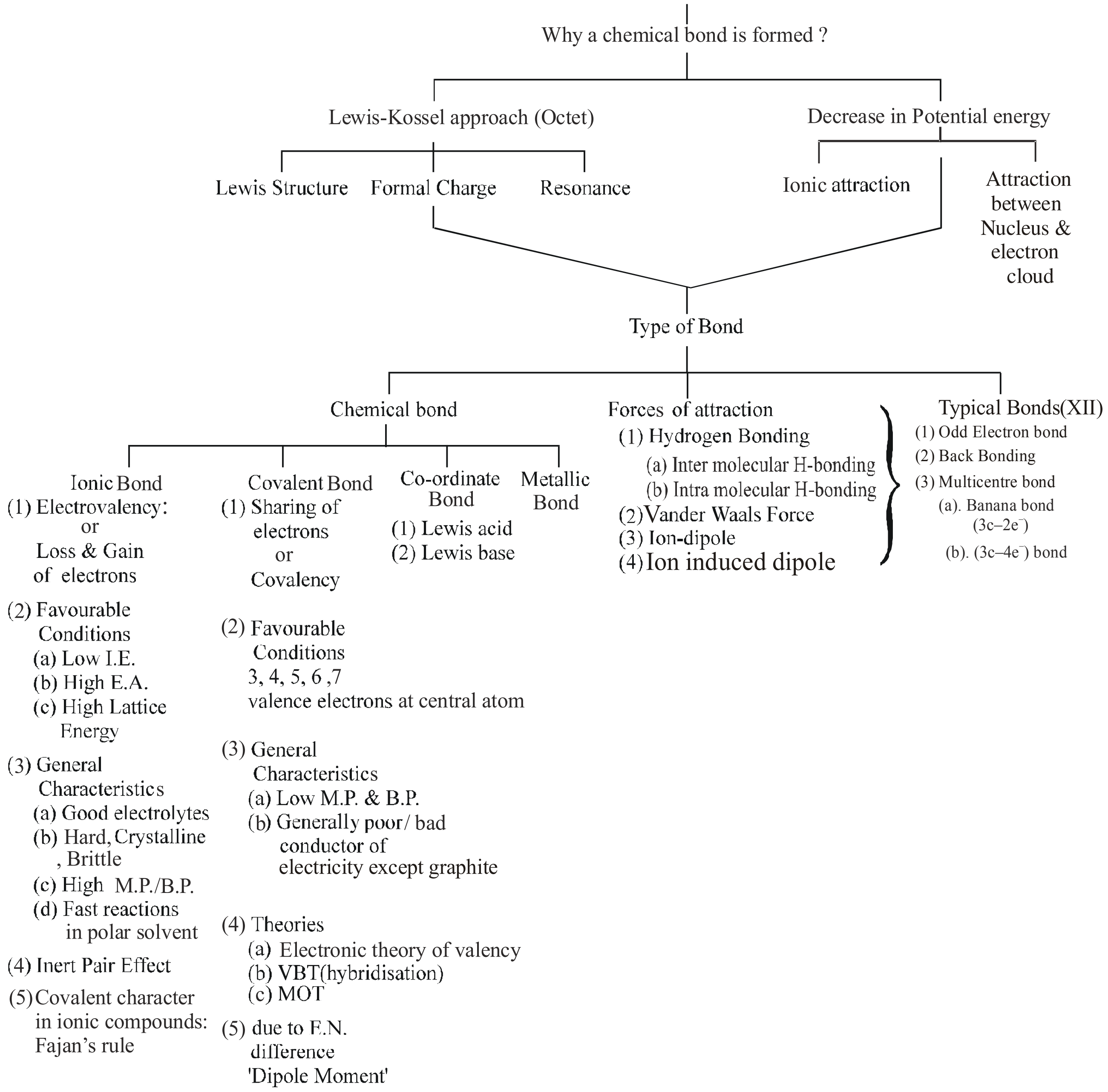
CHEMICAL BONDING

FLOWCHART TO CHEMICAL BONDING



KEY CONCEPT

CHEMICAL BOND

(a) The attractive force which holds various constituents (atoms, ions, etc.) together in different chemical species is called a chemical bond.
(b) It is the combination of two or more chemical species involving redistribution of e^- among them.
(c) This process is accompanied with decrease in energy.
(d) Decrease in energy strengthens the bond.
(e) Therefore, molecules are more stable than atoms.

