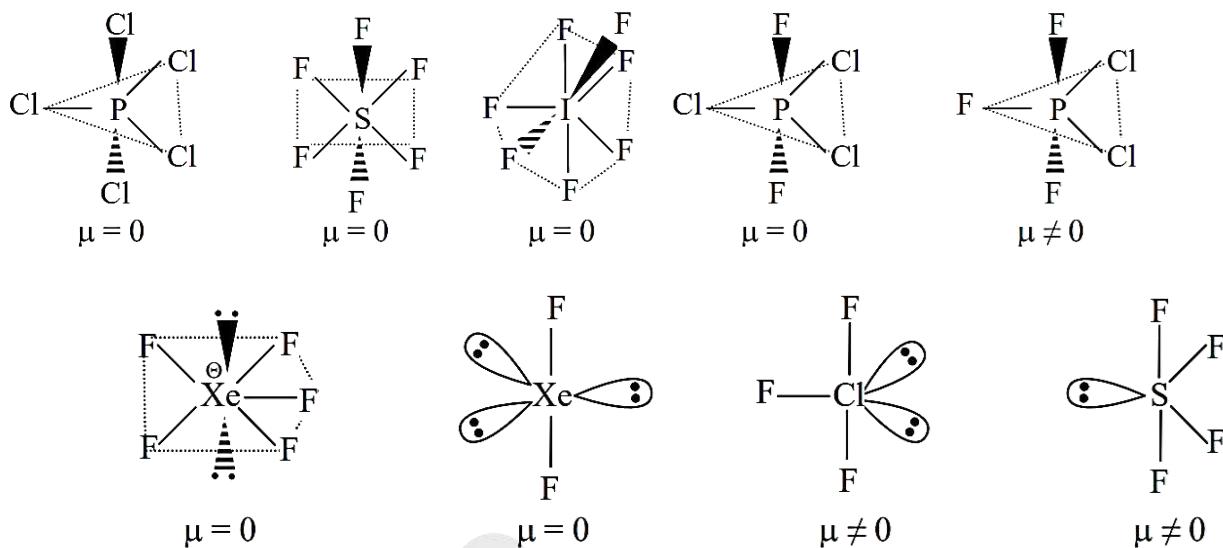


Q.3 Which of the following have zero dipole moment ?

CO_2 , BF_3 , H_2O , NH_3 , CH_4 , PCl_5 , SF_6 , IF_7 , PCl_3 , F_2 , PCl_2 , F_3 , XeF_5^- , XeF_2 , ClF_3 , SF_4 .

Sol.





Some important orders of dipole moments -

- (i) HF > H₂O > NH₃ > NF₃
 - (vi) H₂O > H₂S
 - (ii) CH₃Cl > CH₃F > CH₃Br > CH₃I
 - (vii) BF₃ < NF₃ < NH₃
 - (iii) HF > H₂O > SO₂ > NH₃PH₃ < PCl₃
 - (vii) H₂O < H₂O₂
 - (iv) NO₂⁻ > NO₂ > NO₂⁺
 - (v) CH₃Cl > CH₂Cl₂ > CHCl₃ > CCl₄
- (B) To calculate % ionic character**

$$\% \text{ ionic character} = \frac{\text{Experimental value of } \mu}{\text{Theoretical value of } \mu} \times 100$$

- Ex 1.** Bond length of HC1 is 1.275 Å (Charge = 4.8×10^{-10} e.s.u.) if $\mu = 1.02$ D, then HC1 is-
- (A) 100% ionic
 - (B) 83% covalent
 - (C) 50% covalent
 - (D) 40% ionic

Sol. (B) % ionic character

$$= \frac{\text{observed } \mu}{\text{theoretical } \mu} \times 100 = \frac{102}{1.275 \times 4.8} \times 100 = 17\% \text{ ionic} = 83\% \text{ covalent}$$

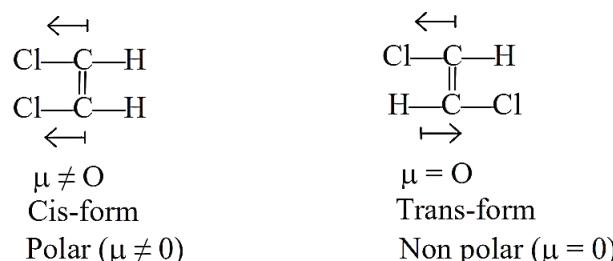
- Ex 2.** For HC1 molecule observed dipole moment is 1.03D and bond length is 1.275 Å. Calculate % ionic character.

Dipole moment = $4.8 \times 10^{-18} \times 1.275 \times 10^{-8} = 4.8 \times 1.275$

Sol. % ionic character = $\frac{1.03 \times 100}{1.275 \times 4.8} \approx 17\%$

(C) To distinguish cis form or trans form :-

- Ex.** Dipole moment of cis isomers is normally higher than trans isomers.



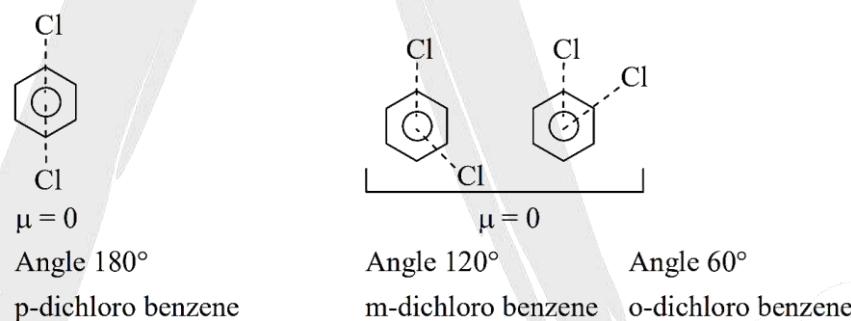
Ex. If two groups have opposite inductive effect then trans-isomer will have greater dipole moment.
e.g. -



(D) To locate position of substituents in aromatic compounds.

$$\text{(Dipole Moment)} \mu \propto \frac{1}{\text{Bond angle}}$$

(I) If same substituents are present in the symmetrical position of benzene ring, μ of compounds will be zero.



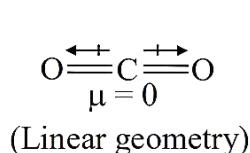
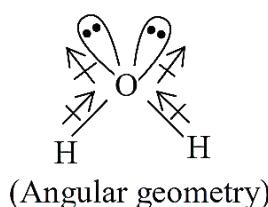
(II) As angle between substituents decreases value of μ increases.

Q.1 Both CO_2 and H_2O contain polar covalent bonds but CO_2 is nonpolar while H_2O is polar because-

- (1) H atom is smaller than C atom
- (2) CO_2 is a linear molecule while H_2O is an angular molecule
- (3) O – H bond is more polar than C-H bond
- (4) CO_2 contains multiple bonds while H_2O has only single bonds

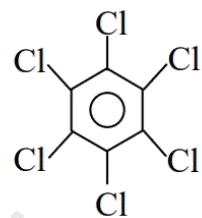
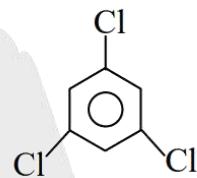
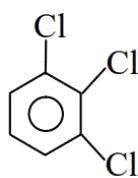
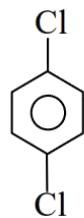
Ans. (2)

Sol.



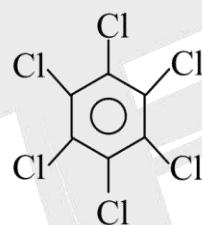
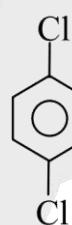
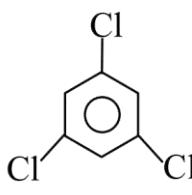
Q.2

Q.2 Find the number of molecule having dipole moment less than the dipole moment of



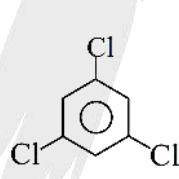
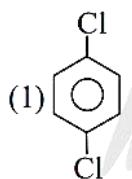
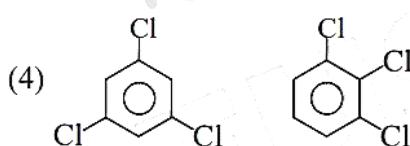
Ans. (3)

Sol.

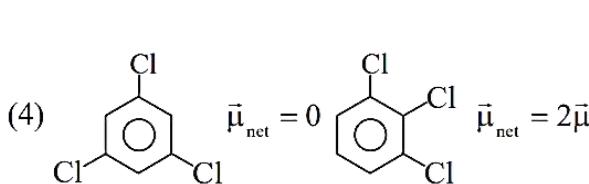
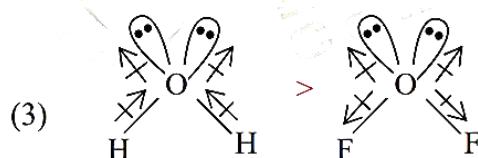
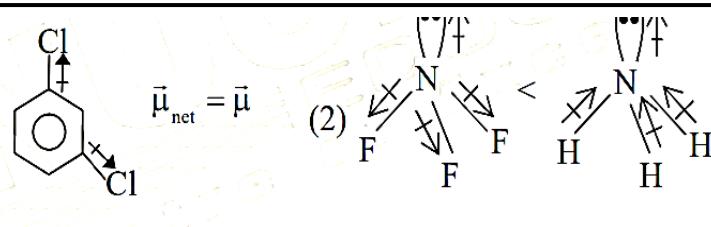
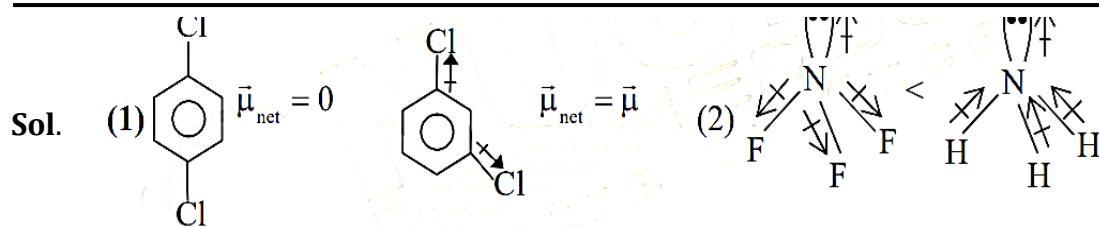


Have zero dipole moment

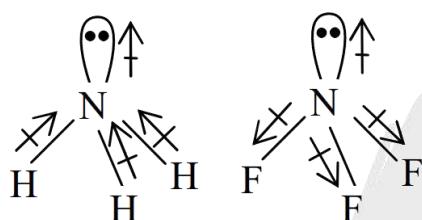
Q.3 In which pair, first compound has more dipole moment than second compound

(2) NF_3, NH_3 (3) $\text{H}_2\text{O}, \text{OF}_2$ 

Ans. (3)

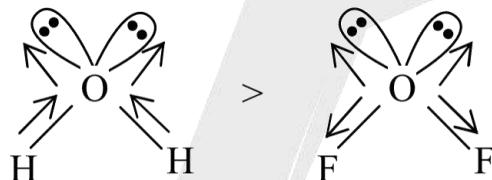


Q.4 Explain μ of NH_3 and NF_3



In case of NF_3 , dipole moment of lone pair reduces the overall dipole moment whereas in NH_3 , dipole moment of lone pair adds to the dipole moment of molecule.

Q.5 Explain μ of H_2O and OF_2



In OF_2 , lone pair moment oppose the moment due to $\text{O} - \text{F}$ bond hence dipole moment decreases.

Q.6 Compare dipole moment in CH_3F , CH_3Cl , CH_3Br , CH_3I .

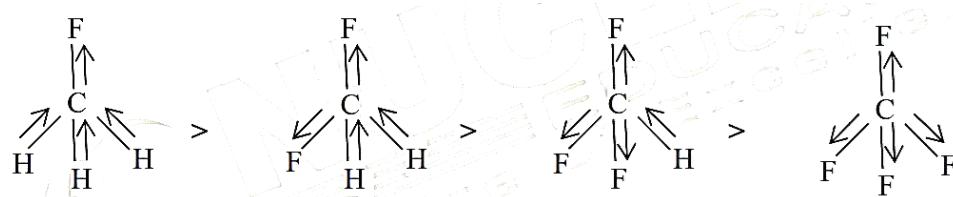
Sol. Expected order $\text{CH}_3\text{F} > \text{CH}_3\text{Cl} > \text{CH}_3\text{Br} > \text{CH}_3\text{I}$

Actual order $\text{CH}_3\text{Cl} > \text{CH}_3\text{F} > \text{CH}_3\text{Br} > \text{CH}_3\text{I}$

In case of Cl, due to sudden increase in size, dipole moment increases. Here distance factor becomes more dominating than charge. ($\mu = q \times d$)

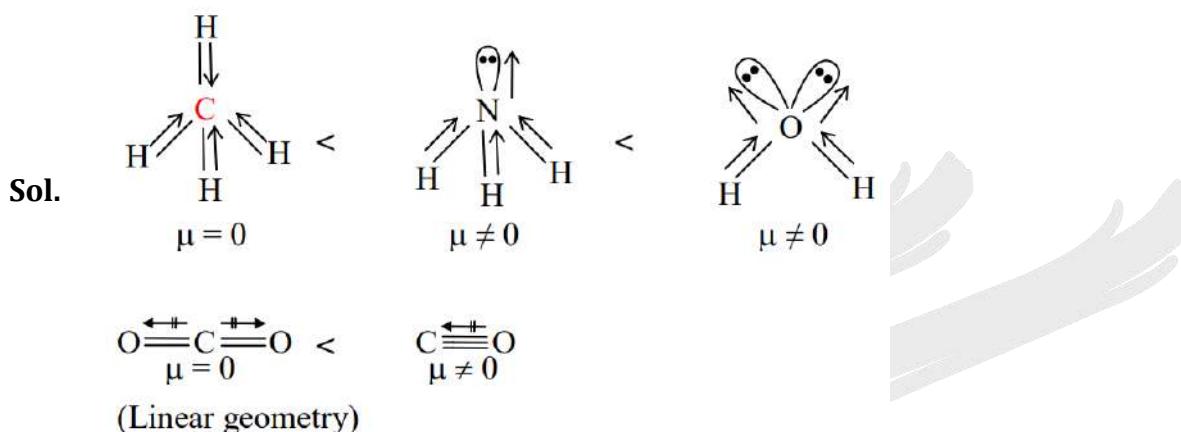
Q.7 Compare dipole moment in CH_3F , CH_2F_2 , CHF_3 & CF_4

Sol. $\text{CH}_3\text{F} > \text{CH}_2\text{F}_2 > \text{CHF}_3 > \text{CF}_4$



As number of F increases, it opposes dipole moment due to other bonds.

Q.8 Compare dipole moment of



Q.9 Dipole moment of HBr is 7.95D & intermolecular distance is 1.94×10^{-10} m. Find % ionic character.

$$\% \text{ Ionic character} = \frac{7.95 \times 3.33 \times 10^{-30}}{1.60 \times 10^{-19} \times 1.94 \times 10^{-10}} \times 100 = 85.2\%$$

Q.10 Calculate the μ of HCl ? If bond distance is 1.34 Å, charge = 4.8×10^{-10} esu and calculate % ionic character if experimental value of $\mu = 1.08\text{D}$?

$$\mu = q \times d = 4.8 \times 10^{-10} \times 1.34 \times 10^{-8}$$

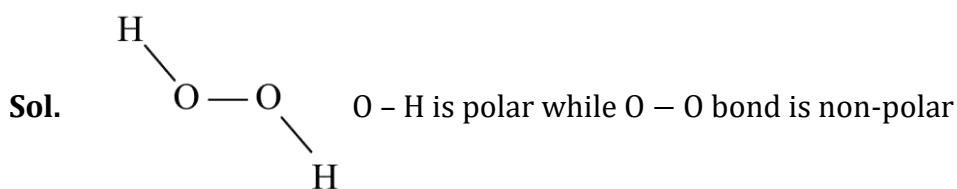
Sol. $\mu = 6.4 \times 10^{-18}$ esucm.

$$\% \text{ ionic character} = \frac{1.08}{6.4 \times 10^{-18}} = 16.79\%$$

Q.11 Which of the following contains polar and nonpolar bonds?

- (1) H₂O₂ (2) CH₄
 (3) HCN (4) NH₄Cl

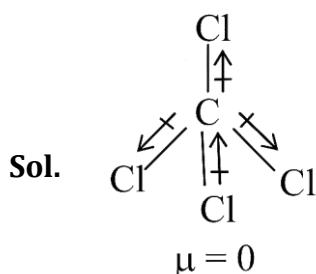
Ans. (1)



Q.12 Carbon tetrachloride has no net dipole moment because of-

- (1) Similar electron affinities of C and Cl
- (2) its regular tetrahedral geometry
- (3) its planar geometry
- (4) similar sizes of C and Cl atoms

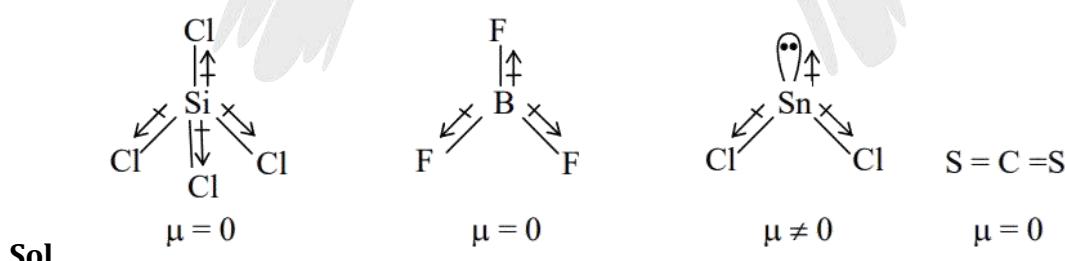
Ans. (2)



Q.13 Which of the following molecules is nonpolar?

- | | |
|-----------------------|----------------------------|
| (i) SiCl_4 | (ii) BF_3 |
| (iii) SnCl_2 | (iv) CS_2 |
| (1) (i), (ii), (iii) | (2) (i), (ii), (iii), (iv) |
| (3) (i), (ii), (iv) | (4) (ii), (iii), (iv) |

Ans. (3)



Q.14 Which of the following has the highest dipole moment?

- (1) *o*-Dichlorobenzene
- (2) *m*-Dichlorobenzene
- (3) *p*-Dichlorobenzene



(4) All have equal values

Ans. (1)

Sol.: o-dichlorobenzene have minimum bond angle.

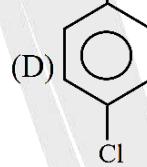
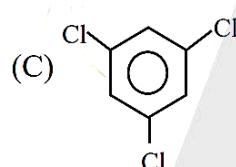
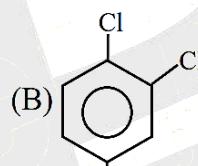
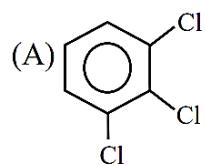
Hence have maximum dipole moment $\mu \propto \frac{1}{BA}$

DO YOURSELF - 4

Q.1 Which of the following molecules are polar?

- | | |
|--------------------|----------------------|
| (A) ClO_2 | (B) SO_2 |
| (C) NO_2 | (D) All of the given |

Q.2 Which of the following species have maximum dipole moment?



Q.3 The species that will have the maximum dipole moment is –

- | | |
|----------------------------|------------------------------|
| (A) CH_3Cl | (B) CH_2Cl_2 |
| (C) CHCl_3 | (D) CH_3F |

Q.4 The dipole moments of the given molecules are such that –

- | | |
|---|---|
| (A) $\text{BF}_3 > \text{NF}_3 > \text{NH}_3$ | (B) $\text{NF}_3 > \text{BF}_3 > \text{NH}_3$ |
| (C) $\text{NH}_3 > \text{NF}_3 > \text{BF}_3$ | (D) $\text{NH}_3 > \text{BF}_3 > \text{NF}_3$ |

Q.5 Of the following molecules, the one, which has permanent dipole moment, is –

- | | |
|--------------------|-------------------|
| (A) SiF_4 | (B) BF_3 |
| (C) PF_3 | (D) PF_5 |

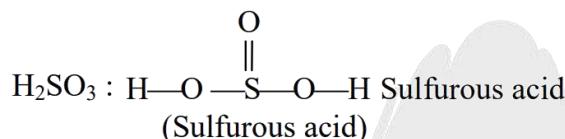
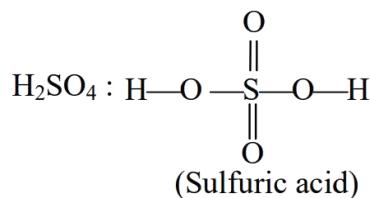


LECTURE NUMBER -14 & 15

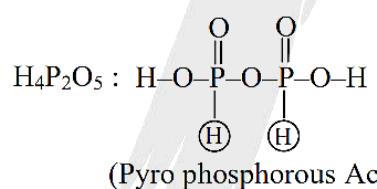
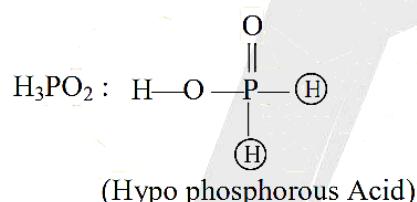
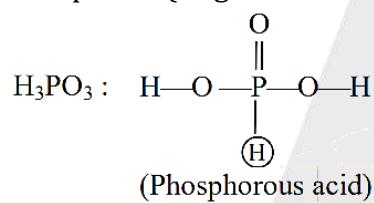
INORGANIC OXY-ACIDS

Those compounds which contain X – O – H bond are called oxy-acids. Where X is usually a nonmetal.

But sometimes X may also be a metal.

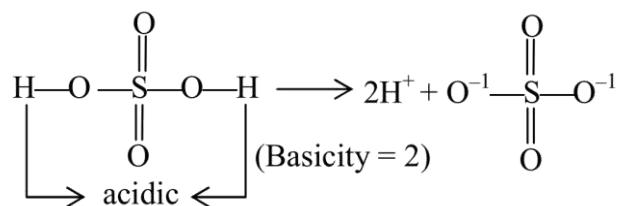


In oxy acids, all the hydrogens are attached with oxygen. Although there are a very few exceptions (as given below), in which all hydrogens are not attached with oxygen.



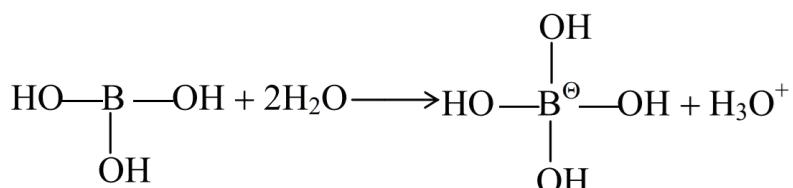
In these three oxyacids circled hydrogens are not attached with oxygen.

In oxyacids, those hydrogens which are attached with oxygen are acidic in nature, i.e., they ionize in solution.



Number of hydrogens attached with oxygen is known as basicity of the acid. One notable exception is H_3BO_3 in which all the three hydrogens are attached with oxygen yet, they do not ionise in solution.

In fact, H_3BO_3 when dissolved in water, it behaves as a monobasic acid.



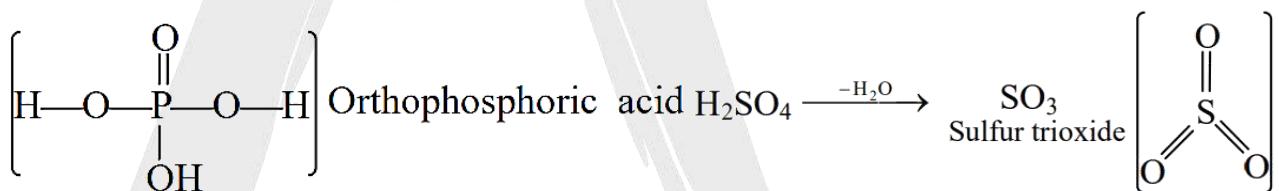
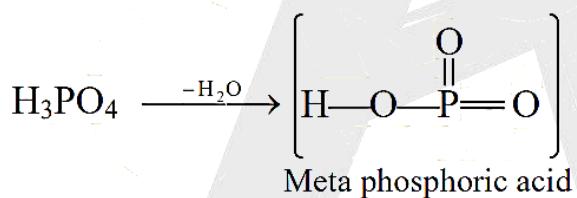
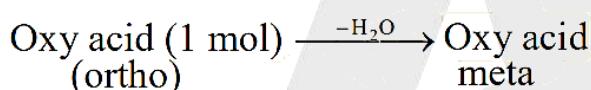
Some acids have suffix-ic acid and some has-ous acid. Usually, when the central atom in oxy acid is in highest oxidation state the name of the acid ends with -ic acid and when the central atom is in lower oxidation state, it's name ends with-ous acid.

Oxyacids can be classified as

ORTHO ACIDS AND META ACIDS

When one mole of H_2O is removed from one mole of an oxy acid, the resulting compound, if an oxy acid (i.e. it contains at least one $\text{X} - \text{OH}$ bond) then the oxy acid from which H_2O is removed is named as ortho acid and the product oxyacid is known as meta acid.

An ortho acid must contain at least three hydrogens.

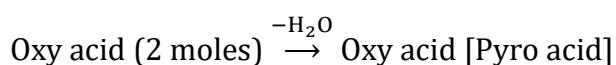


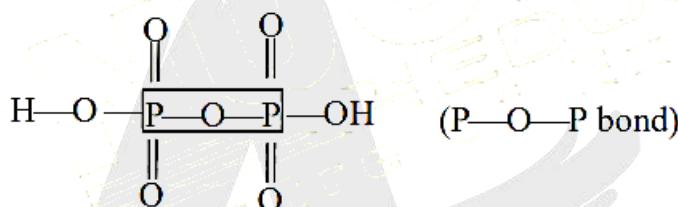
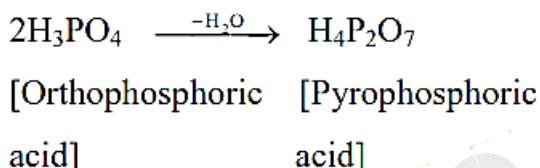
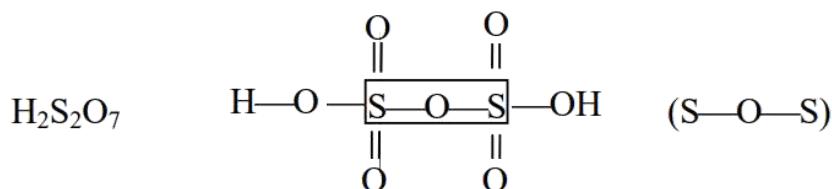
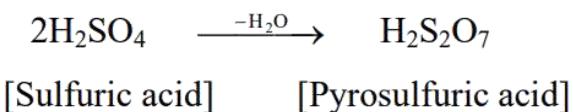
As SO_3 does not contain any hydrogen, SO_3 is not an oxy acid rather it is anhydride of sulfuric acid (H_2SO_4) so, H_2SO_4 can't be prefixed with ortho, and its name does not contain any prefix and it is named as sulfuric acid.