CAUSE OF CHEMICAL COMBINATION

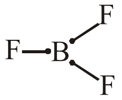
1. **Tendency to acquire minimum energy :**
2. **Tendency to acquire noble gas configuration (Octet rule) :**

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

LIMITIATION OF OCTET RULE

1. **Contraction of octet (incomplete octet)**

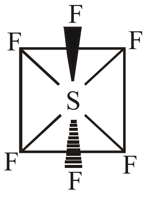
$\underline{Be}F_2$	$\underline{B}F_3$	$\underline{Al}Cl_3$	$\underline{B}Cl_3$
($4e^-$)	($6e^-$)	($6e^-$)	($6e^-$)


($6\ e^-$)

These compounds are hypovalent.

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

PCl_5	SF_6	ClF_3	BrF_5	IF_7
↓	↓	↓	↓	↓
($10e^-$)	($12e^-$)	($10e^-$)	($12e^-$)	($14e^-$)


(12 e)

These compounds are hypervalent.

3. **Odd electron species**

Ex. NO, NO_2, ClO_2 etc.

OTHER EXCEPTIONS OF OCTET RULE

1. **Compounds of Noble gases**

Noble gases which have already completed their octets (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.

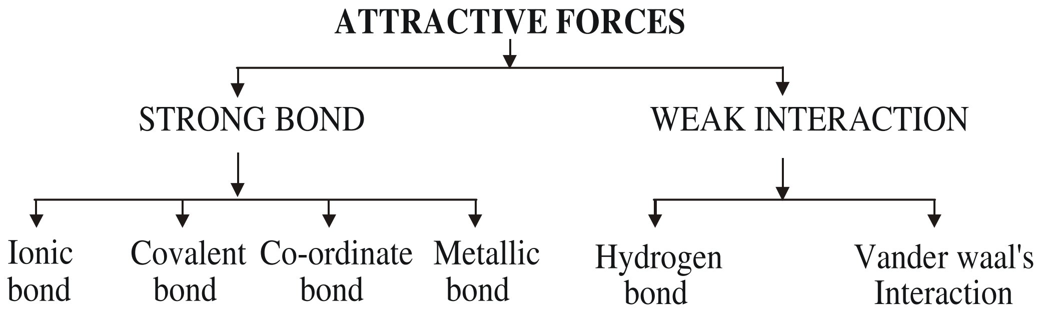
2. **Transition metal ions**

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

3. **Pseudo inert gas configuration [($ns^2np^6nd^{10}$)]**

Zn^{2+}	Cd^{2+}
$[Ar]3d^{10}$	$[Kr]4d^{10}$

CLASSIFICATION OF BONDS

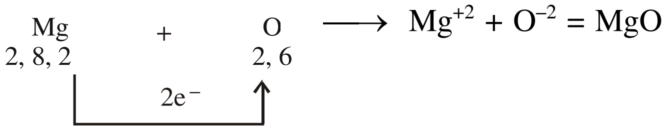


ELECTROVALENT OR IONIC BOND

(a) The chemical bond formed between two or more atoms as a result of the complete transfer of one or more electons from one atom to another is called as Ionic or electrovalent bond.

Example

(i)



$$\underset{2,8,2}{Mg} + \underset{2,6}{O} \longrightarrow Mg^{+2} + O^{-2} = MgO$$

electrovalency of Mg = 2

electrovalency of O = 2

Note : Ionic bond is non-directional.

<u>FACTORS FAVOURING IONIC BONDING</u>

(a) Less Ionization energy of atom forming cation

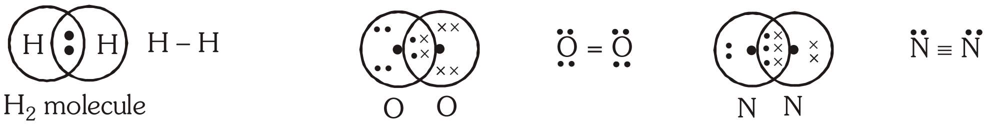
(b) Higher electron affinity of atom forming anion

(c) Greater Lattice energy of formed product.

(d) Greater Electronegativity difference between atoms forming cation & anion.

COVALENT BOND

(a) A covalent bond is formed by the mutual sharing of electrons between two atoms.

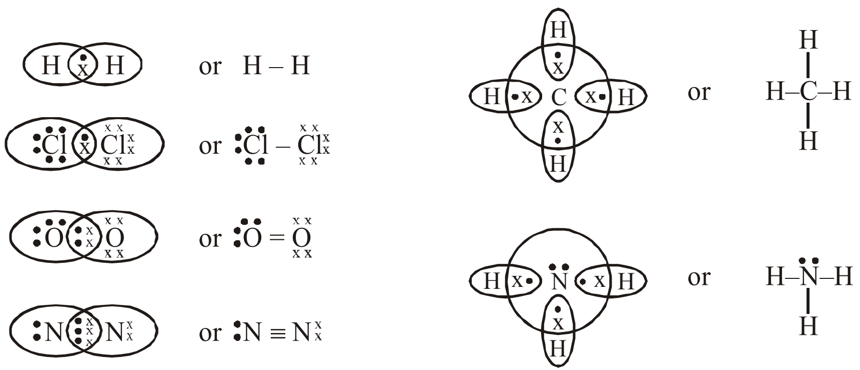


(b) The shared pair of electrons must have opposite spins, and are localised between two atoms concerned.

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

Covalency : Capacity to form covalent bond is known as covalency

It is represented by (–) small line. – means single bond ; = means double bond ; ≡ means triple bond.

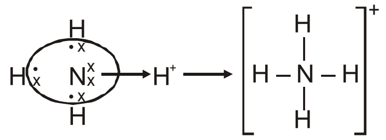


Covalent bonds are directional in nature

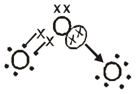
COORDINATE BOND (DATIVE BOND)

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

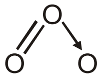
(i) NH_4^+ (ammonium ion)



(ii) O_3 (ozone)



or

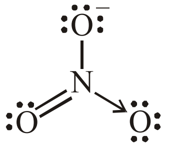


Lewis Dot structures:

- Arrangement of various atoms in a molecule & types of bonding present in it but no idea of geometry of the molecule.
- In most cases we can construct a Lewis structure in three steps :
  1. Decide on the number of electrons that are included in the structure by adding together the number of all the valence electrons provided by the atoms.
  2. Write the chemical symbols of the atoms in the arrangement that shows which atoms are bonded together.
  3. Distribute the electrons in pairs so that there is one pair of electrons forming a single bond between each pair of atom bonded together and then supply electron pairs (to form lone pairs or multiple bonds) until each atom has an octet.
- In oxy acids all 'H' atoms are attached to oxygen as –OH groups except in H_3PO_3(dibasic), H_3PO_2(monobasic) & $H_4P_2O_5$ (dibasic). Which are directly bonded to central atom.

Applications :

- To know various linkages present
- To calculate formal charge of various elements.



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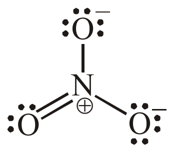
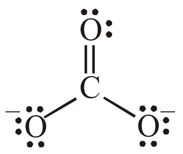
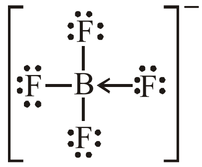


NO_3^-

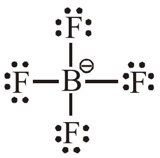


CO_3^{2-}



BF_4^-

or



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.