PREFIX USED FOR OXY ACID

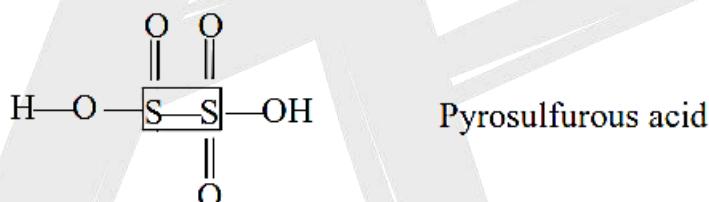
PYRO ACIDS :

When one mole of water is removed from two moles of an oxyacid, the resultant oxy acid is known as pyro acid, pyro acids contain $\text{X} - \text{O} - \text{X}$ bonds. (X is central atom)



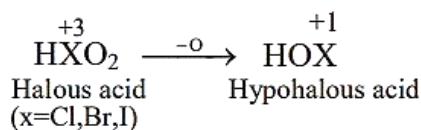
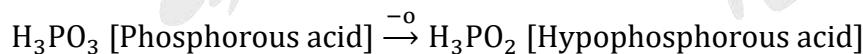


Exception : $\text{H}_2\text{S}_2\text{O}_5$ [Pyrosulfurous acid] does not contain $\text{S}-\text{O}-\text{S}$ linkage.



HYP0 ACID :

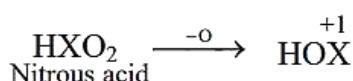
Hypo prefix is added to those oxy acids which is obtained when one oxygen atom is removed from-ous form of parent oxy acid.



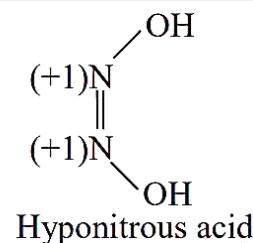
HOCl – Hypochlorous acid

HOBr – Hypobromous acid

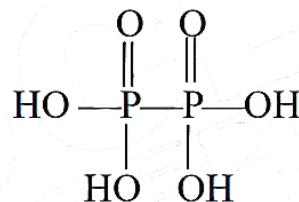
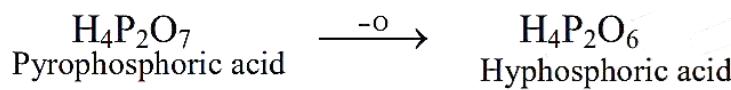
HOI – Hypoiodous acid



HNO exist in dimeric form i.e. as $(\text{HNO})_2 = \text{H}_2\text{N}_2\text{O}_2$



Exception :

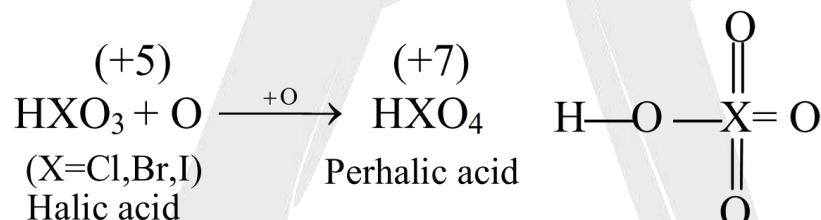


$\text{H}_2\text{S}_2\text{O}_6$: Hyposulphuric

H_2SO_2 : Hyposulphurous acid/Sulphoxalic acid

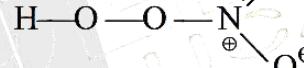
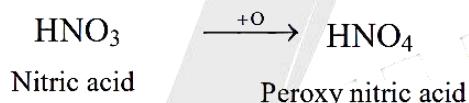
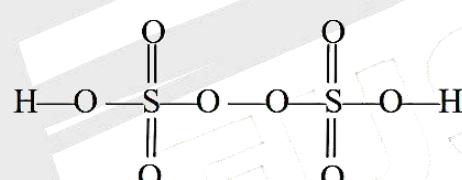
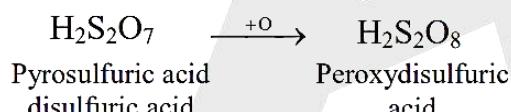
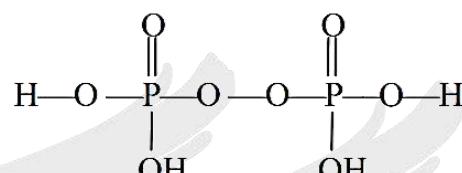
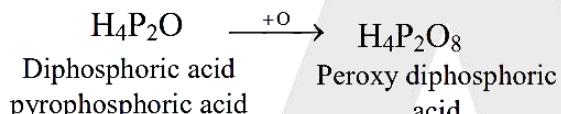
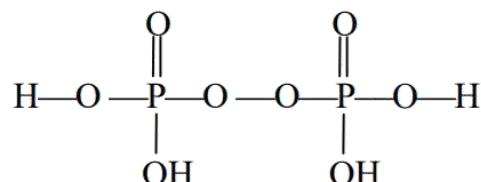
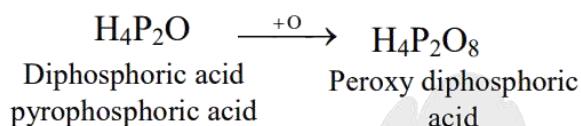
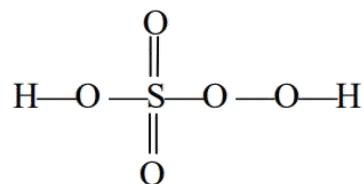
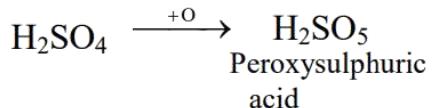
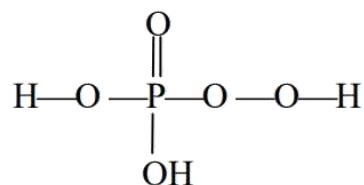
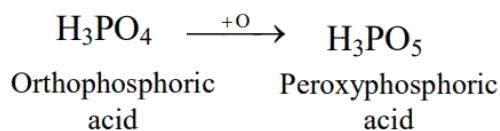
Per Acid and Peroxy Acid :

When one oxygen is added to -ic form of acid and if the oxidation number of central atom in resulting oxy acid is more than the -ic form of acid, then it is per acid.



Ex.: HClO_4 perchloric acid HBrO_4 - Perbromic acid.

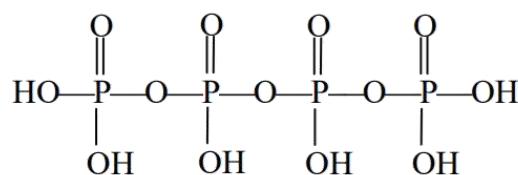
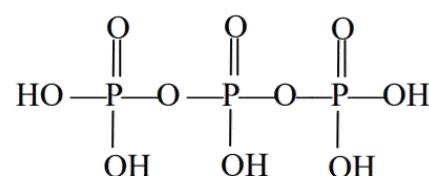
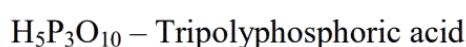
Peroxy prefix is added to those oxy acids which are obtained when one oxygen is added to -ic form of acid and the oxidation number of central atom remains the same. Peroxy acids contain peroxy linkage ($-0-\text{O}-0-$)



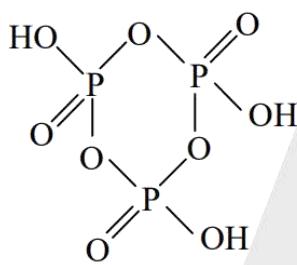
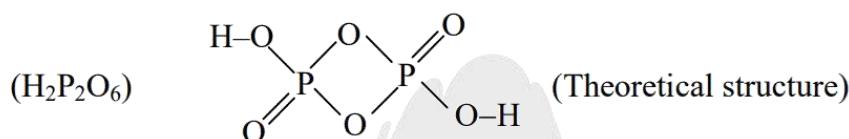
Note : Peroxynitric acid does not contain N-O-H bond, yet it is considered to be oxy acid.

Polyphosphoric acids :

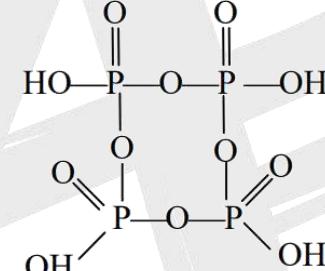
Oxy acids having general formula $\text{H}_{(n+2)}\text{P}_n\text{O}_{(3n+1)}$ are known as polyphosphoric acids. These contain $(n-1)$ P-O-P bonds.



Cyclic metaphosphoric acids :

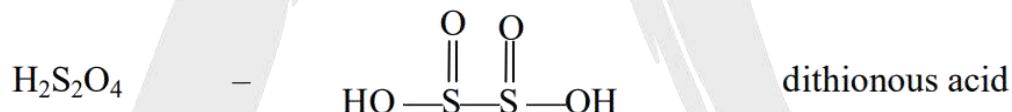


Trimetaphosphoric acid

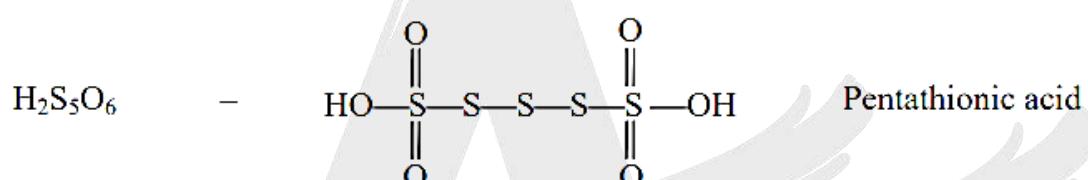
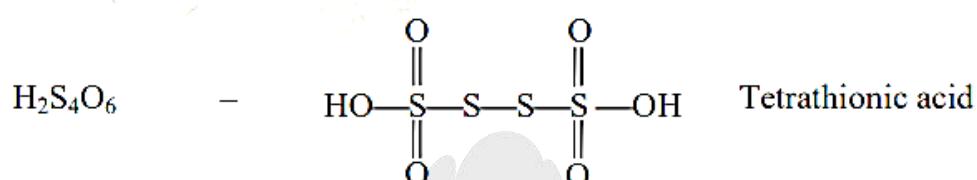
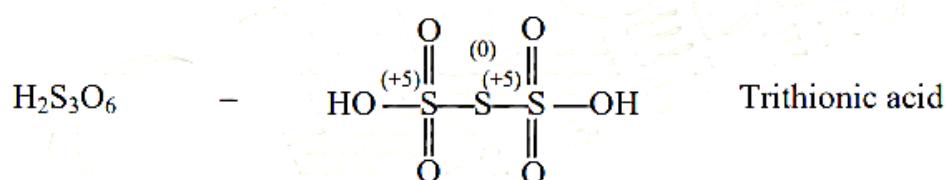
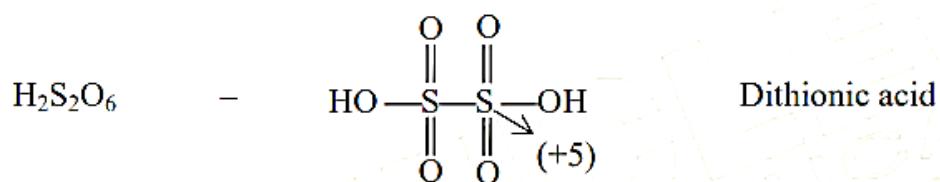


Tetrametaphosphoric acid

Thio acids : Oxy acids of sulfur containing S – S bond are known as thio acids.

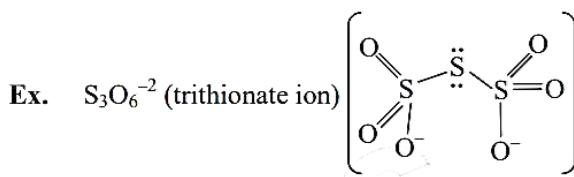
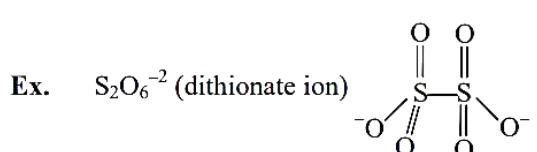
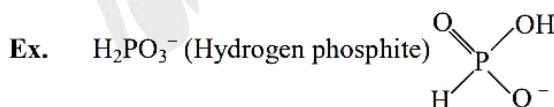
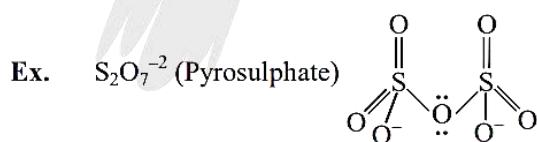
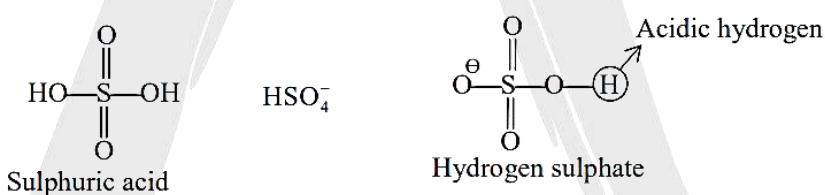


Thionic acids : Oxy acids of sulfur containing S – S bond and having general formula $H_2S_{(n+2)}O_6$ are known as thio acids.



Naming of salts of oxy anion :

- (1) The name of salt ends with - ate if the name of the oxy acid ends with- ic acid.
- (2) If the name of the oxy acid ends with ous acid then the name of the salt ends with 'ite'.
- (3) If all the ionisable hydrogens are not removed from the acid to form salt, then the hydrogen word is added to the name of the salt containing acidic hydrogens.



Other example

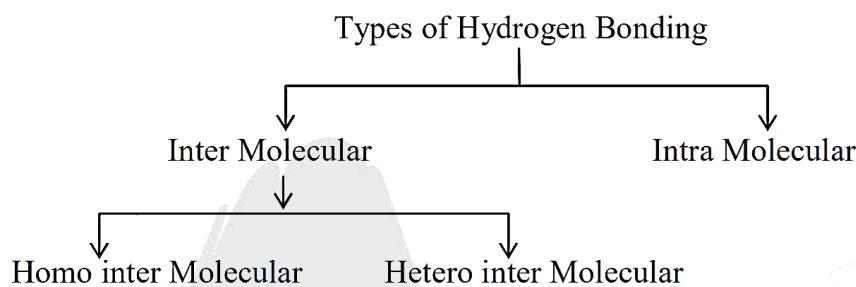
$\text{S}_2\text{O}_3^{2-}$, $\text{S}_2\text{O}_5^{2-}$, $\text{S}_4\text{O}_6^{2-}$, NO_3^- , H_2PO_4^- , IO_6^{5-} , IO_5^{3-} , ClO_4^- , ClO_2^- etc.



LECTURE NUMBER - 16&17

Hydrogen Bond - Special case of dipole -dipole interaction :

A hydrogen atom normally forms a single bond. In some compounds, however, the hydrogen atom may be located between two atoms acting as a bridge between them. Hydrogen atom is now involved in the two bonds, one is a normal covalent bond and the other is a hydrogen bond. A hydrogen bond is always formed between two small size, high electronegative atoms such as fluorine, oxygen and nitrogen.

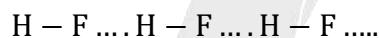


- Intermolecular Hydrogen Bonding - Molecular Association H-bond formation between two or more molecules of either the same or different compounds known as Inter molecular H-bonding These are two types.

(a) Homo-intermolecular :- H-bond between molecules of same compounds. Examples:

(i) Hydrogen fluoride:

HF is a polar molecule, with the fluorine atom acquiring a slight negative charge and the hydrogen atom acquiring an equal positive charge. The electrostatic attraction between the oppositely charged ends results in hydrogen bonding as shown below.



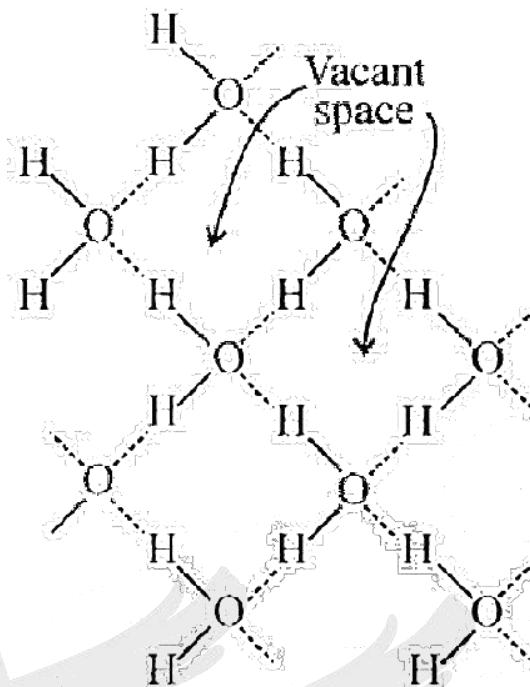
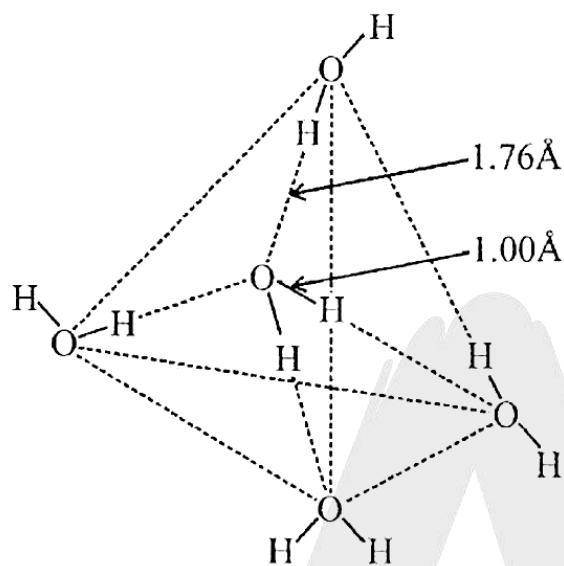
Many H – F units are held together, as $(\text{HF})_n$ by hydrogen bonding. The covalent H – F bond is much shorter than the HF hydrogen bond; so hydrogen bond is much weaker than a covalent bond. Fluorine, with the highest electronegativity forms the strongest hydrogen bond. The nature of bond is considerably electrostatic.

(ii) Water :

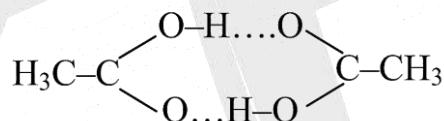
The high boiling point of water compared to that of hydrogen sulphide is due to molecular association through hydrogen bonding.

The crystal structure of ice shows a tetrahedral arrangement of water molecules. Each oxygen atom is surrounded tetrahedrally by 4 others. Hydrogen bond link pairs of oxygen atoms together as shown in Fig. The arrangement of water molecules in ice is a very open structure and this explains the low density of ice. When ice melts, the structure breaks down and the molecules

pack more closely together so that water has a higher density; this packing goes to a maximum upto a temperature of 4°C.



- (iii) Carboxylic acids :** Some carboxylic acids exist as dimers e.g the dimer of acetic acid represented as



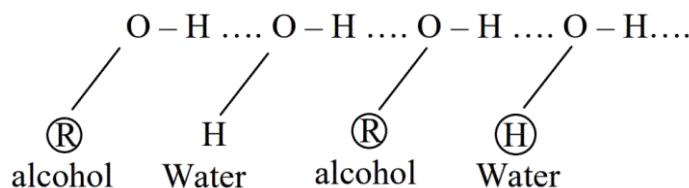
In aqueous solution molecules of carboxylic acid link up with water molecules through hydrogen bonding rather than forming dimers.

- (b) Hetero intermolecular:** H-bond between molecules of different compounds.

Example:

(i) Alcohols and water :

Lower alcohols and phenols are associated due to intermolecular hydrogen bonding. Methanol, ethanol and phenol have relatively much higher boiling points than methane or chloromethane, ethane or chloroethane, benzene or chlorobenzene respectively.



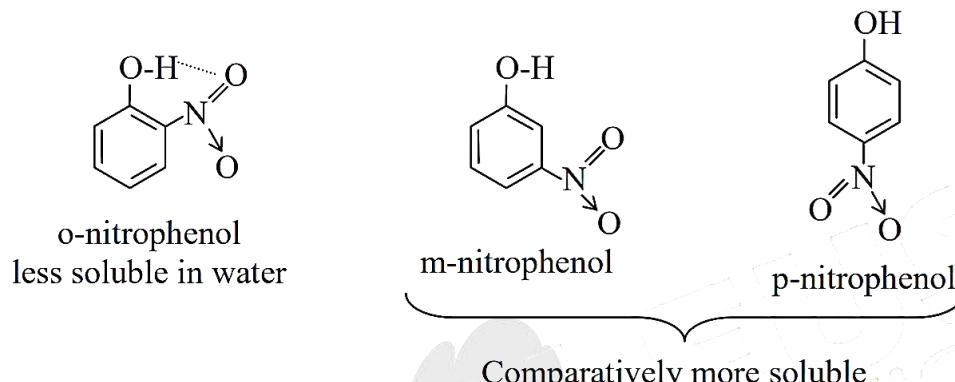
- Intramolecular Hydrogen Bonding - Chelation

Sometimes hydrogen bonding may take place within a molecule; this is known as

intramolecular (or internal) hydrogen bonding. It may lead to the linkage of two groups to from a ring; such an effect is known as chelation,

Examples :

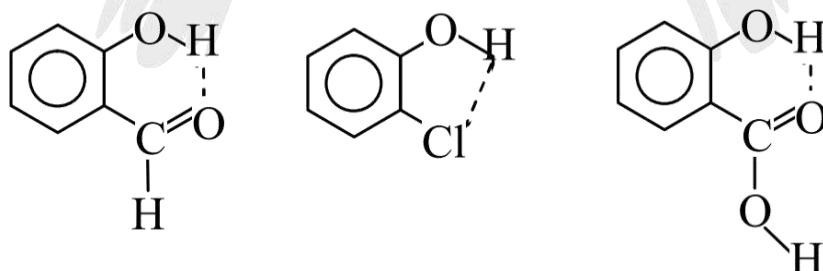
(i) Nitrophenols



Because of the proximity of $-\text{OH}$ and $-\text{NO}_2$ groups in o-nitrophenol there is intramolecular hydrogen bonding which prevents intermolecular hydrogen bonding between two or more molecules. Since molecular association cannot take place, the boiling point of o-nitrophenol is lower than that of the other two. Because of the distance between $-\text{OH}$ and $-\text{NO}_2$ groups in m- and p-nitrophenols there is no possibility of intramolecular hydrogen bonding. Intermolecular hydrogen bonding may take place to a certain extent which cause some degree of molecular association; this is responsible for the higher boiling points of the two nitrophenols.

Further the formation of intramolecular hydrogen bonding in o-nitrophenol prevents it from entering into intermolecular hydrogen bonding with water and this explains its reduced solubility.

- (ii)** Other molecules in which intramolecular hydrogen bonding is present are o-hydroxybenzaldehyde, o-chlorophenol and o-hydroxybenzoic acid.



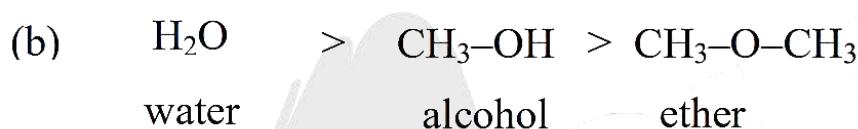
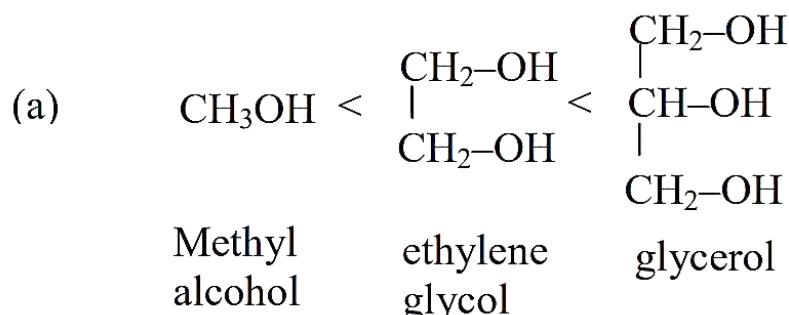
- Effect of H-Bonding on Physical Properties

(i) Solubility

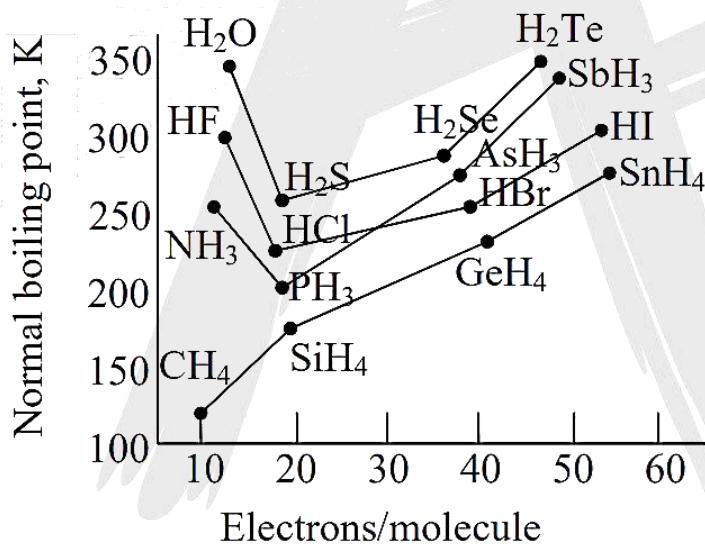
Due to **intermolecular** H-bonding solubility increases for example alcohol and glucose are soluble in water. Due to **intramolecular** H-bonding solubility decreases for example o-hydroxybenzaldehyde is less soluble in water as compare to p-hydroxybenzaldehyde

(ii) Viscosity

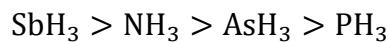
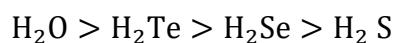
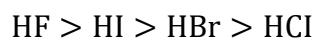
It is the measure of resistance to flow. Due to intermolecular H-bonding association takes place so viscosity increases for example:

**(iii) Melting and boiling Point :**

Due to intermolecular H-bonding melting point and boiling point of compound increases for example :



Order of boiling points of VA, VIA, VIIA hydrides is as follows



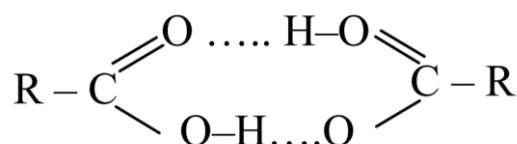
Intramolecular H-bonding gives rise to ring formation, So the force of attraction among these molecules are vander waal force, so M.P. and B.P are low.

(iv) Molecular weight

Due to intermolecular H bonding molecular weight increases.



For example: Molecular wt. of CH_3COOH is double of its molecular formula in benzene, due to dimer formation by H-bonding



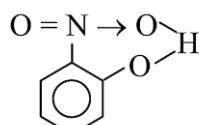
(v) Physical State :

H-bonding affects physical state (solid, liquid, gas) of compound. For example H_2O is liquid whereas H_2S is gas at room temperature.

Ex 1. Which one of the following does not have intermolecular H-bonding -

- (A) H_2O (B) o-Nitrophenol (C) HF (D) CH_3OH

Sol. O-Nitrophenol has intramolecular H bonding as shown below



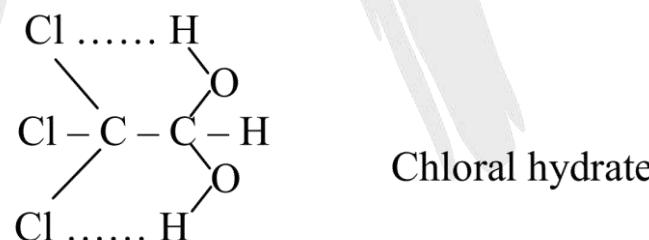
Hence Ans. is (2)

Ex 2. Arrange in increasing order of boiling

- | | |
|---|--|
| (i) HF, HCl, HBr, HI | (ii) H_2O , HF, NH_3 |
| (iii) PH_3 , H_2S , HCl | (iv) H_2O , CH_3OH , CH_3OCH_3 |
| Sol. (i) $\text{HCl} < \text{HBr} < \text{HI} < \text{HF}$ | (ii) $\text{NH}_3 < \text{HF} < \text{H}_2\text{O}$ |
| (iii) $\text{PH}_3 < \text{H}_2\text{S} < \text{HCl}$ | (iv) $\text{CH}_3\text{OCH}_3 < \text{CH}_3\text{OH} < \text{H}_2\text{O}$ |

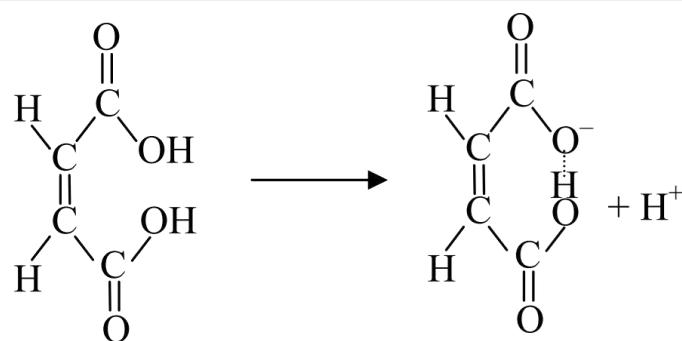
Ex 3. Why chloral hydrate is a stable molecule ?

Sol. Chloral hydrate is a stable due to H-bonding (intramolecular)

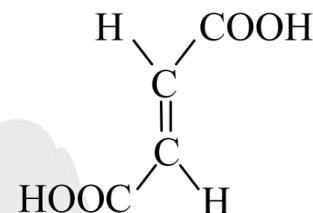


Ex 4. Why maleic acid (cis) is stronger acid than fumaric acid(trans)?

Sol. Maleic acid (cis) is stronger acid than fumaric acid (trans) because conjugate base of maleic acid is stable due to intramolecular H-bonding.

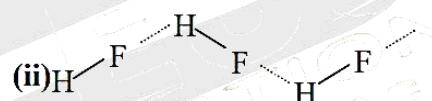
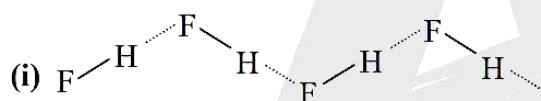


Stable conjugate base of maleic acid



Fumaric acid (No-intramolecular H-bonding)

Que. Which structure of HF is correct?



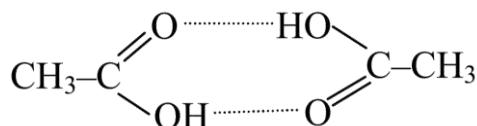
(iv) None

Sol. F has 3 lone pair hence linear structure around F is not possible. Hence correct option is (i).

Que. Heat of vapourisation of water is higher than HF. However strength of H-Bond in HF is higher than water.

Sol. H_2O is surrounded by 4 other H_2O molecules whereas HF is surrounded by only 2 molecules. Due to this, extent of hydrogen bonding in H_2O is more, hence Heat of vapourisation of water is higher.

Que. Experimental molecular weight of acetic acid is just double than theoretical molecular weight. Why?



Sol.

Observed molecular weight = 120

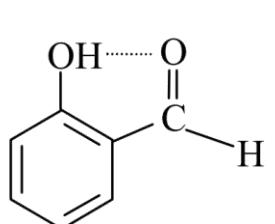
Due to intermolecular, H-Bonding

Q. KHF_2 exists but $KHBr_2$ & KHI_2 does not. Why ?

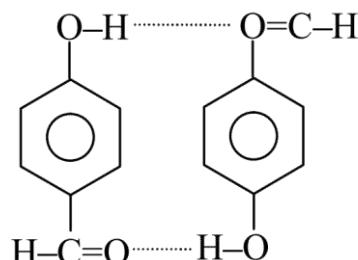
Sol. $\text{KHF}_2 \rightarrow \text{K}^+ + \text{HF}_2^- [\text{F}^- \dots \text{H} - \text{F}]$ H-bonding

$\text{KHBr}_2 \rightarrow \text{K}^+ + \text{HBr}_2^-$ [not stable] }
 $\text{KHI}_2 \rightarrow \text{K}^+ + \text{HI}_2^-$ [not stable] }

Que. o-hydroxybenzaldehyde is liquid white p-hydroxybenzaldehyde is solid at room temperature?
Why?



Intramolecular
H-bonding



Intermolecular
H-bonding

Sol.

DO YOURSELF - 5

Q.1 Which one among the following does not have the hydrogen bond?

- (A) Phenol (B) $\text{NH}_3(\ell)$ (C) $\text{H}_2\text{O}(\ell)$ (D) $\text{HCl}(\ell)$

Q.2 Among the following the strongest hydrogen bond is

- (A) $\text{O}-\text{H} \cdots \cdots \text{S}$ (B) $\text{S}-\text{H} \cdots \cdots \text{O}$ (C) $\text{F}-\text{H} \cdots \cdots \text{F}$ (D) $\text{O}-\text{H} \cdots \cdots \text{O}$

Q.3 Which of the following compounds is most volatile?

- (A) HF (B) HCl (C) HBr (D) HI

Q.4 The hydrogen bond is strongest in:

- (A) $\text{O}-\text{H} \cdots \cdots \text{S}$ (B) $\text{S}-\text{H} \cdots \cdots \text{O}$ (C) $\text{F}-\text{H} \cdots \cdots \text{F}$ (D) $\text{O}-\text{H} \cdots \cdots \text{O}$

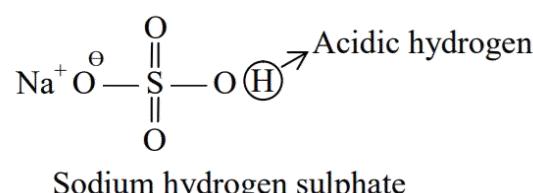
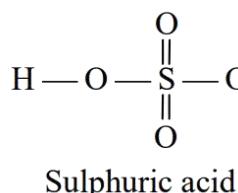
Q.5 Weakest hydrogen bond is:

- (A) $\text{O}-\text{H} \cdots \cdots \text{N}$ (B) $\text{S}-\text{H} \cdots \cdots \text{S}$ (C) $\text{F}-\text{H} \cdots \cdots \text{F}$ (D) $\text{N}-\text{H} \cdots \cdots \text{N}$



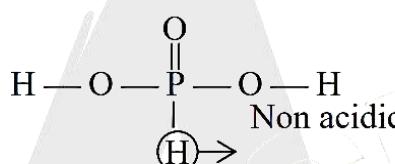
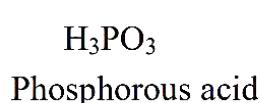
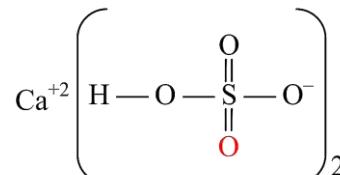
LECTURE NUMBER - 18

- Naming and structure of salts of oxy acids :

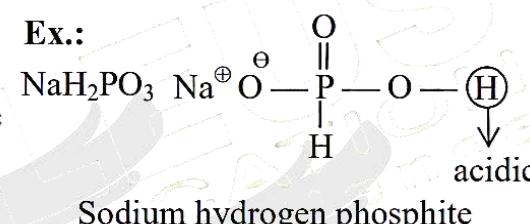


Sodium hydrogen sulphate

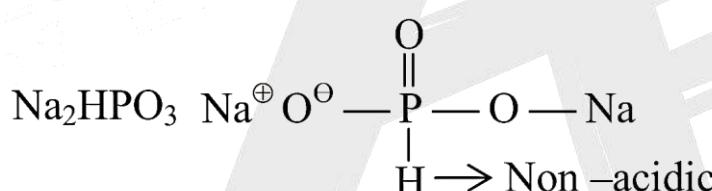
$\text{Ca}(\text{HSO}_4)_2$ calcium hydrogensulphate



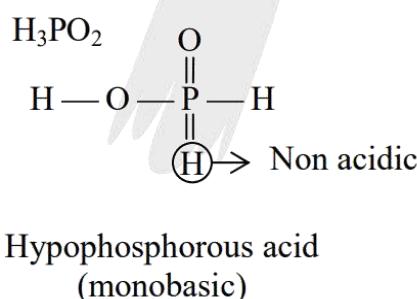
Ex.:



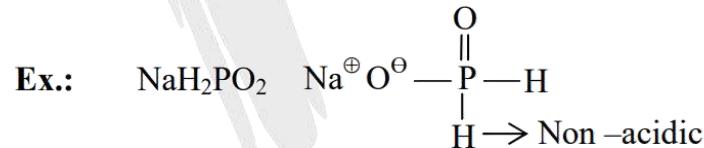
Sodium hydrogen phosphite



Sodium phosphite



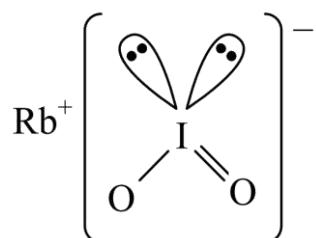
Hypophosphorous acid
(monobasic)



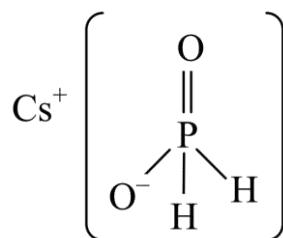
Sodium hypophosphite but not sodium
Dihydrogen phosphate as H is not acidic

Ex. RbIO_2

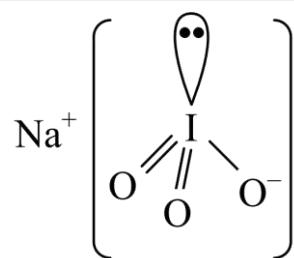
Ex. CsH_2PO_2 (cesium-hypophosphite)



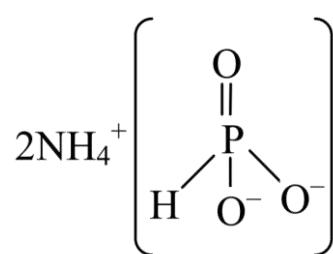
Ex. NaIO_3 (sodium iodate)



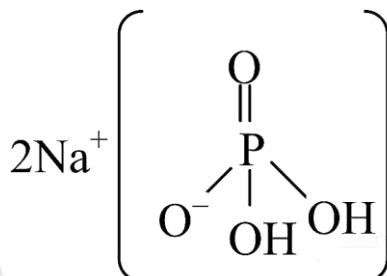
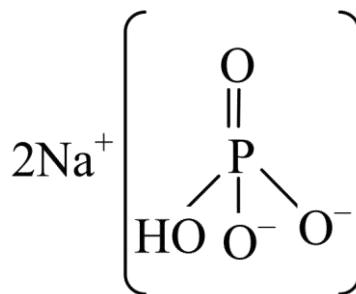
Ex. Ammonium phosphite $(\text{NH}_4)_2\text{HPO}_3$



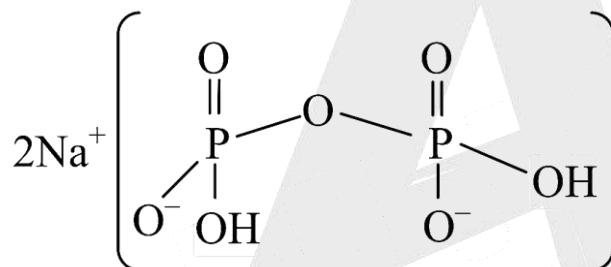
Ex. Sodium Hydrogen phosphate



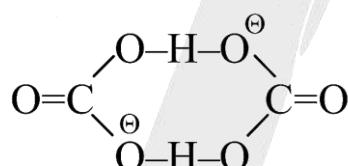
Ex. NaH_2PO_4 (Sodium dihydrogen phosphate)



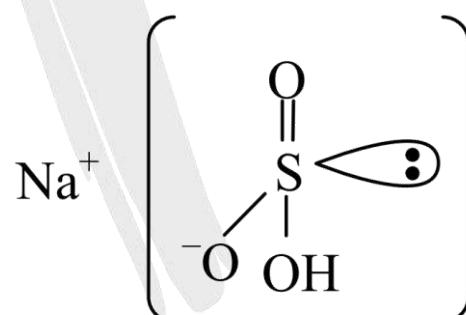
Ex. $\text{Na}_2\text{H}_2\text{P}_2\text{O}_7$ {Sodium dihydrogen pyrophosphate }



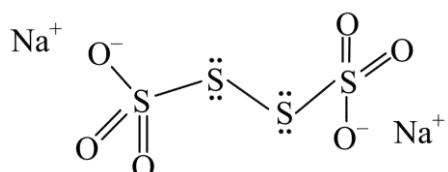
Ex. Potassium bi carbonate (KHCO_3)



Compact H bonding



Ex. $\text{Na}_2\text{S}_4\text{O}_6$ (sodium tetrahionate)



- Some Other example -



Sulphuric acid

Na_2SO_4 – Sodium sulphate

K_2SO_4 – Potassium sulphate

BaSO_4 – Barium sulphate



	FeSO_4 – Ferrous sulphate
	$\text{Al}_2(\text{SO}_4)_3$ – Aluminum sulphate
H_3PO_4	Na_3PO_4 – Sodium orthophosphate
Orthophosphoric acid	K_3PO_4 – Potassium orthophosphate
	$\text{Ca}_3(\text{PO}_4)_2$ – Calcium Orthophosphate
	AlPO_4 – Aluminium orthophosphate
HPO_3	NaPO_3 – Sodium metaphosphate
Meta phosphoric acid	KPO_3 – Potassium metaphosphate
	$\text{Ca}(\text{PO}_3)_2$ – Calcium metaphosphate
HClO_3	$\text{AlO}_3)_3$ – Aluminium metaphosphate
Chloric acid	KClO_3 – Potassium chlorate
	NaClO_3 – Sodium chlorate
HClO	$\text{Ca}_4(\text{ClO}_3)_2$ – Calcium chlorate
Perchloric acid	NaClO_4 – Sodium perchlorate
	KClO_4 – Potassium perchlorate
	NH_4ClO_4 – Ammonium perchlorate
	$\text{Ca}(\text{ClO}_4)_2$ - Calcium perchlorate
H_3PO_4	KH_2PO_4 potassium dihydrogen orthophosphate
Orthophosphoric acid	$\text{Ca}(\text{H}_2\text{PO}_4)_2$ calcium dihydrogen orthophosphate
$(\text{HPO}_3)_6 = \text{H}_6\text{P}_6\text{O}_{18}$	$\text{Na}_6\text{P}_6\text{O}_{18}$
Hexametaphosphoric acid	Sodium hexametaphosphate
HBiO_3	NaBiO_3 . Sodium metabismuthate
Metabismuthic acid	KBiO_3 . Potassium metabismuthate
HBO_2	NaBO_2 sodium metaborate
Metaboric acid	
H_2SO_5	Na_2SO_5 . Sodium peroxy sulphate
Peroxysulphuric acid	
$\text{H}_4\text{P}_2\text{O}_7$ $\text{Na}_4\text{P}_2\text{O}_7$ –	Sodium pyrophosphate
Pyrophosphoric acid	
HClO_2	NaClO_2 sodium chlorite
Chlorous acid	KClO_2 potassium chlorite
	$\text{Ca}(\text{ClO}_2)_2$ calcium chlorite
H_3PO_3	Na_2HPO_3 potassium phosphite
(dibasic acid)	$\text{Ca}_2(\text{HPO}_3)_2$ calcium phosphite

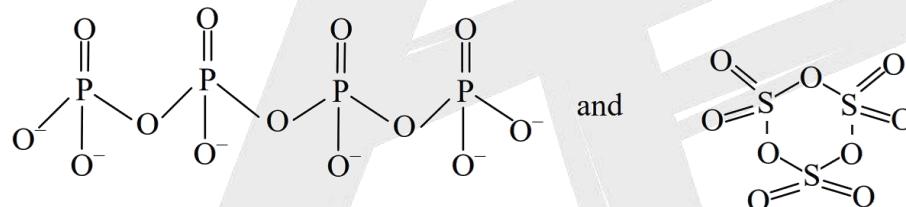
H_2SO_3	KO_2 sodium sulphite
Sulphurous acid	SO_3 potassium sulphite
HNO_2	NaNO_2 sodium nitrite
Nitrous _{acid}	KNO_2 potassium nitrite
HOCl	NaOCl sodium hypochlorite
Hypochlorous acid	KOBr potassium hypobromite
	NaOI sodium hypoiodite
H_3PO_2	NaH_2PO_2 sodium hypophosphite
Hypophosphorous acid (monobasic acid)	$\text{Ba}(\text{H}_2\text{PO}_2)_2$ Barium hypophosphite

- Q.1** Which of the following species has the same number of X – O – X linkage as present in S_3O_9 (i.e. $\gamma - \text{SO}_3$)

(A) $\text{S}_2\text{O}_6^{2-}$ (b) $\text{P}_4\text{O}_{13}^{4-}$ (C) $\text{P}_4\text{O}_{13}^{6-}$ (D) $\text{S}_4\text{O}_6^{2-}$

Ans. (C)

X – O – X linkages in S_3O_9 is 3 and in $\text{P}_4\text{O}_{13}^{6-}$ also it is 3 .



- Q.2** Find the number of ions in which $\frac{\sigma}{\pi}$ ratio is 4 from the following.

$\text{P}_3\text{O}_9^{3-}$, $\text{P}_4\text{O}_{12}^{4-}$, $\text{P}_4\text{O}_{13}^{6-}$, $\text{P}_5\text{O}_{15}^{5-}$, $\text{P}_5\text{O}_{16}^{7-}$, $\text{P}_3\text{O}_{10}^{5-}$

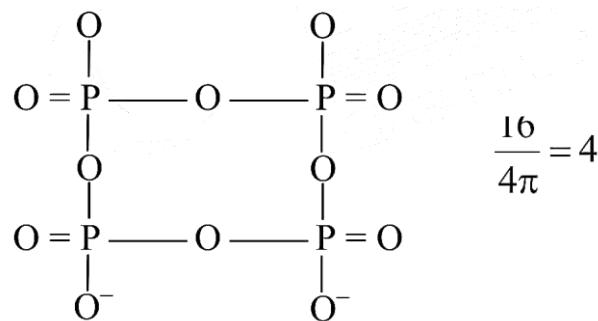
Ans. 6

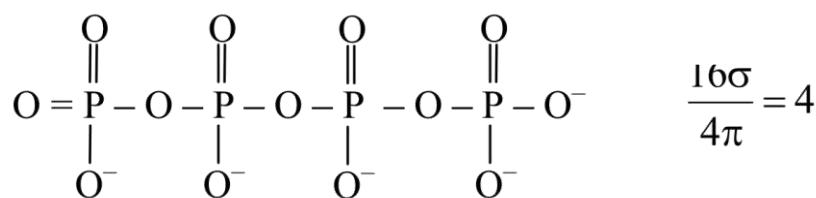
In following anion

no. of σ bond $\Rightarrow n \times 4$

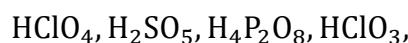
no. of π bond $\Rightarrow n$

Where n is no. of central atom. Hence the ratio of σ and π bond is 4 for each ion. $\text{P}_4\text{O}_{12}^{-4}$:-





Q.3 Find the number of molecules which are per acid as well as peroxy acid.



Ans. 2

H_2SO_5 and $\text{H}_4\text{P}_2\text{O}_8$ having per oxy linkage.

Q.4 Find the number of acid(s) which are having hypo prefix in it's name from the following.



Ans. (4)

- $\text{H}_3\text{PO}_2 \rightarrow$ Hypo phosphorous acid

$\text{HClO} \rightarrow$ Hypo chlorous acid

$(\text{HNO})_2 \rightarrow$ Hypo nitrous acid

$\text{H}_4\text{P}_2\text{O}_6 \rightarrow$ Hypo phosphoric acid

Q.5 Which of the following statement is correct for $\text{H}_3\text{P}_3\text{O}_9$

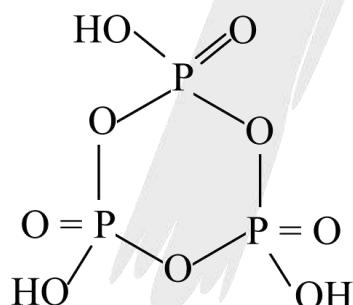
(1) trimetaphosphoric acid

(2) tribasic acid

(3) has cyclic structure

(4) All are correct

Ans. (4)



Q.6 Which of the following having S-O-S linkage -

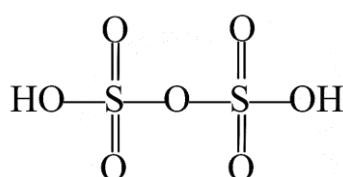
(A) $\text{H}_2\text{S}_2\text{O}_5$

(B) $\text{H}_2\text{S}_2\text{O}_7$

(C) $\text{H}_2\text{S}_3\text{O}_6$

(D) $\text{H}_2\text{S}_2\text{O}_4$

Ans. (B)



Q.7 The number of S-S linkages in sodium tetrathionate

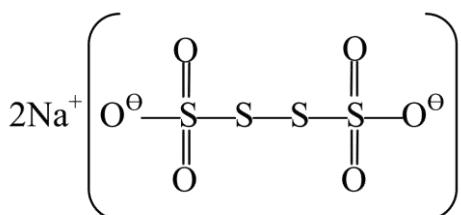
(A) 1

(B) 2

(C) 3

(D) 4

Ans. (C)

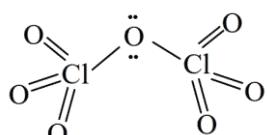


1. Structures of few important compounds Oxides

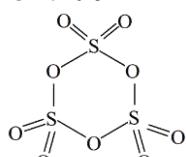
Ex. C_3O_2 (Carbon suboxide)



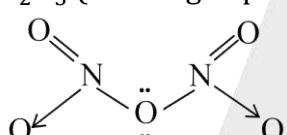
Ex. Cl_2O_7 (Dichlorine heptoxide)



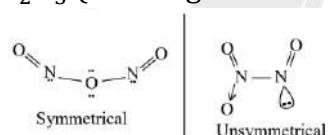
Ex. S_3O_9 (cyclic trimer of SO_3)



Ex. N_2O_5 (Dinitrogen pentoxide)



Ex. N_2O_3 (Dinitrogen trioxide)

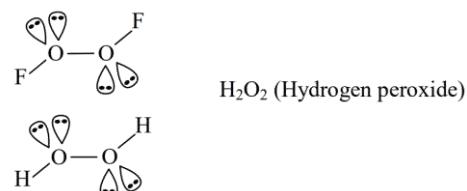


- **Other example :**

$\text{N}_2\text{O}, \text{C}_{12}\text{O}_9, \text{SO}_2, \text{SO}_3, \text{N}_2\text{O}_4, \text{N}_2\text{O}_5$ etc.

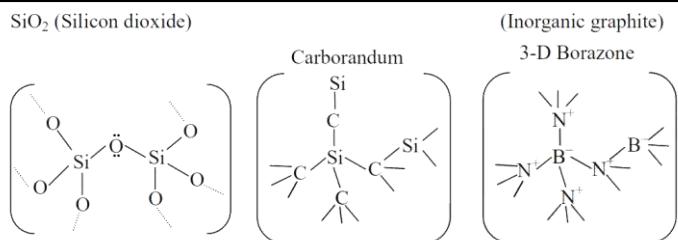
- **Open book like structure:**

Ex. O_2F_2 (Dioxygen di fluoride)

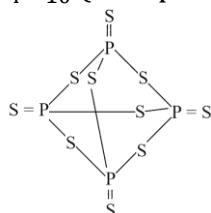


1. 3D Structures

Ex.

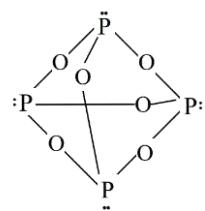
**2. Cyclic structure**

Ex. P₄S₁₀ (Phosphorous pentasulphide)

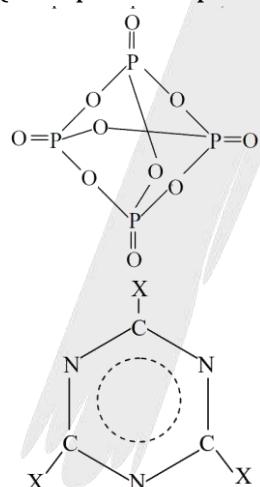


Ex. P₄O₆ (Phosphorous trioxide)

Chemical formula → P₂O₃ or P₄O₆



Ex. P₄O₁₀ (Phosphorous pentoxide)



X = -N₃⁻, -NH₂, Cl⁻

C₃N₃Cl₃ Cyanuric trichloride

C₃N₃(NH₃)₃ Cyanuric triamide

C₃N₃(N₃)₃ Cyanuric triazine

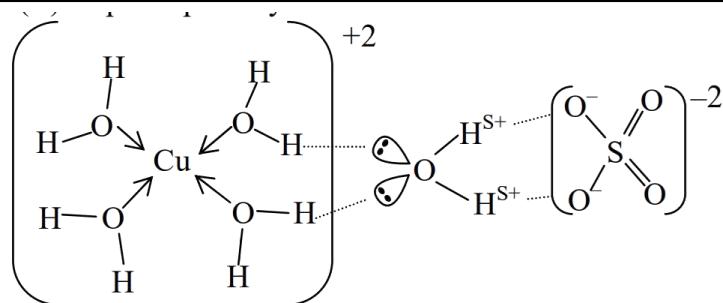
3. Other example

(BO₂²⁻)₃, B₃N₃H₆, C₆H₆

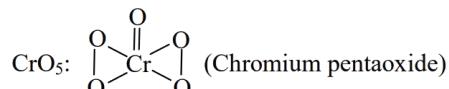
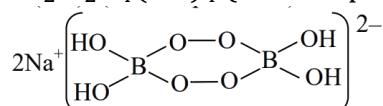
• Special Structures

Ex. CuSO₄ · 5H₂O

Copper (II) sulphate pentahydrate

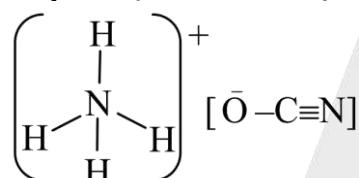


$\text{Na}_2\text{B}_2\text{O}_4(\text{OH})_4$ (Sodium perborate)

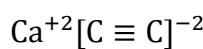


- Other examples:

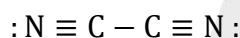
Ex. NH_4OCN (Ammonium cyanate)



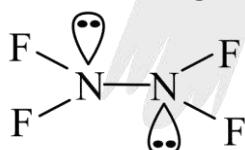
Ex. CaC_2 (Calcium carbide)



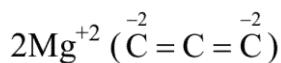
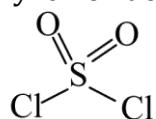
Ex. $(\text{CN})_2$ cyanogen



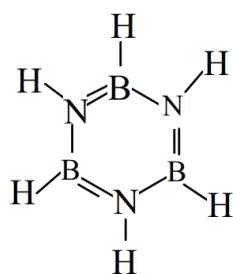
Ex. N_2F_4 $\left\{ \begin{array}{l} \text{Tetra fluoro hydrazine} \\ \text{or} \\ \text{Dinitrogen tetrafluoride} \end{array} \right\}$



Ex. Sulphuryl chloride (SO_2Cl_2)



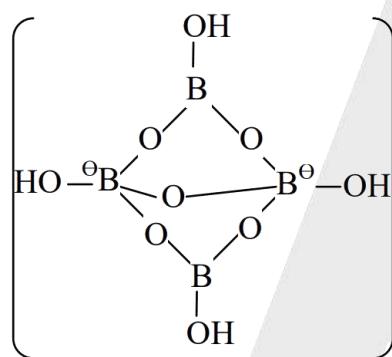
Ex. Inorganic benzene ($\text{B}_3\text{N}_3\text{H}_6$)

**Other examples**

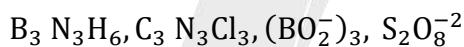
Q.1 Find the number of B – O – B linkage in the following :- $[\text{B}_4\text{O}_5(\text{OH})_4]^{2-}$

Ans. (005)

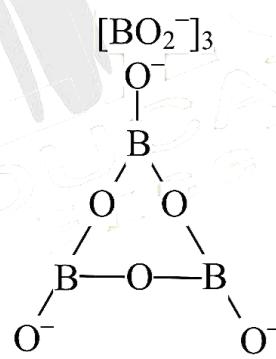
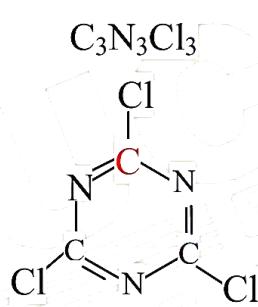
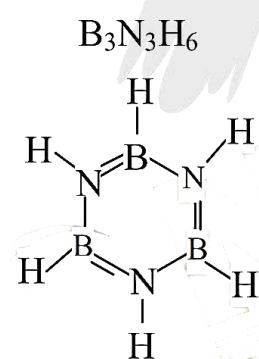
Sol.