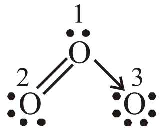
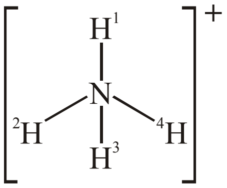
Formal Charge : $Q_F = N_A - N_{L.P.} - \frac{1}{2} N_{B.P.}$

Where :

N_A = Total number of valence electron in the free atom

$N_{L.P.}$ = Total number of non bonding (lone pair) electrons

$N_{B.P.}$ = Total number of bonding(shared) electrons

Molecule	Structure	Formal Charge
O_3		$O(1) = 6 - 2 - \frac{1}{2}(6) = +1$
		$O(2) = 6 - 4 - \frac{1}{2}(4) = 0$
		$O(3) = 6 - 6 - \frac{1}{2}(2) = -1$
CO		$C = 4 - 2 - \frac{1}{2} \times 6 = -1$
		$O = 6 - 2 - \frac{1}{2} \times 6 = +1$
NH_4^+		$N = 5 - 0 - \frac{1}{2}(8) = +1$
		On each $H = 1 - 0 - \frac{1}{2}(2) = 0$

RESONANCE*

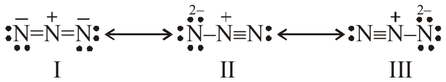
When a molecule cannot be completely represented by a single Lewis structure but it's characteristic properties can be described by two or more different structures, with similar energy position of nuclei, bonding and non-bonding pairs of electrons, then the true structure is said to be resonance hybrid of these structures. The phenomenon is called resonance and different contributing structures are called resonating structures or canonical structures.

- Resonance stabilizes the molecule as the energy of the resonance hybrid is less than the energy of any single canonical structure.
- Resonance averages the bond characteristics as a whole.
- The canonical forms have no real existence.

Resonance Structure of Some Molecules/Ions :

(i) Azide ion, N_3^- :

The azide ion may be represented as -

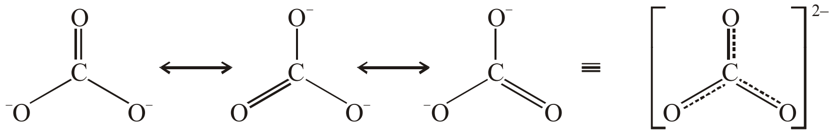


$$\overset{-}{\underset{\cdot\cdot}{:N}}=\overset{+}{\underset{\cdot\cdot}{N}}=\overset{-}{\underset{\cdot\cdot}{N:}} \longleftrightarrow \overset{2-}{\underset{\cdot\cdot}{:\ddot{N}}}-\overset{+}{N}\equiv N: \longleftrightarrow :N\equiv\overset{+}{N}-\overset{2-}{\underset{\cdot\cdot}{\ddot{N}:}}$$

I II III

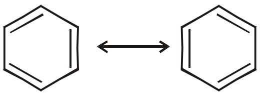
The structures II and III contribute equally and the molecule has almost double bond character in each N–N bond.

(ii)



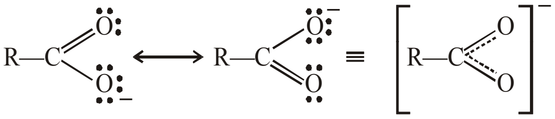
B.O. = 1.33

(iii)



BO = 1.5

(iv)



Bond order = $\frac{2+1}{2}=\frac{3}{2}=1.5$

*Descriptive discussion of concept of resonance will be done in **Organic Chemistry.**

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 :

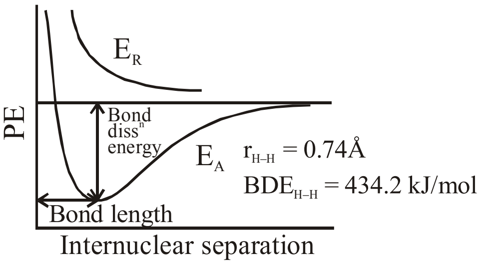
When two 'H'-atoms approaches towards each other for the formation of H_2 molecule. The following interactions takes place.