Q.2 Find the number of planar molecules/ions which are cyclic-



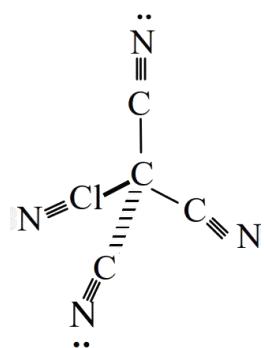
Ans. (3)



Q.3 Find the maximum number of atoms present in one plane in $\text{C}(\text{CN})_4$:-

- | | |
|-------|-------|
| (A) 3 | (B) 5 |
| (C) 7 | (D) 9 |

Ans. (B)



Maximum 5-atom in one plane

Q.4 The number of plane containing maximum number of atoms in $\text{C}(\text{CN})_4$:-

- (A) 8
- (B) 10
- (C) 4
- (D) 6

Ans. (D)

Q.5 Find the number of molecules in which $\frac{\sigma}{\pi}$ ratio is four

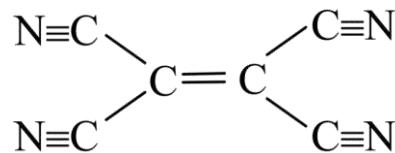


Ans. 3

Molecules	σ/π ratio
$\text{C}_3\text{N}_3\text{Cl}_3$	3
$\text{B}_3\text{N}_3\text{H}_6$	4
$\text{P}_2\text{O}_7^{4-}$	4
$\text{S}_2\text{O}_7^{2-}$	2
$\text{HP}_2\text{O}_6^{3-}$	4

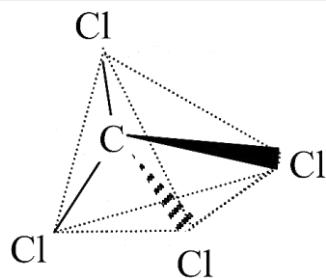
Q.6 Find the number of atoms are lying in the same plane of $\text{C}_2(\text{CN})_4$

Ans. (10)



Q.7 Find the maximum number of plane having maximum same type of atom in CCl_4 .

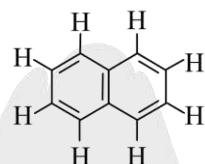
Ans. (4)



Q.8 Find the total number of sigma bond(s) in naphthalene

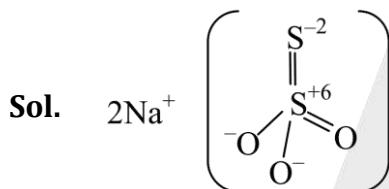
Ans. (19)

Total number of σ -bond = 19



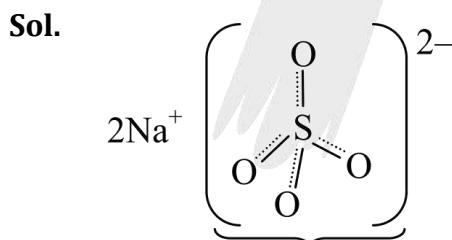
Q.9 Find the average oxidation number of S atoms in sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$)

Ans. (2)



Q.10 Find the number of identical $\widehat{\text{OSO}}$ angles in Na_2SO_4 molecule.

Ans. (6)

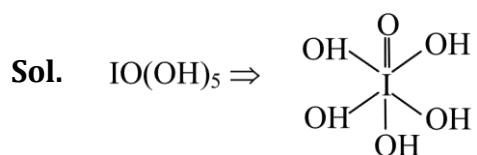


Due to equivalent
Resonance All the
bond angle are equal

Q.11 The shape of $\text{IO}(\text{OH})_5$ is supposed to nearly with respect to I-atom.

- (A) Trigonal bipyramidal
- (B) Square pyramidal
- (C) Octahedral
- (D) See-saw

Ans. (C)



Q.12 Number of atoms that are in same plane in Benzene is

- (A) 6 (B) 12
(C) 5 (D) 10

Ans. (B)

LECTURE NUMBER – 20

ALLOTROPES OF CARBON FAMILY

- Carbon exhibits many allotropic forms; both crystalline as well as amorphous. Diamond and graphite are two well-known crystalline forms of carbon. In 1985, third form of carbon known as **fullerenes** was discovered by H.W. Kroto, E.Smalley and R.F.Curl. For this discovery they were awarded the Nobel Prize in 1996.

Diamond (kinetically most stable allotrope of carbon, meta stable phase of carbon)

It has a crystalline lattice. In diamond each carbon atom undergoes sp^3 hybridisation and linked to four other carbon atoms by using hybridized orbitals in tetrahedral fashion. The C – C bond length is 154pm. The structure extends in space and produces a rigid three dimensional network of carbon atoms.



The structure of diamond

In this structure, directional covalent bonds are present throughout the lattice. It is very difficult to break extended covalent bonding and, therefore, diamond is a very hard substance. It is used as an abrasive for sharpening hard tools, in making dyes and in the manufacture of tungsten filaments for electric light bulbs.

Problem

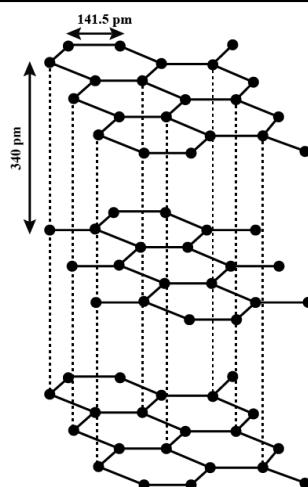
Diamond is covalent, yet it has high melting point. Why ?

Solution

Diamond has a three-dimensional network involving strong C – C bonds, which are very difficult to break and, in turn has high melting point.

Graphite (*Thermodynamically most stable allotrope of carbon*)

Graphite has layered structure. Layers are held by vander Waals forces and distance between two layers is 340pm. Each layer is composed of planar hexagonal rings of carbon atoms. C-C bond length within the layer is 141.5pm. Each carbon atom in hexagonal ring undergoes sp^2 hybridisation and makes three sigma bonds with three neighbouring carbon atoms. Fourth electron forms a π bond. The electrons are delocalised over the whole sheet. Thus, graphite is lusturous.



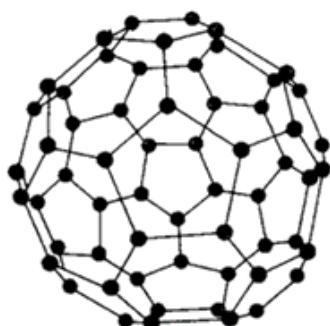
Electrons are mobile and therefore, graphite conducts electricity along the sheet. Graphite cleaves easily between the layers and, therefore, it is very soft and slippery. For this reason graphite is used as a dry lubricant in machines running at high temperature, where oil cannot be used as a lubricant.

Fullerenes:-

Fullerenes are made by the heating of graphite in an electric-arc in the presence of inert gases such as helium or argon. The sooty material formed by condensation of vapourised en small molecules consists of mainly C_{60} with smaller quantity of C_{70} and traces of fullerenes consisting of even number of carbon atoms up to 350 or above. Fullerenes are the only pure form of carbon because they have smooth structure without having 'dangling' bonds. Fullerenes arc cage like molecules. C_{60} molecule has a shape like soccer ball and called **Buckminsterfullerene**.

It contains twenty, six-membered rings and twelve, five membered rings. A six membered ring is fused with six or five membered rings but a five membered ring can only fuse with six membered rings. All the carbon atoms are equal and they undergo sp^2 hybridisation. Each carbon atom forms three sigma bonds with other three carbon atoms. The remaining electron at each carbon is delocalized in molecular orbitals, which in turn give aromatic character to molecule. However, because of non- planar nature of fullerenes, their aromatic character gets diminished and reactivity increases.

This ball shaped molecule has 60 vertices and each one is occupied by one carbon atom and it also contains both single and double bonds with C-C distances of 143.5pm and 138.3pm respectively. Spherical fullerenes are also called bucky balls in short.





[The structure of C_{60} : note that molecule has the shape of a soccer ball (football)]

It is very important to know that graphite is thermodynamically most stable allotrope of carbon and, therefore, ΔH_f of graphite is taken as zero. ΔH_f values of diamond and fullerene, C_{60} are 1.90 and 38.1 kJ mol^{-1} , respectively.

Other forms of elemental carbon like carbon black, coke, and charcoal are all impure forms of graphite or fullerenes. Carbon black is obtained by burning hydrocarbons in a limited supply of air. Charcoal and coke are obtained by heating wood or coal respectively at high temperatures in the absence of air.

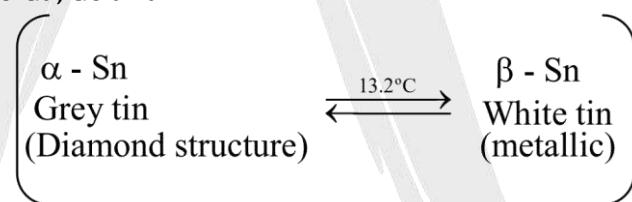
Uses of Carbon:-

Graphite fibres embedded in plastic material form high strength, lightweight composites. The composites are used in products such as tennis rackets, fishing rods, aircrafts and canoes.

Being good conductor, graphite is used for electrodes in batteries and industrial electrolysis.

Crucibles made from graphite are inert to dilute acids and alkalies. Being highly porous, activated charcoal is used in adsorbing poisonous gases; also used in water filters to remove organic contaminants and in airconditioning system to control odour. Carbon black is used as black pigment in black ink and as filler in automobile tyres. Coke is used as a fuel and largely as a reducing agent in metallurgy. Diamond is a precious stone and used in jewellery. It is measured in carats (1 carat = 200mg).

Si, Ge and Sn have a diamond type of structure, though Sn exists as a metallic form. Pb exists only in the metallic form. Ge is unusual because the liquid expands when it forms the solid. This property is unique to Ga, Ge and Bi.



ALLOTROPIES OF OXYGEN FAMILY

Oxygen occurs as two non-metallic forms, dioxygen O_2 and ozone O_3 . Dioxygen O_2 is stable as a diatomic molecule. O_3 molecule is diamagnetic while O_2 is paramagnetic.

Six allotropes of selenium are known.

Tellurium has only one crystalline form, which is silvery white and semimetallic.

This is similar to grey Se, but has stronger metallic interaction.

Sulphur Allotropic forms :

Sulphur forms numerous allotropes of which the yellow rhombic (α -sulphur) and monoclinic (β -sulphur) forms are the most important. The stable form at room temperature is rhombic sulphur, which transforms to monoclinic sulphur when heated above 369 K.

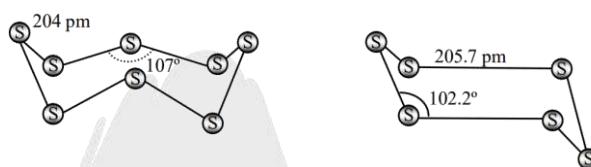
Rhombic sulphur (α -sulphur) (Most stable sulphur allotrope at room temperature)

This allotrope is yellow in colour, m.p. 385.8 K and specific gravity 2.06. Rhombic sulphur crystals are formed on evaporating the solution of roll sulphur in CS_2 . It is insoluble in water but dissolves to some extent in benzene, alcohol and ether. It is readily soluble in CS_2 .

Monoclinic sulphur (β -sulphur)

Its m.p. is 393 K and specific gravity 1.98. It is soluble in CS_2 while water insoluble. This form of sulphur is prepared by melting rhombic sulphur in a dish and cooling, till crust is formed. Two holes are made in the crust and the remaining liquid poured out. On removing the crust, colourless needle shaped crystals of β -sulphur are formed. It is stable above 369 K and transforms into α -sulphur below it. Conversely, α -sulphur is stable below 369 K and transforms into β -sulphur above this. At 369 K, both the forms are stable. This temperature is called transition temperature.

Both rhombic and monoclinic sulphur have S_8 molecules. These S_8 molecules are packed to give different crystal structures. The S_8 ring in both the forms is puckered and has a crown shape. The molecular dimensions are given in the figure.



The structures of (a) S_8 ring in Rhombic sulphur and (b) S_6 form

Several other modifications of sulphur containing 6-20 sulphur atoms per ring have been synthesized in the last two decades. In cyclo- S_6 , the ring adopts the chair form and the molecular dimensions are as shown in figure. At elevated temperatures (~ 1000 K), S_2 is the dominant species and is paramagnetic just like O_2 .

Note: Engel's sulphur (ε -sulphur) is unstable and contains S_6 rings arranged in the chair conformation. It is made by pouring $\text{Na}_2\text{S}_2\text{O}_3$ solution into concentrated HCl and extracting the S with toluene. Plastic sulphur- (χ) is obtained by pouring liquid sulphur into water.

Example

Which form of sulphur shows paramagnetic behavior?

Solution

In vapour state sulphur partly exists as S_2 molecule which has two unpaired electrons in the antibonding π^* orbitals like O_2 and, hence, exhibits paramagnetism.

Alltropes of nitrogen Family :

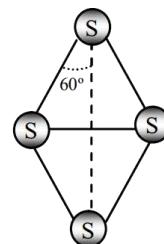
Solid As, Sb and Bi each exist in several allotropic forms. Arsenic vapour contains tetrahedral As_4 molecules. A reactive yellow form of the solid resembles white phosphorus and is thought to contain tetrahedral As_4 units. Sb also has a yellow form. All three elements have much less reactive metallic or α -forms.

PHOSPHORUS ALLOTROPIC FORMS

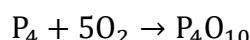
Phosphorus is found in many allotropic forms, the important ones being white, red and black. White phosphorus is a translucent, white, waxy solid, It is poisonous, insoluble in water but soluble in carbon disulphide and glows in dark (chemiluminescence). It dissolves in boiling NaOH solution in an inert atmosphere giving PH_3 .



(Sodium hypophosphite)

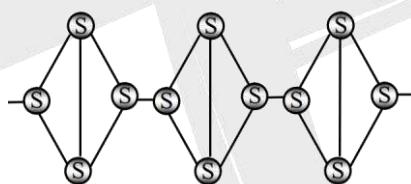
**White Phosphorus**

White phosphorus is less stable and therefore, more reactive than the other solid phases under normal conditions because of angular strain in the P_4 molecule where the angles are only 60° . It readily catches fire in air to give dense white fumes of P_4O_{10} .

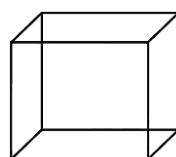


It consists of discrete tetrahedral P_4 molecule as shown in Fig.

Red phosphorus is obtained by heating white phosphorus at 573 K in an inert atmosphere for several days. When red phosphorus is heated under high pressure, a series of phases of black phosphorus is formed. Red phosphorus possesses iron grey lustre. It is odourless, nonpoisonous and insoluble in water as well as in carbon disulphide. Chemically, red phosphorus is much less reactive than white phosphorus. It does not glow in the dark. It is polymeric, consisting of chains of P_4 tetrahedra linked together in the manner as shown in Fig.

**Red Phosphorus**

Black phosphorus has two forms α -black phosphorus and β -black phosphorus α -black phosphorus is formed when red phosphorus is heated in a sealed tube at 803 K. it can be sublimed in air and has opaque monoclinic or rhombohedral crystals it does not oxidize in air. β -Black phosphorus is prepared by heating white phosphorus at 473 K under high pressure. It does not burn in air upto 673 K.



Thermodynamic stability order : Black phosphorus > Red phosphorus > White phosphorus

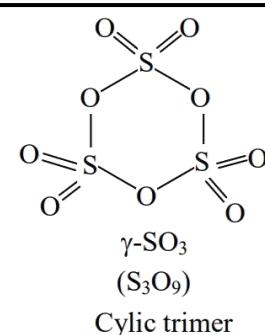
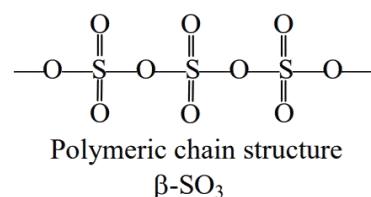
Reactivity order : Black phosphorus < Red phosphorus < White phosphorus

ALLOTROPIC FORM OF SO_3

SO_3 have three allotropic forms $\alpha - SO_3$, $\beta - SO_3$, and $\gamma - SO_3$



$\alpha\text{-SO}_3$
Cross linked solid





QUESTION OF HYDROGEN BONDING

- Q.1 Explain the structure of Boric acid in solid state.
- Q.2 Boiling point of o-Nitrophenol is less than meta and para nitrophenol. Why?
- Q.3 Maleic acid is more acidic than fumaric acid. Why?
- Q.4 H - F is only liquid among halogen acid. Why ?
- Q.5 Ammonia is more easily liquefied than HC1, explain.
- Q.6 Why ice floats on water?
- Q.7 Water shows maximum density at 4°C. Why?
- Q.8 HI is the strongest halogen acid, whereas H – F is the weakest. Why?
- Q.9 Wood pieces are used to hold ice-cream. Why?
- Q.10 KHF₂ is possible but not KHBr₂ or KHI₂. Why?
- Q.11 O - Nitrophenol is less soluble in H₂O than p - Nitrophenol. Why?
- Q.12 o-Hydroxy benzaldehyde is a liquid at room temperature while p-hydroxy benzaldehyde is a high melting solid.
- Q.13 Glycerol is more viscous than ethanol. Explain.
- Q.14 CH₄ and H₂O have nearly same molecular weight. Yet CH₄ has a boiling point 112 K and water 373 K. Explain.
- Q.15 The experimental molecular weight of acetic acid is just double than theoretical molecular weight of acetic acid. Why?
- Q.16 Although chlorine has same electronegativity as nitrogen but the former does not form effective H-bonding. Explain.
- Q.17 Molar entropy change of vapourization of acetic acid is less than that of water. Explain.
- Q.18 Heat of vapourization of water is higher than HF, however strength of H-bond in HF is higher than water. Explain



EXERCISE # 1

INTRODUCTION

- 1** The molecule which contain same number of σ and π bonds is
 (A) $(CN)_2$ (B) C_2H_2 (C) HNO_2 (D) HCN
- 2** Correct energy order of hybrid orbital is:
 (A) $sp < sp^2 < sp^3$ (B) $sp < sp^3 < sp^2$ (C) $sp^3 < sp^2 < sp$ (D) $sp^2 < sp^3 < sp$

LEWIS DOT STRUCTURES

- 3** Which of the following is hypovalent species?
 (A) ICl (B) SO_2 (C) NO_2^+ (D) NH_2^+
- 4** Which one of the following element do not have tendency to form hyper valent compound ?
 (A) P (B) N (C) S (D) Se
- 5** Which of the following set of species are hypovalent?
 (A) NH_3, CO_2 (B) SO_2, CO_2 (C) BeH_2 (D) $BeCl_2, PCl_3$
- 6** Which of the following pair of species are isostructural but not isoelectronic ?
 (A) N_2O and SO_2 (B) CO_3^{2-} and NO_3^{-1}
 (C) NF_3 and NH_3 (D) O_3 and NO_2^\oplus
- 7** Which of the following xenon compound has the same number of lone pairs as in I_3^- ?
 (A) XeO_4 (B) XeF_4 (C) XeF_2 (D) XeO_3
- 8** Which of the following molecules is adequately represented by a single Lewis structure?
 (A) O_3 (B) NOC_1 (C) SO_2 (D) N_2O

TYPES OF BOND

- 9** The molecule which contain both polar and non-polar covalent bond present in its structure?
 (A) $H_2 F_2$ (B) $O_2 F_2$ (C) O_3 (D) All of these
- 10** Which one of the following species have coordinate bond present in its Lewis structure
 (A) SO_2 (B) O_3 (C) NO_2 (D) All of them

- 11** $[\text{Re}_2\text{Cl}_8]^{-2}$ molecule has
 (A) only σ bond (B) only π bond (C) quadruple bond (D) None of these

- 12** Which of the following statement is correct regarding covalent bond?
 (A) Filled orbitals of two or more atoms overlap with one another.
 (B) Unoccupied orbitals of two or more atoms overlap with one another
 (C) Electrons are simultaneously attracted between more than one nucleus.
 (D) Electrons are transferred from one atom to another atom.

VBT

- 13** If x is internuclear axis, δ bond can be formed by :
 (A) $d_{x^2-y^2} + d_{x^2-y^2}$ (B) $d_{xy} + d_{yz}$ (C) $d_{yz} + d_{xy}$ (D) $d_{xz} + d_{xy}$

- 14** Which of the following leads to non-bonding on z -axis
 (A) $p_x + p_x$ (B) $P_y + P_y$ (C) $d_{xy} + d_{xy}$ (D) $d_{xy} + d_{yz}$

- 15** Which of the following statement is false
 (A) δ -bond is a result of 4-lobe interaction between two p-orbitals.
 (B) δ -bond is weaker than π -bond
 (C) δ -bond & σ -bond have unequal bond strength
 (D) Representative elements do not have tendency to form δ -bond.

- 16** Choose the incorrect order of bond strength :-
 (A) $3p_\pi - 3p_\pi < 2p_\pi - 3d_\pi$ (B) $3p_\pi - 3p_\pi < 3d_\pi - 3d_\pi$
 (C) $3p_\pi - 3d_\pi < 2p_\pi - 3d_\pi$ (D) $3p_\pi - 3d_\pi < 3p_\pi - 3p_\pi$

- 17** Which of the following specie does not contain $p_\pi - d_\pi$ bond(s) ?
 (A) SO_2Cl_2 (B) N_2O (C) H_2PO_3^- (D) SO_3^{2-}

- 18** Correct order of bond strength is:
 (A) $1s - 1s > 1s - 2s > 2s - 2p$
 (B) $1s - 1s < 1s - 2s < 2s - 2p$
 (C) $1s - 2s > 2s - 2p > 1s - 1s$
 (D) None of the above

19 If x is internuclear axis, δ bond can be formed by :

- (A) $d_{x^2-y^2} + d_{x^2-y^2}$ (B) $d_{xy} + d_{yz}$ (C) $d_{yz} + d_{yz}$ (D) $d_{xz} + d_{xy}$

20 Choose the CORRECT statement about the structure of SO_2 .

- (A) Two $2p_\pi - 3d_\pi$ bond
 (B) Two $2p_\pi - 3d_\pi$ bond
 (C) One $2p_\pi - 3d_\pi$ & one $2p_\pi - 3p_\pi$ bond
 (D) It is hypervalent

21 The species having no $P_\pi - P_\pi$ bond but has bond order equal to that of O_2 .

- (A) ClO_3^- (B) PO_4^{3-} (C) SO_4^{2-} (D) XeO_3

22 Which of the following orbital cannot form σ bond with d_{xy} orbital .

- (A) s (B) p_x (C) $d_{x^2-y^2}$ (D) All of these

23 Which of the following statement is correct ?

- (A) s-orbital always forms σ bond with p orbital
 (B) s-orbital is more directional than π -orbital
 (C) p-orbital always form 7i-bond
 (D) a covalent bond is directional in nature.

24 Which of the following overlapping is correct regarding σ -bond formation ?

- (A) $2p_x + 2p_x$, when y-axis is inter nuclear axis
 (B) $1s + 2p_x$, when x - axis is inter nuclear axis
 (C) $2p_y + 2p_y$, when z-axis is inter nuclear axis
 (D) $2p_y + 2p_z$, when x-axis is inter nuclear axis

25 Which of the following shows maximum covalency?

- (A) F (B) I (C) S (D) O

26 Which of the following overlapping is not present in XeO_3 molecule ?

- (A) $sp^3 + p_x$ (B) $sp^3 + p_y$
 (C) $d_{xz} + p_x$ (D) $sp^3 + s$



27 According to VBT, which of the following overlapping results π -type covalent bond in O_2 molecule formation, when Z-axis is internuclear axis?

(I) $2s - 2s$ (II) $2p_x - 2p_x$ (III) $1s - 1s$ (IV) $2p_y - 2p_y$

(V) $2p_z - 2p_z$

(A) I, III (B) III, IV (C) II, IV (D) IV, V

28 Which of the following would result in the formation of strongest π -bond if the molecular axis is x-axis?

(A) $2p_x + 2p_x$ (B) $2p_y + 2p_y$ (C) $2p_y + 3d_{xy}$ (D) $2p_z + 4p_z$

29 In which of the following species $p_\pi - d_\pi$ bond is present but $p_\pi - p_\pi$ bond is absent?

(A) SiH_4 (B) CS_2 (C) SO_2 (D) SO_2Cl_2

HYBRIDISATION

30 The set of planar chemical species in which d-orbital participate in hybridisation.

(A) ClO_4^- , ClO_3^- , ClO_2^- (B) XeF_5^0 , IF_4^0 , XeF_4

(C) XeF_5^0 , XeF_6 , XeF_4 (D) IF_7 , ClF_3 , SF_4

31 Hybridisation of N in NO_2 is ?

(A) sp^3 (B) sp
 (C) sp^2 (D) N atom is unhybridized

32 Which one is only V-shaped molecule or ion-

(A) I_3^- (B) N_3^- (C) S_3 (D) C_3^{4-}

33 In which of the following molecules hybridisation of central atom is $sp^3 d^2$.

(A) XeF_6 (B) $S_2 F_{10}$ (C) SF_4 (D) PEt_3

34 Which of the following molecule involve d_{z^2} orbital in it's hybridisation

(A) XeF_4 (B) $XeOF_4$ (C) $XeO_2 F_2$ (D) All of these

35 Hybridisation of $ClFO_3$, SF_4 & SOF_4 respectively will be

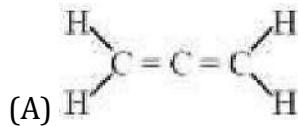
(A) sp^3 , sp^3 dsp^3d (B) sp^3 , sp^3 sp^3

(C) sp^3 , sp^3 $d^2sp^3d^2$ (D) All sp^3 d

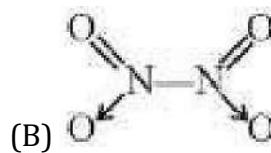
36 Electron geometry of the molecule XeF_2 & ICl_2^- are respectively?

- (A) square bipyramidal, tetrahedral
- (B) linear & linear
- (C) Trigonal bipyramidal & tetrahedral
- (D) Both Trigonal bipyramidal

37 Which of the following molecule have all atoms sp^2 Hybridised ?



(C) Benzene



(D) None of these

38 Which of the following statement is CORRECT?

- (A) Lattice energy is always highest for compound with highest ionic character
- (B) Hydrated radius is inversely proportional to hydration energy
- (C) Dissolution of salt in water depends upon lattice energy and hydration energy
- (D) None of these

39 Correct statement about a molecule of type AB_3L where A = central atom, L = lone pair, B = bond pair.

- (A) It is pyramidal in shape
- (B) NH_3 is one of the example of this case
- (C) It has tetrahedral electron geometry
- (D) All are correct.

40 Phi (ϕ) bond is present in

- (A) $\text{Mn}_2(\text{CO})_{10}$
- (B) U_2
- (C) O_2
- (D) None of these

41 Which of the following compound is planar ?

- (A) PH_4^+
- (B) XeF_4
- (C) XeOF_4
- (D) SF_6

42 Hybridisation of cationic part of $\text{Cl}_2\text{O}_6^-(s)$ is -

- (A) sp^2
- (B) sp^3
- (C) sp^3d
- (D) sp^3d^2

- 43** Which compound given below has sp^3 , sp^2 and sp orbitals in the ratio of 6: 3: 2 ?
- (A) $\text{CH}_3 - \text{CH} = \text{CH} - \text{CH}_2 - \text{C} \equiv \text{C} - \text{CH}_3$
 (B) $\text{CH}_3 - \text{CH} = \text{CH} - \text{CH}_2 - \text{C} \equiv \text{CH}$
 (C) $\text{CH}_3 - \text{CH}_2 - \text{C} \equiv \text{C} - \text{CH} = \text{CH}_2$
 (D) $\text{CH}_3 - \text{CH} = \text{CH} - \text{C} \equiv \text{CH}$
- 44** The molecule/ion in which bond angle is less than 107° .
- (A) NF_4^+ (B) CCl_4 (C) ClO_4^- (D) None of these
- 45** Select pair of compounds in which both have different hybridisation but have same molecular geometry.
- (A) $\text{BF}_3, \text{BrF}_3$ (B) $\text{ICl}_2^-, \text{BeCl}_2$ (C) $\text{BCl}_3, \text{PCl}_3$ (D) $\text{PCl}_3, \text{NCl}_3$
- 46** Choose the correct option for following statements :
- (I) sp^3 hybrid orbitals are at 90° to one another
 (II) sp^3 d² adjacent hybrid orbitals are at 90° to one another
 (III) sp^2 hybrid orbitals are at 120° to one another
 (IV) Bond order of N – O bond in NO_3^- is 1.33
- (A) TFTF (B) TTFF (C) F T T T (D) F T F T
- 47** Which of the following specie has sp^3 d³ hybridisation ?
- (A) XeF_5^- (B) SO_3 (C) SO_2 (D) XeF_2
- 48** If x is the no. of hybrid orbital containing 33.3% s-character and y is the number of hybrid orbital's containing 50% s-character then, find the value of $x \div y$ for allene.
- (A) 2 (B) 3 (C) 6 (D) 3.5
- 49** All fluorine atoms are in same plane in:
- (A) CHF_3 (B) ClF_3 (C) XeOF_4 (D) All of these
- 50** Select hybridisation which have non planar geometry when all are bond pair, but planar when there are 2 lone pairs on central atom:
- (A) sp^3 (B) sp^3 d (C) sp^3 d² (D) All of these



51 Select correct statement for BrF_5 .

- (A) All fluorine atoms are in same plane
- (B) Four fluorine atoms and Br atom is in same plane
- (C) Four fluorine atoms are in same plane
- (D) It has all F – Br – F bond angles at 90°

52 In which of following cases, the central atom is not perfectly sp^3 hybridised?

- (A) BF_4^-
- (B) SiF_4
- (C) CHF_3
- (D) CCl_4

53 Which of the following compound has the smallest bond angle ($X – A – X$) in each series respectively :



54 Molecule which does not contain any $F – X – F$ bond angle which is less than 90° :

(X = central atom)

- (A) IF_7
- (B) BrF_3
- (C) PF_5
- (D) SF_4

55 What is the geometry of the IBr_2^- ion?

(A) Linear

(B) Bent shape with bond angle of about 90°

(C) Bent shape with bond angle of about 109°

(D) Bent shape with bond angle of about 120°

56 What is the shape of the ClF_3 molecule ?

(A) Trigonal planar

(B) Trigonal pyramidal

(C) T-shaped

(D) Tetrahedral

57 The H – O – H bond angles in H_3O^+ are approximately 107° . The orbitals used by oxygen in these bonds are best described as :

(A) p-orbitals

(B) sp-hybrid orbitals

(C) sp^2 -hybrid orbital

(D) sp^3 -hybrid orbital

- 58** The shape of XeF_3^+ is :
 (A) Trigonal planar (B) Pyramidal
 (C) Bent T-shape (D) See-saw
- 59** Which of the following shape are not possible for possible value of ' n ' in X_{eF} molecule? 2
 (A) Linear (B) Square planar
 (C) Trigonal planar (D) Capped octahedral
- 60** Which of the following is the correct set with respect to molecule, hybridization and shape?
 (A) BeCl_2 , sp^2 , linear (B) BeCl_2 , sp^2 triangular planar
 (C) BCl_3 , sp^2 , triangular planar (D) BCl_3 , sp^3 , tetrahedral
- 61** The pair of species with similar shape is :
 (A) PCl_3 , NH_3 (B) CF_4 , SF_4 (C) PbCl_2 , CO_2 (D) PF_5 , IF_5
- 62** The hybridization of the central atom in ICl_2^+ is :
 (A) dsp^2 (B) sp (C) sp^2 (D) sp^3
- 63** The state of hybridization of the central atom is not the same as in the others :
 (A) B in BF_3 (B) O in H_3O^+ (C) N in NH_3 (D) P in PCl_3
- 64** Which is the following pairs of species have identical shapes ?
 (A) NO_2^+ and NO_2^- (B) PCl_5 and BrF_5
 (C) ClO_3^- and SO_3^{-2} (D) TeCl_4 and XeO_4
- 65** The shapes of XeF_4 , XeF_5^- and SnCl_2 are :
 (A) Octahedral, trigonal bipyramidal and bent
 (B) Square pyramidal, pentagonal planar and linear
 (C) Square planar, pentagonal planar and angular
 (D) See-saw, T-shaped and linear
- 66** Which is not correctly matched ?
 (A) XeO_3 - Trigonal bipyramidal (B) ClF_3 - bent T-shape
 (C) XeOF_4 - Square pyramidal (D) XeF_2 – Linear shape



- 67** The geometry of ammonia molecule can be best described as :
- Nitrogen at one vertex of a regular tetrahedron, the other three vertices being occupied by three hydrogens
 - Nitrogen at the centre of the tetrahedron, three of the vertices being occupied by three hydrogens
 - Nitrogen at the centre of an equilateral triangle, three corners being occupied by three hydrogens
 - Nitrogen at the junction of a T, three open ends being occupied by three hydrogens

BOND LENGTH / BOND ORDER

- 68** Which of the following bond length is shortest?
- H – F
 - H – O
 - H – N
 - H – Cl

- 69** CORRECT order of bond length is :-
- Si – O, < P – O < S – O < Cl – O
 - Cl – O < S – O < Si – O < P – O
 - Cl – O < S – O < P – O < Si – O
 - S – O < P – O < Cl – O < Si – O

- 70** The average charge on each O atom and average bond order of I – O bond in IO_6^{5-} is :
- 1 and 1.67
 - $-5/6$ and 1.67
 - $-5/6$ and 1.33
 - $-5/6$ and 1.167

- 71** The correct order of C – N bond length ?

P: CH_3CN

Q: HNCO

R: CH_3CONH_2

- $P > Q > R$
- $P = Q = R$
- $R > Q > P$
- $R > P > Q$

BOND ENERGY

- 72** Which of the following has maximum oxidising character.
- F_2
 - Cl_2
 - Br_2
 - I_2

- 73** Which of the following having second highest bond dissociation energy (out of given molecules).
- F_2
 - Cl_2
 - Br_2
 - I_2



BOND ANGLE

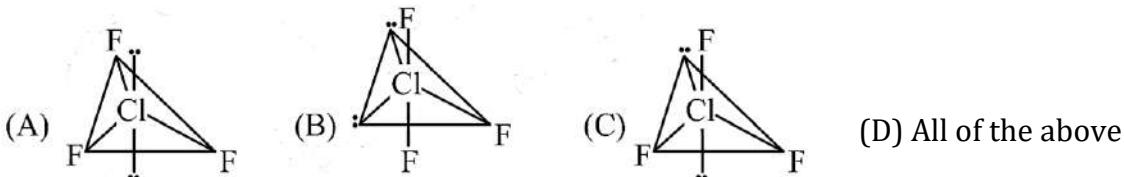
- 74** Which is the correct order of the bond angle ?
 (A) $\text{NH}_3 < \text{NF}_3$ (B) $\text{H}_2\text{O} > \text{Cl}_2\text{O}$ (C) $\text{PH}_3 < \text{SbH}_3$ (D) $\text{H}_2\text{Te} < \text{H}_2\text{S}$
- 75** Which of the following order is/are CORRECT :-
 (A) $\text{CO}_3^{2-} < \text{CO}_2$ (C – O bond length) (B) $\text{NO}_3^- < \text{NO}_2$ (N – O bond length)
 (C) $\text{O}_2 < \text{O}_3$ (O – O bond length) (D) $\text{C}_6\text{H}_6 < \text{C}_2\text{H}_4$ (C – C bond length)
- 76** CORRECT order of bond angle is ?
 (A) $\text{BCl}_3 > \text{BF}_3$ (B) $\text{CCl}_4 > \text{BF}_3$ (C) $\text{BF}_3 > \text{BF}_4^-$ (D) $\text{H}_2\text{O} = \text{O}(\text{CH}_3)_2$
- 77** Which of the following has smallest bond angle X – A – X is present ? (X is halogen & A is central atom)
 (A) COCl_2 (B) COF_2 (C) POCl_3 (D) POF_3
- 78** Maximum bond angle will be present in which of the following molecule?
 (A) CH_4 (B) CF_4 (C) Cl_4 (D) All have same bond angle
- 79** Which one of the following has maximum bond angle ?
 (A) CH_4 (B) CF_4 (C) CCl_4 (D) All have same bond angle
- 80** Number of C-atoms in next homologue of first member of ester family is :
 (A) 5 (B) 4 (C) 3 (D) 2
- 81** The bond angles of NH_3 , NH_4^+ and NH_2^- are in the order
 (A) $\text{NH}_2^- > \text{NH}_3 > \text{NH}_4^+$ (B) $\text{NH}_4^+ > \text{NH}_3 > \text{NH}_2^-$
 (C) $\text{NH}_3 > \text{NH}_2^- > \text{NH}_4^+$ (D) $\text{NH}_3 > \text{NH}_4^+ > \text{NH}_2^-$
- 82** In which of the following pair of species, all bond angles are equal
 (A) CO_3^{2-} , COCl_2 (B) PO_4^{3-} , POCl_3
 (C) BF_4^- , BH_4^- (D) CH_3F , CH_4
- 83** The correct order of bond angle is
 (A) $\text{H}_2\text{O} > \text{OF}_2 > \text{SF}_2$ (B) $\text{H}_2\text{O} > \text{SF}_2 > \text{OF}_2$
 (C) $\text{H}_2\text{O} < \text{OF}_2 > \text{SF}_2$ (D) $\text{H}_2\text{O} > \text{OF}_2 < \text{SF}_2$



VSEPR THEORY

- 84 The shape of $[\text{ClF}_4]^-$ and $[\text{ClF}_2]^-$ ions is respectively
 (A) See-saw and linear (B) See-saw and bent
 (C) Tetrahedral and linear (D) Square planar and linear.

- 85 More correct structure of ClF_3 is :



- 86 Which of the following molecules/species has the minimum number of lone pairs?
 (A) ICl_3 (B) BF_4^- (C) SnCl_2 (D) XeF_4

- 87 The number of $\widehat{\text{FIF}}$ adjacent angles ($90^\circ + 72^\circ$) in IF_7 molecule is
 (A) 10 (B) 15 (C) 20 (D) 14

- 88 The number of $\text{F} - \text{I} - \text{F}$ angles less than 90° and equal to 90° are respectively in IF_7
 (A) 5 and 5 (B) 10 and 5 (C) 5 and 10 (D) 10 and 15

- 89 The number of $\text{I} - \text{F}$ bonds having the longer and shorter lengths are respectively in IF_7
 (A) 5 and 2 (B) 2 and 5 (C) 5 and 5 (D) 2 and 2

- 90 Find the pair of species having the same shape but different hybridization of the central atom.
 (A) SO_3 , CO_3^{2-} (B) NO_2^- , ClO_2^- (C) BeCl_2 , HCN (D) XeF_2 , SnCl_2

- 91 The pair of species with similar shape is?
 (A) XeF_4 & SF_4 (B) PF_5 & IF_5 (C) XeO_2F_2 & SeF_4 (D) All pairs are iso-structural

- 92 Which of the following molecule have all the bond angle equal is?
 (A) PF_5 (B) SF_4 (C) NH_3 (D) None of these

- 93 Which of the following is isostructural with XeOF_4 ?
 (A) BrF_5 (B) PCl_3F_2 (C) SeF_4 (D) XeO_2F_2



- 94** Which of the following is planar?
 (A) XeO_3 (B) BrF_5 (C) ClF_3 (D) All are planar

- 95** The number of species given below having angles equal to 90° are ? BrF_3 , IF_5 , SeF_6 , ICl_4^- , PCl_5
 (A) 3 (B) 4 (C) 5 (D) 2

- 96** Which of the following molecule contain maximum number of atoms in one plane ?
 (A) CCl_4 (B) PF_5 (C) XeF_5^- (D) SF_6

- 97** Which of the following specie is non-planar ?
 (A) ClF_3 (B) H_3O^+ (C) NO_2^- (D) ClO_2^-

- 98** Molecular shape of XeF_3^+ , SF_3^+ and CF_3^+ are :
 (A) the same with 2, 1 and 0 lone pairs of electrons, respectively
 (B) different with 2, 1 and 0 lone pairs of electrons, respectively
 (C) different with 0, 1 and 2 lone pairs of electrons, respectively
 (D) the same with 2, 0 and 1 lone pairs of electrons, respectively

- 99** Which of the following statements is incorrect ?
 (A) In H_2O , the bond angle is less than OF_2
 (B) In ClF_3 , the axial Cl – F bond length is larger than equatorial Cl – F bond length.
 (C) In SF_4 , F – S – F equatorial bond angle is not equal to 120° due to lone pair-bond pair repulsions.
 (D) In ICl_4^- , bond angles is 90°

- 100** According to VSEPR theory, in which species do all the atoms lie in the same plane ?
 1. CH_3^+ 2. CH_3^-
 (A) 1 only (B) 2 only (C) both 1 and 2 (D) neither 1 nor 2

- 101** In SNF_3 , the $\angle \text{FSF}$ should be :
 (A) less than 120° and more than $109^\circ 28'$
 (B) less than $109^\circ 28'$
 (C) less than 180° and more than 120°
 (D) Exactly equal to $109^\circ 28'$



102 Give the correct order of initials T or F for following statements. Use T if statement is true and F if it is false :

- (I) The order of repulsion between different pair of electrons is $l_p - l_p > l_p - b_p > b_p - b_p$
- (II) In general, as the number of lone pair of electrons on central atom increases, value of bond angle from normal bond angle also increases
- (III) The number of lone pair on O in H_2O is 2 while on N in NH_3 is 1
- (IV) The structures of xenon fluorides and xenon oxyfluorides could not be explained on the basis of VSEPR theory

(A) TTTF (B) TFTF (C) TFTT (D) TFFF

103 The H – C – H bond angle in CH_4 is 109.5° , due to lone pair repulsion, the H – O – H angle in H_2O will

(A) remain the same (B) increase (C) decrease (D) become 180°

104 The compound MX_4 is tetrahedral. The number of $\angle \text{XMX}$ angles in the compound is :

(A) three (B) four (C) five (D) six

SOLID OR LIQUID STATE HYBRIDISATION

105 The number of non-axial set of 'd' orbital participate in the hybridisation of the anionic part of PCl_5

(A) 1 (B) 2 (C) 3 (D) 0

106 The (Cl – P – Cl) adjacent angle difference in cationic part and anionic part in $\text{PCl}_5(\text{s})$ is :

(A) 60 (B) 90 (C) 19.5 (D) 10.5

107 Hybridisation of cationic part of $\text{Cl}_2\text{O}_6(\text{s})$ is -

(A) sp^2 (B) sp^3 (C) $\text{sp}^3 \text{ d}$ (D) $\text{sp}^3 \text{ d}^2$

STRUCTURES

108 Ratio of σ/π present in the XeO_3 will be

(A) 1: 4 (B) 1: 2 (C) 1: 1 (D) 2: 1

109 Oxidation state of Cr in CrO_5 is -

(A) +10 (B) +8 (C) +6 (D) +5

110 Which of the following compound has peroxy linkage present in its structure ?

- (A) K_3CrO_8 (B) Cl_2O_6 (C) N_2O_5 (D) $\text{H}_2\text{S}_2\text{O}_7$

111 Which of the following species have maximum $p\pi - p\pi$ bonds ?

- (A) P_4S_{10} (B) HCO_3^- (C) S_3O_9 (D) P_4O_{10}

112 Find the correct statement about P_4O_8 :

- (A) molecule does not exist
- (B) five $\text{P} - \text{O} - \text{P}$ linkage
- (C) four $\text{P} = \text{O}$ bonds present in it's structure
- (D) Six $\text{P} - \text{O} - \text{P}$ linkage

113 In the structure of H_2CSF_4 , which of the following statement is incorrect?

- (A) Two $\text{C} - \text{H}$ bonds are in the same plane of axial $\text{S} - \text{F}$ bonds.
- (B) Two $\text{C} - \text{H}$ bonds are in the same plane of equitorial $\text{S} - \text{F}$ bonds.
- (C) Total Six atoms are in the same plane.
- (D) Equitorial $\text{S} - \text{F}$ bonds are Perpendicular to nodal plane of π bond.

RESONANCE

114 Total number of resonating structure possible of the molecule ClO_4^- is -

- (A) 2 (B) 3 (C) 4 (D) 5

115 The formal charges on the three atoms in O_3 molecule are :

- (A) 0,0,0 (B) 0,0,-1 (C) 0,0,+1 (D) 0,+1,-1

116 Minimum number of resonating structure possible in :-

- (A) O_3 (B) NO_2^- (C) N_3^- (D) COCl_2

117 The compound having shortest $\text{S} - \text{O}$ bond length ?

- (A) SO_3F^- (B) SO_4^{2-} (C) SOF_4 (D) SOCl_2

OXY ACID

118 Which of the following acid have highest number of $\text{P} - \text{H}$ bonds :-

- (A) $\text{H}_4\text{P}_2\text{O}_8$ (B) $\text{H}_4\text{P}_2\text{O}_7$ (C) $\text{H}_4\text{P}_2\text{O}_5$ (D) H_3PO_3

119 Oxidation state of S in $\text{H}_2\text{S}_2\text{O}_8$ is ?

- (A) +5, +5 (B) +6, +5 (C) +5, +6 (D) +6, +6

120 Which of the following oxy acid have sulphur atoms with different oxidation states?

- (A) $\text{H}_2\text{S}_4\text{O}_6$ (B) $\text{H}_2\text{S}_2\text{O}_3$ (C) $\text{H}_2\text{S}_2\text{O}_5$ (D) All of these

121 Which of the following compound has different value of basicity from the others ?

- (A) H_3PO_3 (B) $\text{H}_4\text{P}_2\text{O}_5$ (C) H_3BO_3 (D) H_2SO_5

122 Which of the following acid have highest number of P – H bonds :

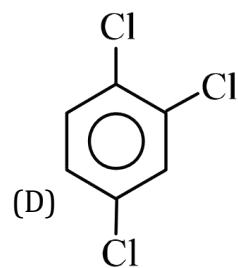
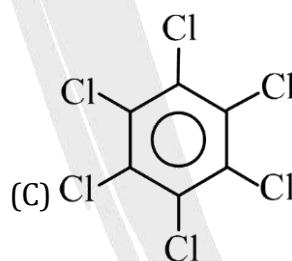
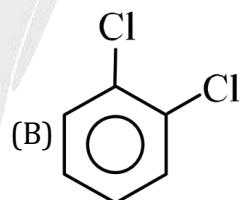
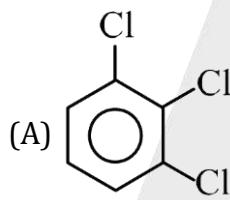
- (A) $\text{H}_4\text{P}_2\text{O}_8$ (B) $\text{H}_4\text{P}_2\text{O}_7$ (C) $\text{H}_4\text{P}_2\text{O}_5$ (D) H_3PO_3

123 Find the value of $\frac{a-b}{c}$ if, a is the total number of sp^3 hybridised atoms, b is total $\text{p}_\pi - \text{p}_\pi$ bonds and c is the total sp^2 hybridised atoms in the structure of $\text{H}_4\text{P}_4\text{O}_{12}$

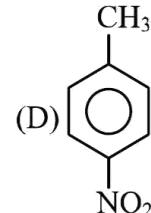
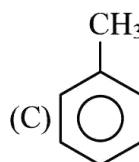
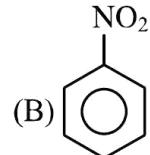
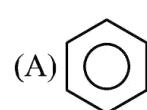
- (A) 2 (B) 1 (C) 3 (D) 4

DIPOLE MOMENT

124 Which of the following have maximum dipole moment?



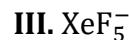
125 Which of the following is most polar in nature ?



126 Which of the following molecule has permanent dipole moment:

- (A) SO_3 (B) SO_2 (C) CO_2 (D) BF_3

127 The correct sequence of polarity of the following molecule :



(P stands for polar and NP stands for non-polar)

- | | I | II | III | IV |
|-----|----|----|-----|----|
| (A) | P | NP | NP | P |
| (B) | NP | NP | NP | P |
| (C) | NP | P | NP | P |
| (D) | NP | P | P | NP |

128 Which of the following is most polar in nature?



129 Total number of polar species among the following will be ?



(A) 2

(B) 4

(C) 5

(D) 3

130 Arrange the following in increasing order of their polarity.

(I) Ortho/chloro/Toluene **(II)** Meta/chloro/Toluene **(III)** Para/chloro/Toluene

(A) III > II > I

(B) II < I > III

(C) III > I > II

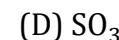
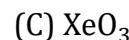
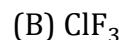
(D) I < II < III

131 Which of the following molecule / species is polar.



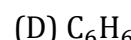
(D) None of these

132 Which of the following molecule is non polar?



HYDROGEN BONDING

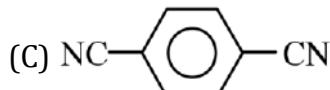
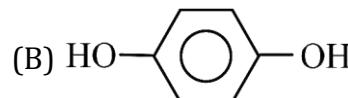
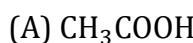
133 Which of the following have intramolecular H-bonding?



134 What is the order of boiling point of the following compounds ? $\text{HF}, \text{NH}_3, \text{H}_2\text{O}, \text{CH}_4$

(A) $\text{CH}_4 > \text{NH}_3 > \text{H}_2\text{O} > \text{CH}_4$ (B) $\text{HF} > \text{H}_2\text{O} > \text{NH}_3 > \text{CH}_4$ (C) $\text{H}_2\text{O} > \text{HF} > \text{NH}_3 > \text{CH}_4$ (D) $\text{H}_2\text{O} > \text{NH}_3 > \text{HF} > \text{CH}_4$

135 Which of the following have weakest intermolecular forces?



136 Select the INCORRECT statement ?

(A) Cationic part of NH_4F can form hydrogen bond with water(B) Hydrogen bonding is not present in ethene ($\text{H}_2\text{C} = \text{CH}_2$)(C) Anionic part of NaHCO_3 have inter molecular hydrogen bonding

(D) Vapour pressure decreases due to intramolecular H-bonding. (O)

137 The strength of H-bonding order is

(A) $\text{H}_2\text{O} > \text{H}_2\text{O}_2 > \text{HF}$ (B) $\text{H}_2\text{O}_2 > \text{H}_2\text{O} > \text{HF}$ (C) $\text{HF} > \text{H}_2\text{O} > \text{H}_2\text{O}_2$ (D) $\text{HF} = \text{H}_2\text{O} = \text{H}_2\text{O}_2$

138 Give the correct order of initials T or F for following statements. Use T if statement is true and F if it is false.

(i) HF boils at a higher temperature than HCl

(ii) HBr boils at lower temperature than HI

(iii) $K_{\text{a}1}$ of maleic acid is higher than that of fumaric acid(iv) $K_{\text{a}2}$ of maleic acid is higher than that of fumaric acid

(A) TFTT

(B) TTTF

(C) TFTF

(D) TTTT

139 Strongest hydrogen bond present in :

(A) O — H S

(B) S — H O

(C) F — H F

(D) F — H O

140 Which of the following will prefer intramolecular hydrogen bonding :

(A) $\text{CCl}_3\text{CHO} \cdot \text{H}_2\text{O}$

(B) Orthodichlorobenzene

(C) Sulphuric acid

(D) Both (A) & (B)

141 Which of the following is correct order for extent of Hydrogen Bonding

(A) $\text{H}_2\text{O}_2 > \text{H}_2\text{O} > \text{HF} > \text{NH}_3$ (B) $\text{H}_2\text{O} > \text{HF} > \text{NH}_3 > \text{H}_2\text{O}_2$ (C) $\text{H}_2\text{O}_2 > \text{H}_2\text{O} > \text{NH}_3 > \text{HF}$ (D) $\text{H}_2\text{O}_2 > \text{NH}_3 > \text{H}_2\text{O} > \text{HF}$



MISCELLANEOUS

142 Which is correct about D_2O

- (A) Its boiling point is higher than that of $H_2O(\ell)$
- (B) O – D O bond is stronger than O – H O bond.
- (C) $D_2O(s)$ sinks in $H_2O(\ell)$.
- (D) all the above are correct.

143 Which of the following do not exist?

- (A) KHF_2
- (B) $CsHCl_2$
- (C) $KHCl_2$
- (D) KF

144 Which of the following species is an example of odd electron molecule?

- (A) NO_2
- (B) N_2O
- (C) ClO_3
- (D) Both (A) and (C)



EXERCISE # 2

LEWIS DOT STRUCTURES

- 1 Lewis theory fails to explain which of the following structure(s) ?
(A) SF_6 (B) XeF_2 (C) XeF_4 (D) $BeCl_2$
- 2 In which of the following molecule/ion the central atom have +1 formal charge ?
(A) O_3 (B) N_3^- (C) NO_3^- (D) CO_3^{-2}
- 3 In which of the following molecule all the atoms are present in ground state ?
(A) PH_3 (B) CO (C) SF_4 (D) HOF
- 4 In which of the following molecule number of lone pairs & number of covalent bonds are equal ?
(A) SO_3 (B) SO_2 (C) CO_2 (D) H_2Se
- 5 Which of the following statement is incorrect regarding molecule $NOCl$
(A) It has covalent as well as ionic bond present in its structure.
(B) It has Cl atom present as a central atom.
(C) It has one lone pair.
(D) It has linear structure.
- 6 Lewis theory fails to explain which of the following structure(s) ?
(A) SF_6 (B) XeF_2 (C) XeF_4 (D) $BeCl_2$

TYPES OF BOND

- 7 Type of bonds present in PH_4I is/are:
(A) Ionic (B) Covalent (C) Co-ordinate (D) H-bond
- 8 Which of the following set of elements have tendency to combine with each other by sharing of valence electron.
(A) Mg & O (B) B & F (C) Na & H (D) P & F
- 9 Coordinate bond is present in the following molecule(s) :
(A) NO_2 (B) N_2O_4 (C) PCl_4^+ (D) CO_3^{-2}



10 Which of the following set contains covalent as well as ionic species ?

- (A) NO, CO, OF_2 (B) $NH_3BF_3AlF_3$ (C) $CO_2, CsCl, NO_2$ (D) SO_3, BCl_3, CaO

VBT

11 Which of the following statement is correct?

- (A) Extent of overlapping : $3p - 4s < 3s - 3s$
 (B) s-orbital can never form π -bond
 (C) p-orbital can form σ and π as well as δ bond.
 (D) non axial d-orbitals (d_{xy}, d_{xz}, d_{yz}) have more directional nature than the axial d-orbitals (d_{z^2} & $d_{x^2-y^2}$)

12 Select the correct statement(s) :

- (A) σ bond is stronger than δ bond
 (B) π bond is the result of collateral overlapping between two half filled atomic orbitals.
 (C) s-orbital & py-orbital can be never form bond on z --axis.
 (D) $p_y \& p_y$ on z --axis form δ bond

13 Choose the correct order(s) of strength of overlapping of orbitals :

- (A) $2p - 2p > 2p - 3p > 3p - 3p$
 (B) $3d - 3d > 3p - 3d > 3p - 3p$
 (C) $2s - 3s > 3p - 3p > 3s - 3p$
 (D) $2s - 2s > 2s - 2p > 2p - 2p$

14 Which of the following molecules have $P_\pi - d_\pi$ bond in their structure ?

- (A) SOF_4 (B) $SO_2 F_2$ (C) CO_3^{2-} (D) CO

HYBRIDISATION

15 Which of the following specie(s) contains all bond angles equal?

- (A) PCl_4^+ (B) AsF_5 (C) $CH_2 F_2$ (D) XeF_4

16 Which of the following combination of bond pair (b.p.) & lone pair (l.p.) gives same shape?

- (i)** 3b.p. + 1 l.p. **(ii)** 2 b.p. + 2 l.p. **(iii)** 3 b.p. + 2 l.p. **(iv)** 2.b.p. + 3 l.p.
(v) 2 b.p. + 1 l.p. **(vi)** 2 b.p. + 0 l.p.
 (A) (ii) & (v) (B) (vi) & (iv) (C) (iii) & (iv) (D) (i) & (iii)



- 17** Which of the following molecules has/have linear structure
 (A) $BeCl_2$ (B) XeF_2 (C) XeO_4 (D) SF_4
- 18** Which of the following molecules have H Bonding
 (A) H_2O (B) NH_3 (C) HF (D) CH_4
- 19** Which of the following molecules is/are sp^3 d hybridised
 (A) PCl_5 (B) PCl_6^- (C) $XeO_2 F_2$ (D) IF_7
- 20** Which of the following molecules has/have $d_{x^2-y^2}$ and d_{z^2} orbitals in hybridisation
 (A) SF_6 (B) XeF_4 (C) SF_2 (D) NO_2^+
- 21** Which of the following molecules has/have capped octahedral geometry
 (A) XeF_6 (B) IF_6^- (C) $XeOF_5^-$ (D) XeF_2
- 22** In which of following, vacant orbital take part in hybridisation :
 (A) BF_3 (B) PCl_6^- (C) BF_4^- (D) NH_3
- 23** Which of the following is correct match for AB_xL_y (where B = Bond pair & L = lone pair).
 (A) $x = 3, y = 2$ planar & polar (B) $x = 3, y = 1$ polar & non planar
 (C) $x = 2, y = 3$ non planar & non polar (D) $x = 4, y = 1$, non planar & polar

BONED LENGTH / BOND ORDER

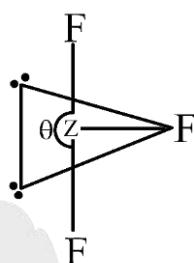
- 24** Select the INCORRECT Order ?
 (A) $SO_3 < SO_3^{-2} < SO_4^{-2}$ ($S - O$ bond order)
 (B) $CO > CO_2 > CO_3^{2-}$ ($C - O$ bond order)
 (C) $CN^- < NCN^{-2} < RCNH_2$ ($C - N$ bond order)
 (D) $ClO^- > ClO_2^- > ClO_3^- > ClO_4^-$ ($Cl - O$ bond order)

BOND ENERGY

- 25** The correct order of bond dissociation energy will be ?
 (A) $H - H > Cl - Cl > Br - Br$ (B) $Si - Si > P - P > Cl - Cl$
 (C) $C - C > N - N > O - O$ (D) $F - F > Cl - Cl > Br - Br$

VSEPR THEORY

- 26** There are three elements X, Y and Z which belong to the p -block of periodic table they all form trifluorides with F_2 , such that ' XF_3 ' is lewis acid but ' YF_3 ' is weak Lewis base (dipole moment = $0.23D$). These two compounds react with each other in presence of F_2 to produce $YF_4^+XF_4^-$. The compound ZF_3 is a T-shape interhalogen molecule. Which of the following is/are correct statements with reference to above information?



- (A) All the $Z - F$ bond lengths are equal in ZF_3 molecules
 - (B) In the structure the angle $\theta \neq 180^\circ$
 - (C) The Y and X both are sp^3 hybridised in $YF_4^+XF_4^-$
 - (D) The elements X, Y, Z can be B, N and Cl respectively
- 27** In which of the following species all bond lengths are not identical ?
- (A) ClF_6^+
 - (B) SeF_4
 - (C) SO_4^{2-}
 - (D) IF_3
- 28** Which of the following molecule(s) is/are planar
- (A) BF_3
 - (B) H_2O
 - (C) ICl_2^-
 - (D) ClF_3

STRUCTURES

- 29** Which of the following statements is/are true for P_4O_6 molecule -
- (A) It contains six P-O bonds and three P-P-bonds
 - (B) It contains six P-O-P linkage and 16 lone pairs
 - (C) It has all atoms sp^3 -hybridised
 - (D) It has planar structure
- 30** Select the CORRECT statement about $C_3N_3(N_3)_3$ (cyanuric triazide) :
- (A) Total number of sp^2 hybridized atom in the molecule is 12
 - (B) Total number of σ bond present in molecule is 15
 - (C) Total number of π bond present in molecule is 9
 - (D) Total number of lone pair present in molecule is 12



- 31 Find the correct statement about croconate ion $C_5O_5^{-2}$
- (A) It is cyclic compound
 - (B) It is in particular aromatic and symmetric as the double bond and the negative charge become delocalized over the five CO units
 - (C) $C_5O_5^{-2}$ has four π bonds
 - (D) $C_5O_5^{-2}$ has three π bonds in rings.

OXY ACID

- 32 Select the INCORRECT statement(s) about the structure of $H_2S_2O_3$.
- (A) Two $2p\pi - 3d\pi$ bonds present in the structure.
 - (B) Hybridization of each 'S' atom is sp^3
 - (C) Oxidation states of 'S' are +6 & -2
 - (D) Total number of lone pair present in molecule is 8.
- 33 Which of the following oxy acid have per-oxy linkage :-
- (A) $H_2S_2O_8$
 - (B) H_3PO_5
 - (C) HNO_3
 - (D) $H_2S_2O_3$

DIPOLE MOMENT

- 34 Which of the following statement (s) is/are true about lone pair moments ?
- (A) $sp > sp^2 > sp^3$: Order of lone pair moment
 - (B) The unshared pairs residing in pure s or p orbitals do not contribute to the resultant molecular polarity
 - (C) The unshared pair residing in hybrid orbitals contributes to the resultant molecular polarity
 - (D) The lone pair moments acts in the opposite directions in which it is projected.
- 35 Correct Statement among following ?
- (A) Dipole moment order $BF_3 = CCl_4 = PCl_5 = SF_6$
 - (B) dipole moment of $CHCl_3 > CHF_3$
 - (C) $\mu_{\text{experimental}}$ is less than $\mu_{\text{theoretical}}$ for CO molecule
 - (D) If a AX_4 type molecule has $\mu = 0$ then it can have either tetrahedral or octahedral electron geometry (A = central atom, X = side atom)



HYDROGEN BONDING

36 Choose the INCORRECT order(s) of boiling point .

- (A) $NH_3 > SbH_3 > AsH_3 > PH_3$
- (B) $H_2O > TeH_2 > SeH_2 > SH_2$
- (C) $HF > HI > HBr > HCl$
- (D) $CH_4 > SnH_4 > GeH_4 > SiH_4$

37 Which of the following statement(s) is/are not correct ?

- (A) Density of water increases from $0^\circ C$ to $4^\circ C$ then further increases on increasing the temperature
- (B) Solid boric acid has 2-D sheet like structure due to intermolecular hydrogen bonding
- (C) Urea has high boiling point due to intramolecular hydrogen bonding.
- (D) HCl^- ion exists with Cs^+ .

38 Hydrogen bonding is responsible for ?

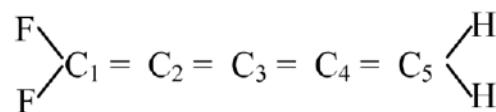
- (A) Lower volatility of HF than that of HCl .
- (B) More viscosity of glycerol than glycol.
- (C) Stability of chloral hydrate
- (D) High boiling point of SbH_3 than that of NH_3

39 Which of the following contain H-Bonding ?

- (A) K_2HPO_4
- (B) K_2HPO_3
- (C) Chloral hydrate
- (D) O-nitro phenol

MISCELLANEOUS

40 Choose the CORRECT statement about given molecule :-



If $\begin{array}{c} F \\ \diagup \\ C_1 \end{array}$ lies in xz plane then

- (A) Nodal plane of π -bond between $C_1 - C_2$ lies in xz plane.
- (B) Nodal plane of π -bond between $C_3 - C_4$ lies in xz plane.
- (C) C_5 / H part lies in yz plane
- (D) Maximum number of atom in plane is 7



EXERCISE # 3

INTEGER

- 1** Find total number of orbitals in which electron density is observed along any of the axis (x, y or z).

$p_x, p_y, p_z, d_{xy}, d_{xz}, d_{yz}, d_{z^2}, d_{x^2-y^2}$

- 2** Total number of molecules which follow octet rule among the given molecules are:
 $\text{AlBr}_3, \text{BeCl}_2, \text{MgF}_2, \text{SF}_4, \text{NO}_2, \text{NO}, \text{CO}, \text{LiF}, \text{SO}_2\text{Cl}_2, \text{XeF}_2, \text{PH}_3,$

- 3** The number of set of orbitals given below forming π -bonds are ?

Orbitals	Inter Nuclear Axis
(1) $p_x + p_y$	— x
(2) $p_z + p_z$	— y
(3) $d_{xy} + d_{xy}$	— z
(4) $d_{yz} + d_{yz}$	— z
(5) $d_{yz} + p_z$	— z
(6) $d_{xz} + p_z$	— x
(7) $d_{x^2-y^2} + p_y$	— x

- 4** Number of orbitals which can form π bond with p_x orbital on y-axis :

$d_{z^2}, d_{xy}, p_x, p_z, s, d_{x^2-y^2}, d_{xz}$

- 5** Atomicity of O, S, P and He are p, q, r & s respectively : Calculate the value of $p + q + r + s$?
[Write your answer as sum of digits till you get the single digit answer]

- 6** How many sets of given orbitals can from π bond ?

(z - axis is internuclear axis)

$p_x + p_y, p_y + p_y, p_z + p_x, p_z + p_z, d_{x^2-y^2} + d_{z^2}p_z + d_{xy}p_y, p_z + d_{xz}, p_z + d_{yz}, d_{xz} + d_{yz}, d_{yz} + d_{yz}, d_{xy} + d_{xy}, d_{xy} + d_{x^2-y^2}$

- 7** Find the number of molecules having sp^3 d hybridization $\text{I}_3^-, \text{SF}_4, \text{BeCl}_2, \text{XeF}_4$

- 8** Find out the number of species which have at least one atom is sp^3 d hybridised among the following :-

$\text{O}_3, \text{O}_2, \text{F}_2, \text{I}_3^-, \text{I}(\text{CN})_2^-, \text{PF}_3\text{Cl}_2, \text{XeF}_6, \text{IOF}_5, \text{XeF}_5^+$

9 The number of planes of symmetry in SbF_5 is –

10 Find the number of $p\pi - d\pi$ bonds present in $\text{P}_4 \text{S}_{10}$

11 Total number of angle(s) in SeCl_4 which are less than 90°

12 Number of molecules having all bond angles equal are ?



13 Total number of identical bond angle in CF_2Cl_2 is –

14 How many of the following are planar molecules/ions



15 Total number of molecules which contain any $\text{F} - \hat{\text{X}} - \text{F}$ bond angle which is less than 90° ?

(X = Central atom)



16 How many planes are present in $\text{PCl}_3 \text{F}_2$ molecule which contains maximum number of atoms?

17 Number of non-polar molecule among the following is x and number of planar molecule is y. calculate the value of $x + y$.



18 Number of atomic orbitals involve in hybridisation of anion part of $\text{Cl}_2\text{O}_6(\text{s})$ is –

19 In tetrathionic acid number of $p\pi - p\pi$ bonds is :

20 In the structure of $\text{P}_4 \text{S}_{10}$ molecule, total number of sp^3 Hybridised atoms = x, total number of $p\pi - d\pi$ bonds = y, total number of bridging sulphur = z, calculate the value of $x + y + z$.

21 Total number of species among the following in which $\text{X} - \text{O} - \text{X}$ linkage is present [X = P, S]
 $\text{H}_2 \text{S}_2\text{O}_6, \text{H}_2\text{SO}_5, \text{H}_2 \text{S}_2\text{O}_7, \text{H}_2 \text{S}_2\text{O}_8, \text{P}_4\text{O}_{10}, \text{S}_4\text{O}_6^{2-}, \text{S}_2\text{O}_6^{2-}, \text{P}_4\text{O}_6$

22 The number of water molecules(s) directly bonded to the metal centre in $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. is –



23 Observe the following statements about the structure of molecule F_3SSF

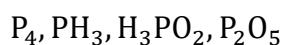
(a) Total number of lone pairs present in molecule is x

(b) Number of S – S bond present is y

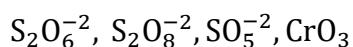
Calculate the value of ' $x + y$ ' ?

[Write your answer as sum of digits till you get the single digit answer]

24 The sum of oxidation states of all P atoms in the following compound of phosphorus is



25 How many of the following contains peroxy linkage in their structures :



26 Find the number of lone pair in $\text{N}_3^- \text{S}_3\text{Cl}_3$.

Fill your answer as sum of digits (excluding decimal places) till you get the single digit answer.

27 Find the correct statements about $[\text{NPCl}_2]_3$ (phosphazene).

(i) Resonance structure can be drawn analogous to those for benzene indicating aromaticity in the rings.

(ii) The d_{xz} orbital of the phosphorous atom overlaps with the p_z orbitals of nitrogen atoms adjacent to it (if x is inter nucleuar axis).

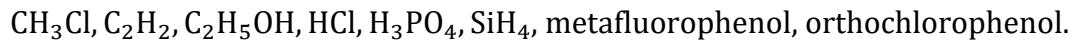
(iii) PNCl_2 monomer is analogous to RCN .

(iv) σ/π ratio is 3 in $[\text{NPCl}_2]_3$.

28 In tetrathionic acid number of $p_\pi - p_\pi$ bonds is :

29 In $(\text{HF})_4$ the number of H bonds is

30 Total number of molecules which can have intermolecular hydrogen bonding ?



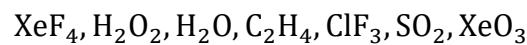
31 Find the number of H bond form by one boric acid in solid state

32 Find the number of hexagonal rings in C_{60} fullerene.

Fill your answer as sum of digits till you get the single digit answer.



33 Number of following species which are planar & polar ?



34. Find the number of chemical species(s) which are planar and nonpolar in the following:





EXERCISE - 4

Paragraph for question no. 1 to 2

According to Lewis Longmuir concept atoms combine to complete their respective octet.

1. The species following the octet rule is

(A) ICl_3	(B) SbCl_3
(C) BeCl_2	(D) AlCl_3
2. From the species given below which one is hypervalent ?

(A) Al F_3	(B) SF_4
(C) OCl_2	(D) NF_3

Paragraph for question nos. 3 to 4

The formation of BH_3CH_4 & NH_3 like compounds cannot be explained by V.B.T. For example explained. Hence a new phenomenon is introduced to explain the above observation, which is known as hybridisation. Hybridisation can be defined as the mixing of pure atomic orbitals of comparable energy.

3. Select the correct statement ?

(A) Hybridisation takes place in all covalent as well as ionic compounds.	(B) Intermixing of different shells takes place in hybridisation
(C) Hybrid orbitals are more directional than the pure atomic orbitals.	(D) If % p character increases in hybrid orbital, it becomes bulkier & shorter.
4. Which of the following orbital may involve in hybridisation in PCl_5 ?

(A) d_{xz}	(B) d_{yz}
(C) d_{z^2}	(D) $d_{x^2-y^2}$

Paragraph for question no. 5 to 6

Valence Bond Theory explains the formation of covalent bond such as two filled atomic orbitals having e^- with opposite spin combine axially or collaterally to form σ and π bond respectively.

5. Which of the following orbital cannot form σ bond with d_{xy} orbital .

(A) s	(B) p_x
(C) $d_{x^2-y^2}$	(D) All of these
6. Which of the following statement is correct?

(A) s -orbital always forms σ bond with p orbital	(B) s-orbital is more directional than p-orbital
(C) p-orbital always form π -bond	(D) a covalent bond is directional in nature.

Paragraph for question no. 7 to 9

IF_7 is a molecule in which I atom is in the maximum oxidation state, and the hybridization for I atom is $\text{sp}^3 \text{d}^3$.

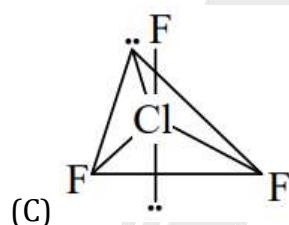
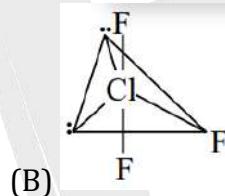
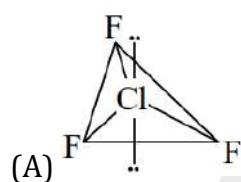


7. The number of $\widehat{\text{FIF}}$ adjacent angles ($90^\circ + 72^\circ$) in IF_7 molecule is
 (A) 10 (B) 15
 (C) 20 (D) 14
8. The number of $\widehat{\text{FIF}}$ angles less than 90° and equal to 90° are respectively
 (A) 5 and 5 (B) 10 and 5
 (C) 5 and 10 (D) 10 and 15
9. The number of I – F bonds having the longest and shortest lengths are respectively
 (A) 5 and 2 (B) 2 and 5
 (C) 5 and 5 (D) 2 and 2

Paragraph for question no. 10 to 11

hybridisation helps to determine the shape of a molecule but shape of a molecule is mainly define by VSEPR theory According to this theory $1.p > l.p > b.p > b.p - b.p$

10. In which of the following pairs hybridisation of the central atom is not same?
 (A) $\text{ClF}_3, \text{ClF}_3\text{O}$ (B) $\text{ClF}_3\text{O}, \text{ClF}_3\text{O}_2$
 (C) $[\text{ClF}_2\text{O}]^+[\text{ClF}_4\text{O}]^-$ (D) $[\text{ClF}_4\text{O}]^-[\text{XeOF}_4]$
11. More correct structure of ClF_3 is :



(D) All of the above

Paragraph for question no. 12 to 13

Valence shell electron pair repulsion theory (VSEPR) can be used to predict the approximate shape of a molecule. Electrons in bonds and in lone pairs can be thought of as "charge cloud" that repel one another and stay as far apart possible, thus causing molecules to assume specific shapes.

The repulsive interactions of electron pairs decrease in the order :

Lone pair-lone pair > Lone pair - bond pair > Bond pair-bond pair.

These repulsions result in deviations from idealized shapes and alteration in bond angles in molecules.

12. Molecular shape of XeF_3^+ , SF_3^+ and CF_3^+ are :
 (A) the same with 2, 1 and 0 lone pairs of electrons, respectively

- (B) different with 2, 1 and 0 lone pairs of electrons, respectively
- (C) different with 0, 1 and 2 lone pairs of electrons, respectively
- (D) the same with 2, 0 and 1 lone pairs of electrons, respectively

13. Which of the following statements is incorrect?

- (A) In H_2O , the bond angle is less than OF_2
- (B) In ClF_3 , the axial Cl – F bond length is larger than equatorial Cl – F bond length.
- (C) In SF_4 , F – S – F equatorial bond angle is not equal to 120° due to lone pair-bond pair repulsions.
- (D) In ICl_4^- , bond angles is 90°

Paragraph for Question 14 to 15

According to the VSEPR theory of molecular geometry in chemistry, which is based on the general principle of maximizing the distances between points, a square antiprism is the favored geometry when eight pairs of electrons surround a central atom. Square antiprism, in which the eight atoms occupy the eight vertices of the antiprism, and the eight triangle edges of the antiprism correspond to single covalent bonds.

14. Which of the following molecules have square anti prismatic structure

- (A) XeF_8^{-2}
- (B) PaF_8^{-3}
- (C) S_8
- (D) XeF_6

15. In molecule nitrosonium octa fluoro xenate (VI) central atom Xe has

- (A) $\text{fsp}^3 \text{d}$
- (B) $d^4 \text{sp}^3$
- (C) $\text{sp}^3 \text{d}^3$
- (D) no hybridisation

Paragraph for question no. 16 to 17

Various oxy acids of non metals are found in nature. Some derivatives of oxy acids can also be derived from the parent oxy acid.

Derivatives of oxy acid can be derived by removing H_2O molecule from the parent oxy acids such as : 2 moles of oxy acid – H_2O = pyro acid.

1 mole of oxy acid – H_2O = meta acid.

16. Parent oxy acid of $\text{H}_4\text{P}_2\text{O}_5$ acid is ?

- | | |
|---------------------------|---------------------------|
| (A) phosphorous acid | (B) ortho phosphoric acid |
| (C) pyro phosphorous acid | (D) hypophosphorous acid |

17. Which of the following is not a hypo acid ?

- | | |
|--------------------------------------|--------------------------------------|
| (A) $\text{H}_2\text{N}_2\text{O}_2$ | (B) HOCl |
| (C) $\text{H}_2\text{S}_2\text{O}_7$ | (D) $\text{H}_4\text{P}_2\text{O}_6$ |

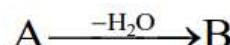
Paragraph for Question 18 to 19

Various derivatives of oxy acids can be derived from the parent oxy acids for example pyro acids and meta acids can be derived from various parent oxy acid by removing a water molecule, from two moles of oxy acid (for pyro acid) and from one mole of oxy acid (for meta acid) respectively.



- 18.** For which of the following oxy acid meta acid is not possible :
- (A) $\text{H}_2\text{S}_2\text{O}_8$ (B) $\text{H}_2\text{S}_2\text{O}_6$
 (C) H_3PO_4 (D) H_2SO_3

- 19.** For A is any parent acid observe the following reaction :



Which of the following statement is INCORRECT ?

- (A) If A is H_3PO_4 then there are four P – O – P linkage present in the cyclic trimer of B.
 (B) If A is H_2SO_4 then there are 6 shorter S – O bond lengths are present in cyclic trimer of B.
 (C) If A is HNO_3 then meta form of A does not exist.
 (D) If A is HNO_2 then on removing one mole of water from A will give a mixed anhydride.

Paragraph for Question 20 to 21

Polar covalent molecules exhibit dipole moment. Dipole moment is equal to the product of charge separation q and the bond length d for the bond. Unit of dipole moment is debye. One debye is equal to 10^{-18} esu cm.

Dipole moments is a vector quantity. It has both magnitude and direction. Hence, dipole moment of a molecule depends upon the relative orientation of the bond dipoles, but not on the polarity of bonds alone. A symmetrical structure shows zero dipole moment. Thus, dipole moment helps to predict the geometry of a molecule. Dipole moment values can be used to distinguish between cis-and transisomers, orhto-, meta-and para-forms of a substance, etc.

- 20.** Arrange the following in increasing order of their polarity.
- | | | |
|--------------------------|--------------------------|---------------------------|
| (I) Ortho chloro Toluene | (II) Meta chloro Toluene | (III) Para chloro Toluene |
| (A) III > II > I | (B) II < I > III | (C) III > I > II |
| | | (D) I < II < III |
- 21.** Correct Statement among following?
- (A) Dipole moment order $\text{BF}_3 = \text{CCl}_4 = \text{PCl}_5 = \text{SF}_6$
 (B) dipole moment of $\text{CHCl}_3 > \text{CHF}_3$
 (C) $\mu_{\text{experimental}}$ is less than $\mu_{\text{theoretical}}$ for CO molecule
 (D) If a AX_4 type molecule has $\mu = 0$ then it can have either tetrahedral or octahedral electron geometry (A = central atom, X = side atom)
- 22.** Which of the following chemical species having inter molecular hydrogen bonding.
- | | |
|-------------------------------|------------------------|
| (A) Ortho boric acid | (B) Ortho nitrophenol |
| (C) Ortho hydroxybenzaldehyde | (D) Ortho chlorophenol |
- 23.** Which of the following boiling point order is INCORRECT.
- | | |
|--|---|
| (A) $\text{H}_3\text{BO}_3 > \text{B}(\text{OMe})_3$ | (B) $\text{C}_2\text{H}_5\text{OH} > \text{CH}_3\text{OCH}_3$ |
| (C) $\text{HF} > \text{HCl}$ | (D) $\text{NH}_3 > \text{SbH}_3$ |
- 24.** Which of the following molecule will form Hydrogen-bond with water ?
- | | |
|---------------------|-------------------------------------|
| (A) Chloral hydrate | (B) $\text{C}_6\text{H}_5\text{OH}$ |
| (C) NH_3 | (D) $\text{C}_2\text{H}_5\text{OH}$ |



Paragraph for question no. 25 to 26

A hydrogen bond is an electrostatic attraction between two polar groups that occurs when a hydrogen atom covalently bound to a highly electronegative atom.

25. Correct order of boiling point is -
 (A) $\text{H}_2\text{O} > \text{NH}_3 > \text{HF}$ (B) $\text{HF} > \text{NH}_3 > \text{H}_2\text{O}$
 (C) $\text{HF} > \text{H}_2\text{O} > \text{NH}_3$ (D) $\text{H}_2\text{O} > \text{HF} > \text{NH}_3$
26. In which of the following compound H-bond is not present ?
 (A) KH_2PO_3 (B) K_2HPO_3
 (C) KH_2PO_4 (D) K_2HPO_4

Paragraph for question no. 27 to 28

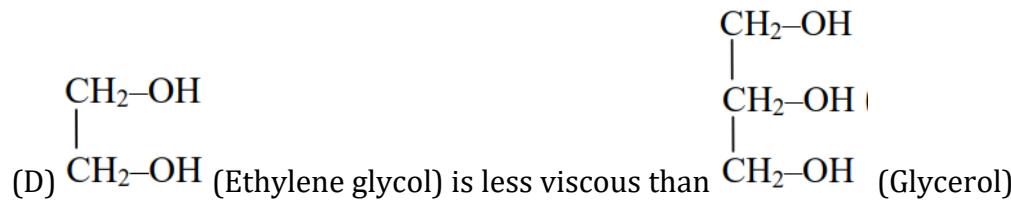
In an oxy acid the acidic hydrogen is connected to the oxygen atom covalently. And generally the oxygen is covalently bonded to a non-metal. And in Hydra acid Hydrogen is covalently bonded to a more electronegative atom (Eg.: halogen) except oxygen.

27. Which of the following has higher boiling point
 (A) HF (B) HI (C) HCl (D) HBr
28. Which of the following compound(s) doesn't have hydrogen bond
 (A) K_3PO_4 (B) K_2HPO_4 (C) KH_2PO_4 (D) H_3PO_4

Paragraph for question no. 29 to 30

Hydrogen bonding originates from the dipole-dipole interaction between H-atom and any of the other atom like F, O, N and in some cases with Cl atom. There are two types of H-bonding like intermolecular and intramolecular H-bonding.

29. Which of the following molecule consist of intramolecular H-bonding.
 (A) HF (B) Ice
 (C) Boric acid (D) Chloral hydrate
30. Which of following statement is incorrect
 (A) Boiling point of H_2O_2 is greater than that of H_2O
 (B) Ortho-nitrophenol has less boiling point than para-nitrophenol.
 (C) In ice each ' O ' atom is tetrahedrally bonded by four H-atoms which are all equidistant.



31. Which of the following is correct order for extent of Hydrogen Bonding
 (A) $\text{NH}_3 > \text{H}_2\text{O}_2 > \text{H}_2\text{O} > \text{HF}$ (B) $\text{H}_2\text{O} > \text{HF} > \text{NH}_3 > \text{H}_2\text{O}_2$
 (C) $\text{H}_2\text{O}_2 > \text{H}_2\text{O} > \text{HF}$ (D) $\text{H}_2\text{O}_2 > \text{NH}_3 > \text{H}_2\text{O} > \text{HF}$



EXERCISE # 5

MATRIX MATCH

1. Column-I

- (A) N_3^-
 (B) NO_3^-
 (C) I_3^-
 (D) CO

Column-II

(Sum of lone pair + Bond pair + π bond)

- (P) 11
 (Q) 10
 (R) 7
 (S) 13

2. Column-I

- (A) XeO_3
 (B) XeO_2F_4
 (C) XeO_2F_2

Column-II

- (P) Pyramidal geometry
 (Q) Non-planar molecule
 (R) d_{z^2} orbital is involved in hybridization of central atom

3. Column-I

- (A) NH_2^-
 (B) XeOF_2
 (C) ICl_4^-
 (D) $[\text{SbF}_5]^{2-}$

Column-II

- (P) Square pyramidal
 (Q) V-shaped
 (R) T-shaped
 (S) Square planer

4. Match the compounds with their properties.

Column-I

- (A) BCl_3
 (B) SiF_4
 (C) SiC

Column-II

- (P) All atoms are central atom.
 (Q) It has only σ -bond.
 (R) It is non-planar.

5. List - I

(Oxy Acid)

- (P) H_3BO_3
 (Q) H_3PO_3
 (R) H_4SiO_4
 (S) H_3PO_4

List - I

(Basicity)

- (1) Tetrabasic
 (2) Tribasic
 (3) Dibasic
 (4) Monobasic

Code:

	P	Q	R	S		P	Q	R	S
(A)	1	2	3	4	(B)	4	3	2	1
(C)	4	3	1	2	(D)	1	2	4	3

6. List-I

- (P) HF

List-II

- (1) 2-D sheet like structure



- | | |
|-----------------------------|--|
| (Q) H_3BO_3 | (2) inter molecular H-bonding |
| (R) H_3PO_4 | (3) Zig-zag chain like |
| (S) chloral hydrate | (4) 5 membered chelate ring found in structure |

Code:

	P	Q	R	S		P	Q	R	S
(A)	1	2	3	4	(B)	3	1	2	4
(C)	4	3	2	1	(D)	1	3	2	4

7. Match the following list :-

List-I (Molecules)

- (P) SF_4
 (Q) H_2O
 (R) SF_6
 (S) CO_2

List-II (Molecular properties)

- (1) Planar and polar
 (2) Non-planar and polar
 (3) Planar and non-polar
 (4) Non-planar and non-polar

Code:

	P	Q	R	S		P	Q	R	S
(A)	1	2	3	4	(B)	2	1	4	3
(C)	2	3	4	1	(D)	3	2	1	4

8. **Column-I**

- (A) $\text{H}_2\text{S}_2\text{O}_6$
 (B) $\text{H}_2\text{S}_2\text{O}_3$
 (C) $\text{B}_3\text{N}_3\text{H}_6$
 (D) Trimeta phosphoric acid

Column-II

- (P) Basicity = 3
 (Q) $X - X$ single bond is present (where x is a central atom)
 (R) Aromatic nature present in its structure
 (S) Weakest $p\pi - d\pi$ bond present in structure among the given molecules

9. **Column-I****(Pair of species)**

- (A) PCl_3F_2 , PCl_2F_3
 (B) BF_3 and BCl_3
 (C) CO_2 and NO_2^+
 (D) C_6H_6 and $\text{B}_3\text{N}_3\text{H}_6$

Column-II**(Identical property in pairs of species)**

- (Q) Shape of molecule / ion
 (R) μ_{net} (dipole moment)
 (S) Total number of electrons
 (T) All bond length are equal within molecule



EXERCISE - 6 # JEE-MAIN

1. Which of the following statements is true? [AIEEE-2002]
 - (A) HF is less polar than HBr
 - (B) Water does not contain any ions
 - (C) Chemical bond formation takes place when forces of attraction overcome the forces of repulsion
 - (D) In covalent bond, transfer of electrons takes place

2. Which one of the following pairs of molecules will have permanent dipole moments for both members [AIEEE-2003]

(A) NO ₂ and CO ₂	(B) NO ₂ and O ₃
(C) SiF ₄ and CO ₂	(D) SiF ₄ and NO ₂

3. The pair of species having identical shapes for molecules of both species is [AIEEE-2003]

(A) XeF ₂ , CO ₂	(B) BF ₃ , PCl ₃
(C) PF ₅ , IF ₅	(D) CF ₄ , SF ₄

4. The correct order of bond angles (smallest first) in H₂S, NH₃, BF₃ and SiH₄ is : [AIEEE-2004]

(A) H ₂ S < NH ₃ < SiH ₄ < BF ₃	(B) NH ₃ < H ₂ S < SiH ₄ < BF ₃
(C) H ₂ S < SiH ₄ < NH ₃ < BF ₃	(D) H ₂ S < NH ₃ < BF ₃ < SiH ₄

5. Lattice energy of an ionic compound depends upon [AIEEE-2005]

(A) charge on the ion only	(B) size of the ion only
(C) packing of the ion only	(D) charge and size of the ion

6. Of the following sets which one does not contain isoelectronic species ? [AIEEE-2005]

(A) PO ₄ ³⁻ , SO ₄ ²⁻ , ClO ₄ ⁻	(B) CN ⁻ , N ₂ , C ₂ ²⁻
(C) SO ₃ ²⁻ , CO ₃ ²⁻ , NO ₃ ⁻	(D) BO ₃ ³⁻ , CO ₃ ²⁻ , NO ₃ ⁻

7. In which of the following molecules/ions are all the bonds not equal? [AIEEE-2006]

(A) XeF ₄	(B) BF ₄ ⁻
(C) SF ₄	(D) SiF ₄

8. Which of the following hydrogen bonds is the strongest [AIEEE-2007]

(A) F – H F	(B) O – H O
(C) O – H F	(D) O – H N

9. The hybridisation of orbitals of N atom in NO₃⁻, NO₂⁺ and NH₄⁺ are respectively:- [AIEEE-2011]

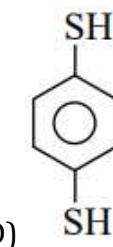
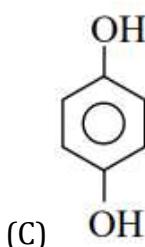
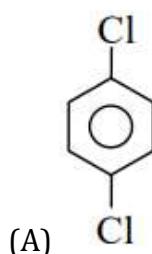
(A) sp ² , sp, sp ³	(B) sp ² , sp, sp ³
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- (A) sp, sp^3, sp^2 (B) sp^2, sp^3, sp
 (C) sp, sp^2, sp^3 (D) sp^2, sp, sp^3
10. The structure of IF_7 is :- [AIEEE-2011]
 (A) octahedral (B) pentagonal bipyramidal
 (C) square pyramid (D) trigonal bipyramidal
11. Which of the following has maximum number of lone pairs associated with Xe [AIEEE-2011]
 (A) XeO_3 (B) XeF_4 (C) XeF_6 (D) XeF_2
12. The molecule having smallest bond angle is :- [AIEEE-2012]
 (A) PCl_3 (B) NCl_3 (C) $AsCl_3$ (D) $SbCl_3$
13. In which of the following pairs the two species are not isostructural ? [AIEEE-2012]
 (A) AlF_6^{3-} and SF_6 (B) CO_3^{2-} and NO_3^-
 (C) PCl_4^+ and $SiCl_4^+$ (D) PF_5 and BrF_5
14. The number of S – S bonds in SO_3 , $S_2O_3^{2-}$, $S_2O_6^{2-}$ and $S_2O_8^{2-}$ respectively are :- [JEE-MAINS-2012]
 (A) 1,0,1,0 (B) 0,1,1,0
 (C) 1,0,0,1 (D) 0,1,0,1
15. Among the following species which two have trigonal bipyramidal shape ? [JEE-MAINS-2012]
 (I) NI_3 (II) I_3^- (III) SO_3^{2-} (IV) NO_3^-
 (A) II and III (B) III and IV
 (C) I and IV (D) I and III
16. Which of the following has the square planar structure :- [JEE-MAINS-2012]
 (A) NH_4^+ (B) CCl_4 (C) XeF_4 (D) BF_4^-
17. The compound of Xenon with zero dipole moment is :- [JEE-MAINS-2012]
 (A) XeO_3 (B) XeO_2
 (C) XeF_4 (D) $XeOF_4$
18. Among the following the molecule with the lowest dipole moment is :- [JEE-MAINS-2012]
 (A) $CHCl_3$ (B) CH_2Cl_2
 (C) CCl_4 (D) CH_3Cl
19. The formation of molecular complex $BF_3 - NH_3$ results in a change in hybridisation of boron :- [JEE-MAINS-2012]
 (A) from sp^3 to sp^3 d (B) from sp^2 to dsp^2
 (C) from sp^3 to sp^2 (D) from sp^2 to sp^3



20. Trigonal bipyramidal geometry is shown by: [JEE-MAINS-2013]
(A) $\text{XeO}_3 \text{F}_2$ (B) XeOF_2
(C) XeO_3 (D) $\text{FXeOSO}_2 \text{F}$
21. Which one of the following molecules is polar? [JEE-MAINS-2013]
(A) CF_4 (B) SbF_5
(C) IF_5 (D) XeF_4
22. Oxidation state of sulphur in anions SO_3^{2-} , $\text{S}_2\text{O}_4^{2-}$ and $\text{S}_2\text{O}_6^{2-}$ increases in the orders : [JEE-MAINS-2013]
(A) $\text{S}_2\text{O}_6^{2-} < \text{S}_2\text{O}_4^{2-} < \text{SO}_3^{2-}$ (B) $\text{SO}_3^{2-} < \text{S}_2\text{O}_4^{2-} < \text{S}_2\text{O}_6^{2-}$
(C) $\text{S}_2\text{O}_4^{2-} < \text{SO}_3^{2-} < \text{S}_2\text{O}_6^{2-}$ (D) $\text{S}_2\text{O}_4^{2-} < \text{S}_2\text{O}_6^{2-} < \text{SO}_3^{2-}$
23. XeO_4 molecule is tetrahedral having : [JEE-MAINS-2013]
(A) Two pp-dp bonds (B) Four pp-dp bonds
(C) One pp-dp bond (D) Three pp-dp bonds
24. Bond distance in HF is 9.17×10^{-11} m. Dipole moment of HF is 6.104×10^{-30} Cm. The percent ionic character in HF will be : (electron charge = 1.60×10^{-19} C) [JEE-MAINS-2013]
(A) 61.0% (B) 38.0% (C) 35.5% (D) 41.5%
25. The shape of IF_6^- is : [JEE-MAINS-2013]
(A) distorted octahedron (B) Pyramidal
(C) Octahedral (D) Square antiprism
26. Which has trigonal bipyramidal shape ? [JEE-MAINS-2013]
(A) XeOF_4 (B) XeO_3
(C) $\text{XeO}_3 \text{F}_2$ (D) XeOF_2
27. The catenation tendency of C, Si and Ge is in the order Ge < Si < C. The bond energies (in kJmol^{-1}) of C – C, Si – Si and Ge – Ge bonds are respectively : [JEE-MAINS-2013]
(A) 348,260,297 (B) 348,297,260
(C) 297,348,260 (D) 260,297,348
28. In which of the following sets, all the given species are isostructural ? [JEE-MAINS-2013]
(A) $\text{BF}_3, \text{NF}_3, \text{PF}_3, \text{AlF}_3$ (B) $\text{PCl}_3, \text{AlCl}_3, \text{BCl}_3, \text{SbCl}_3$
(C) $\text{BF}_4^-, \text{CCl}_4, \text{NH}_4^+, \text{PCl}_4^+$ (D) $\text{CO}_2, \text{NO}_2, \text{ClO}_2, \text{SiO}_2$
29. For which of the following molecule significant $\mu \neq 0$ [JEE-M-2014]



30. Among the following oxoacids, the correct decreasing order of acid strength is :-

(A) $\text{HClO}_4 > \text{HClO}_3 > \text{HClO}_2 > \text{HOCl}$ (B) $\text{HClO}_2 > \text{HClO}_4 > \text{HClO}_3 > \text{HOCl}$
 (C) $\text{HOCl} > \text{HClO}_2 > \text{HClO}_3 > \text{HClO}_4$ (D) $\text{HClO}_4 > \text{HOCl} > \text{HClO}_2 > \text{HClO}_3$

31. The number and type of bonds in C_2^2 ion in CaC_2 are:

[AIEEE-2005, AIEEE-2011, JEE-MAINS-2014 (On line)]

(A) Two σ bonds and one π – bond (B) Two σ bonds and two π - bonds
 (C) One σ bond and two π – bonds (D) One σ bond and one π – bond

32. For the compounds CH_3Cl , CH_3Br , CH_3I and CH_3F , the correct order of increasing C-halogen bond length is :

(A) $\text{CH}_3\text{F} < \text{CH}_3\text{Br} < \text{CH}_3\text{Cl} < \text{CH}_3\text{I}$ (B) $\text{CH}_3\text{F} < \text{CH}_3\text{Cl} < \text{CH}_3\text{Br} < \text{CH}_3\text{I}$
 (C) $\text{CH}_3\text{Cl} < \text{CH}_3\text{Br} < \text{CH}_3\text{F} < \text{CH}_3\text{I}$ (D) $\text{CH}_3\text{F} < \text{CH}_3\text{I} < \text{CH}_3\text{Br} < \text{CH}_3\text{Cl}$

33. Shapes of certain interhalogen compounds are stated below. Which one of them is not correctly stated?

(A) IF_7 : Pentagonal bipyramidal (B) BrF_5 : Trigonal bipyramidal
 (C) ICl_3 : Planar dimeric (D) BrF_3 : Planar T-shaped

34. Which of the following molecules has two sigma (σ) and two pi (π) bonds :-

[JEE-MAINS-2014]

(A) HCN (B) $\text{C}_2\text{H}_2\text{Cl}_2$
 (C) N_2F_2 (D) C_2H_4

35. The species in which the N atom is in a state of sp hybridization is

[JEE-MAINS-2016]

(A) NO_2 (B) NO_2^+
 (C) NO_2^- (D) NO_3^-

36. The pair in which phosphorous atoms have a formal oxidation state of +3 is :-

[JEE-MAINS-2016]

(A) Pyrophosphorous and pyrophosphoric acids
 (B) Orthophosphorous and pyrophosphorous acids
 (C) Pyrophosphorous and hypophosphoric acids
 (D) Orthophosphorous and hypophosphoric acids



- 37.** The group of molecules having identical shape is : [JEE-MAINS-2016]
- (A) SF_4 , XeF_4 , CCl_4 (B) ClF_3 , XeOF_2 , XeF_3^+
 (C) PCl_5 , IF_5 , $\text{XeO}_2 \text{ F}_2$ (D) BF_3 , PCl_3 , XeO_3
- 38.** Assertion : Among the carbon allotropes, diamond is an insulator, whereas, graphite is a good conductor of electricity. [JEE-MAINS-2016]
- Reason : Hybridization of carbon in diamond and graphite are sp^3 and sp^2 , respectively.
- (A) Assertion is incorrect statement, but the reason is correct.
 (B) Both assertion and reason are correct, and the reason is the correct explanation for the assertion.
 (C) Both assertion and reason are incorrect.
 (D) Both assertion and reason are correct, but the reason is not the correct explanation for the assertion.
- 39.** Aqueous solution of which salt will not contain ions with the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6$? [JEE-MAINS-2016]
- (A) NaCl (B) CaI_2 (C) KBr (d) NaF
- 40.** In the following reactions, ZnO is respectively acting as a/an: [JEE-MAINS(offline)-2017]
- (a) $\text{ZnO} + \text{Na}_2\text{O} \rightarrow \text{Na}_2\text{ZnO}_2$ (b) $\text{ZnO} + \text{CO}_2 \rightarrow \text{ZnCO}_3$
 (A) base and base (B) acid and acid
 (C) acid and base (D) base and acid
- 41.** $\text{sp}^3 \text{ d}^2$ hybridization is not displayed by : [JEE-MAINS(online)-2017]
- (A) SF_6 (B) BrF_5 (C) PF_5 (D) $[\text{CrF}_6]^{3-}$
- 42.** The number of $\text{S} = \text{O}$ and $\text{S} - \text{OH}$ bonds present in peroxodisulphuric acid and pyrosulphuric acid respectively are :
 (A) (2 and 4) and (2 and 4)
 (B) (4 and 2) and (4 and 2)
 (C) (4 and 2) and (2 and 4)
 (D) (2 and 2) and (2 and 2)
- 43.** The group having triangular planar structure is : [JEE-MAINS(online)-2017]
- (A) BF_3 , NF_3 , CO_3^{2-} (B) CO_3^{2-} , NO_3^- , SO_3
 (C) NH_3 , SO_3 , CO_3^{2-} (D) NCl_3 , BCl_3 , SO_3
- 44.** The number of $\text{P} - \text{OH}$ bonds and the oxidation state of phosphorus atom in pyrophosphoric acid ($\text{H}_4\text{P}_2\text{O}_7$) respectively are : [JEE-MAINS(online)-2017]

- (A) five and four (B) four and five
 (C) five and five (D) four and four
- 45.** The correct sequence of decreasing number of π -bonds in the structure of H_2SO_3 , H_2SO_4 and $\text{H}_2\text{S}_2\text{O}_7$ is : **[JEE-MAINS(online)-2017]**

- (A) $\text{H}_2\text{S}_2\text{O}_7 > \text{H}_2\text{SO}_3 > \text{H}_2\text{SO}_4$
 (B) $\text{H}_2\text{S}_2\text{O}_7 > \text{H}_2\text{SO}_4 > \text{H}_2\text{SO}_3$
 (C) $\text{H}_2\text{SO}_4 > \text{H}_2\text{S}_2\text{O}_7 > \text{H}_2\text{SO}_3$
 (D) $\text{H}_2\text{SO}_3 > \text{H}_2\text{SO}_4 > \text{H}_2\text{S}_2\text{O}_7$

- 46.** The decreasing order of bond angles in BF_3 , NH_3 , PF_3 and I_3^- is :- **[JEE-MAINS-2018]**
- (A) $\text{I}_3^- > \text{BF}_3 > \text{NH}_3 > \text{PF}_3$
 (B) $\text{BF}_3 > \text{NH}_3 > \text{PF}_3 > \text{I}_3^-$
 (C) $\text{I}_3^- > \text{NH}_3 > \text{PF}_3 > \text{BF}_3$
 (D) $\text{BF}_3 > \text{I}_3^- > \text{PF}_3 > \text{NH}_3$

- 47.** In hydrogen azide (above) the bond orders of bonds (I) and (II) are :- **[JEE-MAINS-2018]**
- | | | | |
|---------|------|-----|---------|
| (I) | (II) | (I) | (II) |
| (A) > 2 | < 2 | (2) | < 2 < 2 |
| (C) < 2 | > 2 | (4) | > 2 > 2 |

- 48.** Identify the pair in which the geometry of the species is T-shape and square-pyramidal, respectively :- **[JEE-MAINS-2018]**
- (A) IO_3^- and IO_2F_2^- (B) XeOF_2 and XeOF_4
 (C) ICl_2^- and ICl_5 (D) ClF_3 and IO_4^-
- 49.** The type of hybridisation and number of lone pair(s) of electrons of Xe in XeOF_4 respectively, are: **[JEE-MAINS-2019]**
- (A) sp^3d and 2 (B) sp^3d^2 and 2
 (C) sp^3d and 1 (D) sp^3d^2 and 1

- 50.** The relative strength of interionic/ intermolecular forces in decreasing order is:

[JEE Main online - 2020]

- (A) dipole-dipole > ion-dipole > ion-ion
 (B) ion-dipole > dipole-dipole > ion-ion
 (C) ion-dipole > ion-ion > dipole-dipole
 (D) ion-ion > ion-dipole > dipole-dipole
- 51.** The dipole moments of CCl_4 , CHCl_3 and CH_4 are in the order: **[JEE Main online - 2020]**
- (A) $\text{CH}_4 = \text{CCl}_4 < \text{CHCl}_3$ (B) $\text{CCl}_4 < \text{CH}_4 < \text{CHCl}_3$
 (C) $\text{CHCl}_3 < \text{CH}_4 = \text{CCl}_4$ (D) $\text{CH}_4 < \text{CCl}_4 < \text{CHCl}_3$



52. The number of bonds between sulphur and oxygen atoms in $S_2O_8^{2-}$ and the number of bonds between sulphur and sulphur atoms in rhombic sulphur, respectively, are :

[JEE Main online - 2020]

- (A) 4 and 6 (B) 8 and 8 (C) 4 and 8 (D) 8 and 6

53. The predominant intermolecular forces present in ethyl acetate, a liquid, are :

[JEE Main online - 2020]

- (A) London dispersion, dipole-dipole and hydrogen bonding [JEE Main online - 2020]
 (B) hydrogen bonding and London dispersion
 (C) Dipole-dipole and hydrogen bonding
 (D) London dispersion and dipole-dipole

54. Arrange the following bonds according to their average bond energies in descending order :



[JEE Main online - 2020]

- (A) $C - F > C - Cl > C - Br > C - I$
 (B) $C - Cl > C - Br > C - I > C - F$
 (C) $C - I > C - Br > C - Cl > C - F$
 (D) $C - Br > C - I > C - Cl > C - F$

55. If the magnetic moment of a dioxygen species is 1.73 B.M, it may be :

[JEE Main online - 2020]

- (A) O_2^- or O_2^+
 (B) O_2 or O_2^-
 (C) O_2 or O_2^+
 (D) O_2, O_2^- or O_2^+

56. The acidic, basic and amphoteric oxides, respectively, are:

[JEE Main online - 2020]

- (A) MgO, Cl_2O, Al_2O_3
 (B) N_2O_3, Li_2O, Al_2O_3
 (C) Cl_2O, CaO, P_4O_{10}
 (D) Na_2O, SO_3, Al_2O_3

57. The number of sp^2 hybrid orbitals in a molecule of benzene is :

[JEE Main online - 2020]

- (A) 6 (B) 24 (C) 18 (D) 12

58. The sum of the total number of bonds between chromium and oxygen atoms in chromate and dichromate ions is _____.

[JEE Main online - 2020]



59. Which of the following are isostructural pairs? [JEE Main 2021]

- | | |
|--|---|
| (A) SO_4^{2-} and CrO_4^{2-} | (B) SiCl_4 and TiCl_4 |
| (C) NH_3 and NO_3^- | (D) BCl_3 and BrCl_3 |
| (A) A and C only | (B) A and B only |
| (C) B and C only | (D) C and D only |

60. The correct shape and I-I-I bond angles respectively in I_3^- ion are : [JEE Main 2021]

- (A) Trigonal planar; 120°
- (B) Distorted trigonal planar; 135° and 90°
- (C) Linear; 180°
- (D) T-shaped; 180° and 90°

61. According to molecular orbital theory, the species among the following that does not exist is:

- | | | | |
|---------------------|---------------------|-----------------------|-------------------|
| (A) He_2^- | (B) He_2^+ | (C) O_2^{2-} | (D) Be_2 |
|---------------------|---------------------|-----------------------|-------------------|

62. Which among the following species has unequal bond lengths?

- | | | | |
|--------------------|--------------------|---------------------|-------------------|
| (A) XeF_4 | (B) SiF_4 | (C) BF_4^- | (D) SF_4 |
|--------------------|--------------------|---------------------|-------------------|

63. Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R.

Assertion A : Dipole-dipole interactions are the only non-covalent interactions, resulting in hydrogen bond formation

Reason R : Fluorine is the most electronegative element and hydrogen bonds in HF are symmetrical In the light of the above statements, choose the most appropriate answer from the options given below : [JEE Main 2021]

- (A) A is false but R is true
- (B) Both A and R are true and R is the correct explanation of A
- (C) A is true but R is false
- (D) Both A and R are true and R is not the correct explanation of A

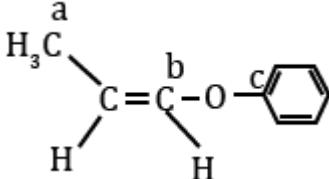
64. Match List-I with List-II. [JEE Main 2021]

List-I (Molecule)	List-II (Bond order)
-------------------	----------------------

- | | |
|-------------------|---------|
| (a) Ne_2 | (i) 1 |
| (b) N_2 | (ii) 2 |
| (c) F_2 | (iii) 0 |
| (d) O_2 | (iv) 3 |

Choose the correct answer from the options given below:

[JEE Main 2021]

- (A) (a) - (iii), (b) - (iv), (c) - (i), (d) - (iii)
 (B) (a) - (i), (b) - (ii), (c) - (iii), (d) - (iv)
 (C) (a) - (ii), (b) - (i), (c) - (iv), (d) - (iii)
 (D) (a) - (iv), (b) - (iii), (c) - (ii), (d) - (i)
- 65.** AX is a covalent diatomic molecule where A and X are second row elements of periodic table. Based on Molecular orbital theory, the bond order of AX is 2.5. The total number of electrons in AX is ____ (Round off to the Nearest Integer). **[JEE Main 2021]**
- 66.** In the following molecules,
- 
- Hybridisation of carbon a, b and c respectively are : **[JEE Main 2021]**
- (A) sp^3, sp, sp (B) sp^3, sp^2, sp
 (C) sp^3, sp^2, sp^2 (D) sp^3, sp, sp^2
- 67.** The number of species below that have two lone pairs of electrons in their central atom is ____ (Round off to the Nearest integer) $SF_4, BF_4^-, CIF_3, AsF_3, PCl_5, BrF_5, XeF_4, SF_6$ **[JEE Main 2021]**
- 68.** Identify the species having one π -bond and maximum number of canonical forms from the following : **[JEE Main 2021]**
- (A) SO_3 (B) O_2 (C) SO_2 (D) CO_3^{2-}
- 69.** Given below are two statements: One is labelled as Assertion A and the other labelled as Reason R. **[JEE Main 2021]**
- Assertion A : Lithium halides are somewhat covalent in nature.
 Reason R : Lithium possess high polarisation capability.
- In the light of the above statements, choose the most appropriate answer from the options given below:
- (A) A is true but R is false
 (B) A is false but R is true
 (C) Both A and R are true but R is NOT the correct explanation of A
 (D) Both A and R are true and R is the correct explanation of A
- 70.** The total number of electrons in all bonding molecular orbitals of O_2^{2-} is ____ (Round off to the nearest integer) **[JEE Main 2021]**



71. Match List I with List II :

[JEE Main 2022]

List-I (molecule)	List-II (hybridization; shape)
A. XeO_3	I. $\text{sp}^3 \text{ d}$; linear
B. XeF_2	II. sp^3 ; pyramidal
C. XeOF_4	III. $\text{sp}^3 \text{ d}^3$; distorted octahedral
D. XeF_6	IV. $\text{sp}^3 \text{ d}^2$; square pyramidal

Choose the correct answer from the options given below:

(A) A-II, B-I, C-IV, D-III

(B) A-II, B-IV, C-III, D-I

(C) A-IV, B-II, C-III, D-I

(D) A-IV, B-II, C-I, D-III

72. The total number of acidic oxides from the following list is: NO , N_2O , B_2O_3 , N_2O_5 , CO , SO_3 , P_4O_{10}

(A) 3

(B) 4

(C) 5

(D) 6

[JEE Main 2022]

73. Arrange the following in increasing order of their covalent character.

(A) CaF_2 (B) CaCl_2 (C) CaBr_2 (D) CaI_2

[JEE Main 2022]

Choose the correct answer from the options given below.

(A) $\text{B} < \text{A} < \text{C} < \text{D}$ (B) $\text{A} < \text{B} < \text{C} < \text{D}$ (C) $\text{A} < \text{B} < \text{D} < \text{C}$ (D) $\text{A} < \text{C} < \text{B} < \text{D}$

74. The number of molecule(s) or ion(s) from the following having non-planar structure is

 NO_3^- , H_2O_2 , BF_3 , PCl_3 , XeF_4

[JEE Main 2022]

 SF_4 , XeO_3 , PH_4^+ , SO_3 , $[\text{Al}(\text{OH})_4]^-$

75. Based upon VSEPR theory, match the shape (geometry) of the molecules in List-I with the

molecules in List-II and select the most appropriate option

[JEE Main 2022]

List-I (Shape)**List-II (Molecules)**

(A) T-shaped

(I) XeF_4

(B) Trigonal planar

(II) SF_4

(C) Square planar

(III) ClF_3

(D) See-saw

(IV) BF_3

(A) (A) - I, (B) - (II), (C) - (III), (D) - (IV)

(B) (A) - (III), (B) - (IV), (C) - (I), (D) - (II)

(C) (A) - (III), (B) - (IV), (C) - (II), (D) - (I)

(D) (A) - (IV), (B) - (III), (C) - (I), (D) - (II)



- 76.** Consider the species CH_4 , NH_4^+ and BH_4^- . Choose the correct option with respect to the three species: [JEE Main 2022]
- (A) They are isoelectronic and only two have tetrahedral structures
 - (B) They are isoelectronic and all have tetrahedral structures
 - (C) Only two are isoelectronic and all have tetrahedral structures
 - (D) Only two are isoelectronic and only two have tetrahedral structures
- 77.** What is the number of unpaired electron(s) in the highest occupied molecular orbital of the following species : N_2 : N_2^+ ; O_2 ; O_2^+ ? [JEE Main 2023]
- (A) 0,1,2,1
 - (B) 2,1,2,1
 - (C) 0,1,0,1
 - (D) 2,1,0,1
- 78.** **Statement I :-** 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.
Statement II :- The crossed arrow of the dipole moment symbolizes the direction of the shift of charges in the molecules.
 In the light of the above statements, choose the most appropriate answer from the options given below : - [JEE Main 2023]
- (A) Both Statement I and Statement II are correct.
 - (B) Statement I is incorrect but Statement II is correct.
 - (C) Both Statement I and Statement II are incorrect.
 - (D) Statement I is correct but Statement II is incorrect.
- 79.** The number of given orbitals which have electron density along the axis is _____
 $p_x, p_y, p_z, d_{xy}, d_{yz}, d_{xz}, d_{z^2}, d_{x^2-y^2}$ [JEE Main 2023]
- 80.** Match List I with List II
- | LIST-I
(molecules/ions) | | LIST-II
(No. of lone pairs of e^- on central atom) | |
|--|------------------|--|-------|
| (A) | IF_7 | I. | Three |
| (B) | ICl_4^- | II. | One |
| (C) | XeF_6 | III. | Two |
| (D) | XeF_2 | IV. | Zero |
- Choose the correct answer from the options given below: [JEE Main 2023]
- (A) A – II, B – III, C – IV, D – I
 - (B) A – IV, B – III, C – II, D – I
 - (C) A – II, B – I, C – IV, D – III
 - (D) A – IV, B – I, C – II, D – III



81. Match List I with List II

[JEE Main 2023]

List I	List II
A. XeF_4	I. See - saw
B. SF_4	II. Square planar
C. NH_4^+	III. Bent T-shaped
D. BrF	IV. Tetrahedral

Choose the correct answer from the options given below:

(A) A-IV, B-III, C-II, D-I

(B) A-II, B-I, C-III, D-IV

(C) A-IV, B-I, C-II, D-III

(D) A-II, B-I, C-IV, D-III

82. Amongst the following, the number of species having the linear shape is _____.

 $\text{XeF}_2, \text{I}_3^+, \text{C}_3\text{O}_2, \text{I}_3^-, \text{CO}_2, \text{SO}_2, \text{BeCl}$ and BCl_2^\ominus

[JEE Main 2023]



EXERCISE - 7 # JEE-ADVANCED

Integer Type

1. The number of water molecule(s) directly bonded to the metal centre in $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is
[JEE 2009]
2. Based on VSEPR theory, the number of 90 degree $\text{F} - \text{Br} - \text{F}$ angles in BrF_5 is
[JEE 2010]
3. The difference in the oxidation numbers of the two types of sulphur atoms in $\text{Na}_2\text{S}_4\text{O}_6$ is.
[JEE 2011]
4. The total number of lone-pairs of electrons in melamine is
[JEE Adv. 2013]

One or more than one correct

5. The linear structure is assumed by :
(A) SnCl_4 (B) NCO^- (C) CS_2 (D) NO_2^+
[IIT-1991]
6. Which of the following has zero dipole moment?
(A) ClF (B) PCl_3 (C) SiF_4 (D) CFCl_3
[IIT-1993]
7. Among the following molecules, which one is planar?
(A) BCl_3 (B) SO_2Cl_2 (C) NH_3 (D) NF_3
[IIT-1994]
8. Which of the following species is / are non-linear?
(A) H_2S (B) NH_3 (C) CO_2 (D) SO_2
[IIT-1995]
9. Which contains both polar and non-polar bonds?
(A) CH_4 (B) HCN (C) H_2O_2 (D) NH_4Cl
[IIT-1997]
10. Which of the following compounds has sp^2 hybridisation?
(A) CO_2 (B) SO_2 (C) N_2O (D) CO
[IIT-1997]
11. Which one of the following molecules is planar?
(A) NF_3 (B) NCl_3 (C) BF_3 (D) PH_3
[IIT-1996]
12. The number and type of bonds between two carbon atoms in CaC_2 are:
(A) 1σ and 1π (B) 1σ and 2π (C) 1σ and 1.5π (D) 1σ
[IIT-1996]
13. Among the species NF_3 , NO_3^- , BF_3 , H_3O^+ and HN_3 , identify the isostructural species :
[IIT-1996]

(A) $(\text{NF}_3, \text{NO}_3^-)$ and $(\text{BF}_3, \text{H}_3\text{O}^+)$ (C) $(\text{NF}_3, \text{H}_3\text{O}^+)$ and $(\text{NO}_3^-, \text{BF}_3)$	(B) $(\text{NF}_3, \text{HN}_3)$ and $(\text{NO}_3^-, \text{BF}_3)$ (D) $(\text{NF}_3, \text{H}_3\text{O}^+)$ and $(\text{HN}_3, \text{BF}_3)$
--	---
14. Among the following the one that is polar and has the central atom with sp^2 hybridisation is :
[IIT-1997]

(A) H_2CO_3	(B) SiF_4	(C) BF_3	(D) HClO_2
-----------------------------	--------------------	-------------------	---------------------

15. The geometry & the type of hybrid orbitals present about the central atom in BF_3 is :

[JEE98]

- | | |
|-------------------------------|------------------------------------|
| (A) linear, sp | (B) trigonal planar, sp^2 |
| (C) tetrahedral sp^3 | (D) pyramidal, sp^3 |

16. Which one of the following statement (s) is (are) correct? [JEE1998]

- (A) The electronic configuration of Cr is $[\text{Ar}]3\ \text{d}^5 4\ \text{s}^1$. (Atomic No. of Cr = 24)
- (B) The magnetic quantum number may have a negative value
- (C) In silver atom, 23 electrons have a spin of one type and 24 of the opposite type.
(Atomic No. of Ag = 47)
- (D) The oxidation state of nitrogen in HN_3 is -3 .

17. Element X is strongly electronegative and element Y is strongly electropositive. Both are univalent. The compound formed would be : [JEE1998]

- (A) $\text{X}^\rightarrow\text{Y}$
- (B) Y^+X^-
- (C) X^+Y^-
- (D) $\text{Y}^\rightarrow\text{X}$

18. The correct order of increasing C – O bond length of, CO, CO_3^{2-} , CO_2 is :- [JEE '99]

- (A) $\text{CO}_3^{2-} < \text{CO}_2 < \text{CO}$
- (B) $\text{CO}_2 < \text{CO}_3^{2-} < \text{CO}$
- (C) $\text{CO} < \text{CO}_3^{2-} < \text{CO}_2$
- (D) $\text{CO} < \text{CO}_2 < \text{CO}_3^{2-}$

19. The geometry of H_2S and its dipole moment are [JEE '99]

- (A) angular & non zero
- (B) angular & zero
- (C) linear & non zero
- (D) linear & zero

20. In compounds type ECl_3 , where E = B, P, As or Bi, the angles Cl – E – Cl for different E are in the order [JEE '99]

- (A) $\text{B} > \text{P} = \text{As} = \text{Bi}$
- (B) $\text{B} > \text{P} > \text{As} > \text{Bi}$
- (C) $\text{B} < \text{P} = \text{As} = \text{Bi}$
- (D) $\text{B} < \text{P} < \text{As} < \text{Bi}$

21. The most likely representation of resonance structure of p-nitrophenoxide is :

22. Amongst H_2O , H_2S , H_2Se and H_2Te , the one with the highest boiling point is [JEE 2000]

- (A) H_2O because of hydrogen bonding
- (B) H_2Te because of higher molecular weight
- (C) H_2S because of hydrogen bonding
- (D) H_2Se because of lower molecular weight

23. The hybridization of atomic orbitals of nitrogen in NO_2^+ , NO_3^- and NH_4^+ are [JEE 2000]

- (A) sp^2 , sp^3 and sp^2 respectively
- (B) sp , sp^2 and sp^3 respectively
- (C) sp^2 , sp and sp^3 respectively
- (D) sp^2 , sp^3 and sp respectively



- 24.** The correct order of hybridization of the central atom in the following species NH_3 , PtCl_4^{2-} , PCl_5 and BCl_3 is [JEE 2001]
- (A) dsp^2 , sp^3 d, sp^2 and sp^3
 (B) sp^3 , dsp^2 , sp^3 d, sp^2
 (C) dsp^2 , sp^2 , sp^3 , sp^3 d
 (D) dsp^2 , sp^3 , sp^2 , sp^3 d
- 25.** Specify hybridization of N and B atoms in a 1: 1 complex of BF_3 and NH_3 [JEE 2002]
- (A) N : tetrahedral, sp^3 ; B : tetrahedral, sp^3
 (B) N: pyramidal, sp^3 ; B: pyramidal, sp^3
 (C) N : pyramidal, sp^3 ; B : planar, sp^2
 (D) N : pyramidal, sp^3 ; B : tetrahedral, sp^3
- 26.** The nodal plane in the π -bond of ethene is located in [JEE 2002]
- (A) the molecular plane
 (B) a plane parallel to the molecular plane
 (C) a plane perpendicular to the molecular plane which bisects, the carbon-carbon s bond at right angle
 (D) a plane perpendicular to the molecular plane which contains, the carbon-carbon bond.
- 27.** Which of the following are isoelectronic and isostructural? NO_3^- , CO_3^{2-} , ClO_3^- , SO_3 [JEE 2003]
- (A) NO_3^- , CO_3^{2-} (B) SO_3 , NO_3^- (C) ClO_3^- , CO_3^{2-} (D) CO_3^{2-} , SO_3
- 28.** Which species has the maximum number of lone pair of electrons on the central atom? [JEE 2005]
- (A) ClO_3^- (B) XeF_4 (C) SF_4 (D) I_3^-
- 29.** The percentage of p-character in the orbitals forming P – P bonds in P_4 is [JEE 2007]
- (A) 25 (B) 33 (C) 50 (D) 75
- 30.** The structure of XeO_3 is [JEE 2007]
- (A) linear (B) planar (C) pyramidal (D) T-shaped
- 31.** Statement-1 : p-Hydroxybenzoic acid has a lower boiling point than o-hydroxybenzoic acid. because
 Statement-2 : o-Hydroxybenzoic acid has intramolecular hydrogen bonding. [JEE 2007]
- (A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
 (B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for



- Statement-1.
- (C) Statement-1 is True, Statement-2 is False.
(D) Statement-1 is False, Statement-2 is True.
32. Statement-1 : In water, orthoboric acid behaves as a weak monobasic acid.because
Statement-2 : In water, orthoboric acid acts as a proton donor. [JEE 2007]
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.
(C) Statement-1 is True, Statement-2 is False.
(D) Statement-1 is False, Statement-2 is True.
33. The nitrogen oxide(s) that contain(s) N – N bond(s) is/are [JEE 2009]
(A) N_2O (B) N_2O_3 (C) N_2O_4 (D) N_2O_5
34. The species having pyramidal shape is/are : [JEE 2010]
(A) SO_3 (B) BrF_3 (C) SiO_3^{2-} (D) OSF_2
35. Which ordering of compounds is according to the decreasing order of the oxidation state of nitrogen- [JEE 2012]
(A) $\text{HNO}_3, \text{NO}, \text{NH}_4\text{Cl}, \text{N}_2$ (B) $\text{HNO}_3, \text{NO}, \text{N}_2, \text{NH}_4\text{Cl}$
(C) $\text{HNO}_3, \text{NH}_4\text{Cl}, \text{NO}, \text{N}_2$ (D) $\text{NO}, \text{HNO}_3, \text{NH}_4\text{Cl}, \text{N}_2$
36. The shape of XeO_2F_2 molecule is : [JEE 2012]
(A) Trigonal bipyramidal (B) Square planar
(C) tetrahedral (D) see-saw
37. The compound(s) with TWO lone pairs of electrons on the central atom is(are) [JEE 2016]
(A) BrF_5 (B) ClF_3 (C) XeF_4 (D) SF_4
38. The crystalline form of borax has [JEE 2016]
(A) Tetranuclear $[\text{B}_4\text{O}_5(\text{OH})_4]^{2-}$ unit
(B) All boron atoms in the same plane
(C) Equal number of sp^2 and sp^3 hybridized boron atoms
(D) One terminal hydroxide per boron atom
39. The sum of the number of lone pairs of electrons on each central atom in the following species is $[\text{TeBr}_6]^{2-}$, $[\text{BrF}_2]^+$, SNF_3 , and $[\text{XeF}_3]^-$ [JEE 2017]
(A) Atomic numbers: 7, F = 9, S = 16, Br = 35, Te = 52, Xe = 54)
40. The order of the oxidation state of the phosphorus atom in H_3PO_2 , H_3PO_4 , H_3PO_3 , and $\text{H}_4\text{P}_2\text{O}_6$ is:- [JEE 2017]



- (A) $\text{H}_3\text{PO}_4 > \text{H}_3\text{PO}_2 > \text{H}_3\text{PO}_3 > \text{H}_4\text{P}_2\text{O}_6$ (B) $\text{H}_3\text{PO}_2 > \text{H}_3\text{PO}_3 > \text{H}_4\text{P}_2\text{O}_6 > \text{H}_3\text{PO}_4$
 (C) $\text{H}_3\text{PO}_3 > \text{H}_3\text{PO}_2 > \text{H}_3\text{PO}_4 > \text{H}_4\text{P}_2\text{O}_6$ (D) $\text{H}_3\text{PO}_4 > \text{H}_4\text{P}_2\text{O}_6 > \text{H}_3\text{PO}_3 > \text{H}_3\text{PO}_2$

41. The option (s) with only amphoteric oxides is(are) : [JEE 2017]

- (A) $\text{Cr}_2\text{O}_3, \text{BeO}, \text{SnO}, \text{SnO}_2$ (B) $\text{ZnO}, \text{Al}_2\text{O}_3, \text{PbO}, \text{PbO}_2$
 (C) $\text{NO}, \text{B}_2\text{O}_3, \text{PbO}, \text{SnO}_2$ (D) $\text{Cr}_2\text{O}_3, \text{CrO}, \text{SnO}, \text{PbO}$

42. The total number of compounds having at least one bridging oxo group among the molecules given below is _____.
 $\text{N}_2\text{O}_3, \text{N}_2\text{O}_5, \text{P}_4\text{O}_6, \text{P}_4\text{O}_7, \text{H}_4\text{P}_2\text{O}_5, \text{H}_5\text{P}_3\text{O}_{10}, \text{H}_2\text{S}_2\text{O}_3, \text{H}_2\text{S}_2\text{O}_5$ [JEE 2018]

43. Each of the following options contains a set of four molecules. Identify the option(s) where all four molecules possess permanent dipole moment at room temperature. [JEE 2019]

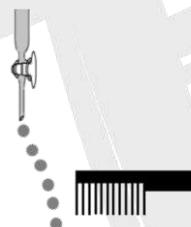
- (A) $\text{NO}_2, \text{NH}_3, \text{POCl}_3, \text{CH}_3\text{Cl}$ (B) $\text{BeCl}_2, \text{CO}_2, \text{BCl}_3, \text{CHCl}_3$
 (C) $\text{SO}_2, \text{C}_6\text{H}_5\text{Cl}, \text{H}_2\text{Se}, \text{BrF}_5$ (D) $\text{BF}_3, \text{O}_3, \text{SF}_6, \text{XeF}_6$

44. Consider the following compounds in the liquid form :



[JEE Adv. 2020]

When a charged comb is brought near their flowing stream, how many of them show deflection as per the following figure?



45. For diatomic molecules, the correct statement(s) about the molecular orbitals formed by the overlap of two $2p_z$ orbitals is(are) [JEE Adv. 2022]

- (A) σ orbital has a total of two nodal planes.
 (B) σ^* orbital has one node in the xz -plane containing the molecular axis.
 (C) π orbital has one node in the plane which is perpendicular to the molecular axis and goes through the center of the molecule.
 (D) π^* orbital has one node in the xy -plane containing the molecular axis.



ANSWER KEY

DO YOURSELF - 1

Question	1	2	3	4	5
Answer	D	B	D	A	C

DO YOURSELF - 2

Question	2	3	4	5
Answer	C	B	C	A

DO YOURSELF - 3

Question	1	2	3	4	5
Answer	A	D	D	A	D

DO YOURSELF - 4

Question	1	2	3	4	5
Answer	D	A	A	C	C

DO YOURSELF - 5

Question	1	2	3	4	5
Answer	D	C	B	C	B



ANSWER KEY

EXERCISE-1

1.	D	2.	A	3.	D	4.	B	5.	C	6.	C	7.	C
8.	B	9.	B	10.	D	11.	C	12.	C	13.	C	14.	D
15.	A	16.	D	17.	B	18.	A	19.	C	20.	C	21.	D
22.	D	23.	D	24.	B	25.	B	26.	D	27.	C	28.	B
29.	D	30.	B	31.	C	32.	C	33.	B	34.	D	35.	D
36.	D	37.	D	38.	C	39.	D	40.	B	41.	B	42.	A
43.	A	44.	D	45.	B	46.	C	47.	A	48.	B	49.	D
50.	D	51.	C	52.	C	53.	D	54.	C	55.	A	56.	C
57.	D	58.	C	59.	C	60.	C	61.	A	62.	D	63.	A
64.	C	65.	C	66.	A	67.	B	68.	A	69.	C	70.	D
71.	C	72.	A	73.	C	74.	D	75.	C	76.	C	77.	D
78.	D	79.	D	80.	C	81.	B	82.	C	83.	A	84.	D
85.	B	86.	C	87.	B	88.	C	89.	A	90.	B	91.	C
92.	C	93.	A	94.	C	95.	A	96.	C	97.	B	98.	B
99.	A	100.	A	101.	B	102.	B	103.	C	104.	D	105.	D
106.	C	107.	A	108.	C	109.	C	110.	A	111.	B	112.	D
113.	B	114.	C	115.	D	116.	D	117.	C	118.	C	119.	D
120.	D	121.	C	122.	C	123.	C	124.	A	125.	D	126.	B
127.	B	128.	C	129.	B	130.	D	131.	A	132.	D	133.	B
134.	C	135.	C	136.	D	137.	C	138.	B	139.	C	140.	D
141.	C	142.	D	143.	C	144.	D						

EXERCISE-2

1. A,B,C,D	2. A,B,C	3. A,B,D	4. A,C,D	5. A,B,C,D	6. A,B,C,D	7. A,B,C
8. B,D	9. A,B,C	10. B,C,D	11. A,B	12. A,B,C	13. A,B,C	14. A,B
15. A,D	16. A,B	17. A,B	18. A,B,C	19. A,C	20. A,B	21. A,B,C
22. B,C	23. A,B,D	24. A,C,D	25. A,C	26. B,C,D	27. B,D	28. A,B,C,D
29. B,C	30. A,B,C,D	31. A,B,C	32. A,B	33. A,B	34. A,B,C	35. A,B,C,D
36. A,D	37. A,C	38. A,B,C	39. A,C,D	40. A,B,C		



EXERCISE-3

1. (5) 2. (4) 3. (3) 4. (2) 5. (15) 6. (2) 7. (2)
 8. (3) 9. (4) 10. (4) 11. (4) 12. (2) 13. (4) 14. (2)
 15. (4) 16. (4) 17. (8) 18. (4) 19. (0) 20. (20) 21. (3)
 22. (4) 23. (16) 24. (8) 25. (2) 26. (15) 27. (3) 28. (0)
 29. (3) 30. (4) 31. (6) 32. (2) 33. (3) 34. (2)

EXERCISE-4

1. (B) 2. (B) 3. (C) 4. (C) 5. (D) 6. (D) 7. (B)
 8. (C) 9. (A) 10. (C) 11. (B) 12. (B) 13. (A) 14. (A,B,C)
 15. (B) 16. (A) 17. (C) 18. (A,B,D) 19. (A,D) 20. (D) 21. (A,B,C,D)
 22. (A) 23. (D) 24. (B,C,D) 25. (D) 26. (B) 27. (A) 28. (A)
 29. (D) 30. (C) 31. (C)

EXERCISE-5

1. (A) → (Q) ; (B) → (S) ; (C) → (P) ; (D) → (R)
 2. (A) – (PQ) ; (B) – (QR) ; (C) – (QR)
 3. (A) → (Q) ; (B) → (R) ; (C) → (S) ; (D) → (P)
 4. (A) → (Q) ; (B) → (Q,R) ; (C) → (P,Q,R)
 5. C 6. B 7. B
 8. (A) → (Q) ; (B) → (S) ; (C) → (R) ; (D) → (P)
 9. [(A) P,Q ; (B) P,Q,R,T ; (C) P,Q,R,S,T ; (D) P,Q,R,S]

EXERCISE-6 JEE-MAIN

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	C	B	A	A	D	C	C	A	D	B
Que.	11	12	13	14	15	16	17	18	19	20
Ans.	D	D	D	B	BONUS	C	C	C	D	A
Que.	21	22	23	24	25	26	27	28	29	30
Ans.	C	C	B	D	A	C	B	C	B	A
Que.	31	32	33	34	35	36	37	38	39	40
Ans.	C	B	B	A	B	B	B	D	D	C
Que.	41	42	43	44	45	46	47	48	49	50
Ans.	C	B	B	B	B	A	C	B	D	D



Que.	51	52	53	54	55	56	57	58	59	60
Ans.	A	B	D	A	A	B	C	12	B	C
Que.	61	62	63	64	65	66	67	68	69	70
Ans.	D	D	C	A	15	C	2	D	D	10
Que.	71	72	73	74	75	76	77	78	79	80
Ans.	A	B	B	3	B	B	A	D	5	B
Que.	81	82								
Ans	D	5								

EXERCISE-7 JEE-ADVANCED

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	4	0	5	6	B,C,D	C	A	A,B,D	C	B
Que.	11	12	13	14	15	16	17	18	19	20
Ans.	C	B	C	A	B	A,B,C	B.	D	A	B
Que.	21	22	23	24	25	26	27	28	29	30
Ans.	A	A	B	B	A	A	A	D	D	C
Que.	31	32	33	34	35	36	37	38	39	40
Ans.	D	C	A, B, C or A, C	D	B	D	B, C	A, C, D	6	D
Que.	41	42	43	44	45					
Ans.	AB	5,6	A,C	6	A,D					