(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.



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.

At this stage two hydrogen atoms are said to be bonded together to form a stable molecule having the bond length of 74 pm. 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.

$H_2(g) + 434.2 \text{ kJ mol}^- \rightarrow H(g) + H(g)$

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 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 :

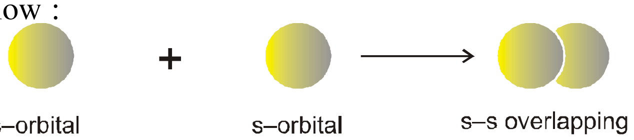
The valence bond theory explains the formation and directional properties of bonds in polyatomic molecules like CH_4, NH_3 and H_2O , etc. in terms of overlap and hybridisation of atomic orbitals.

Types of Overlapping and Nature of Covalent Bonds

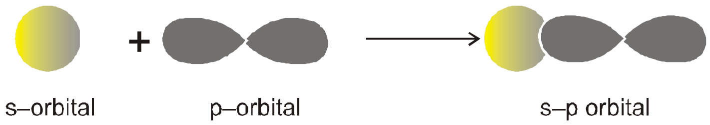
The covalent bond may be classified into following types depending upon the types of overlapping :-
(i) sigma(σ) bond (ii) pi (π) bond (iii) delta(δ) bond

(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 :



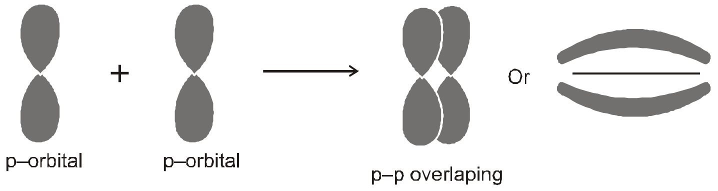
- s-p overlapping: This type of overlap occurs between half filled s-orbital of one atom and half filled p-orbital of another atom.



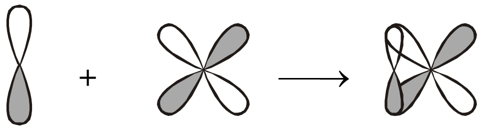
- p-p overlapping : This type of overlap takes place between half filled similar p-orbitals of the two approaching atoms.

(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) p_π–p_π

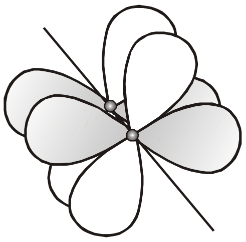


(b) p_π–d_π



p-orbital d-orbital p-d orbital overlaping

(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.



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 explain 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 four 109°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.

HYBRIDISATION

The phenomenon of intermixing of the orbitals of slightly different energies so as to redistribute their energies, resulting in the formation of new set of orbitals of equivalent energies and shape. For example when one 2s and three 2p-orbitals of carbon hybridise, there is the formation of four new sp^3 hybrid orbitals.

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 hybridisation

(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 Hybridisation

There are various types of hybridisation involving s, p and d orbitals. The different types of hybridisation are as under :

(i) *sp hybridisation* (ii) *sp^2 hybridisation* (iii) *sp^3 hybridisation*

(iv) *sp^3d hybridisation:* (v) *sp^3d^2 hybridisation:* (vi) *sp^3d^3 hybridisation:*

Determination of hybridisation state –

To predict hybridisation following formula may be used :

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

Molecule	Method	Hybridisation
NH_4^+	S.N. = 4 + 0 = 4	sp^3 hybridisation.

Number of hybrid orbitals	Hybridisation
two	sp
three	sp^2
four	sp^3
five	sp^3d
six	sp^3d^2
seven	sp^3d^3

Hybridisation in Ionic solid species :

Species	Cationic part	Anionic part
PCl_5	PCl_4^+ (sp^3)	PCl_6^- (sp^3d^2)
PBr_5	PBr_4^+ (sp^3)	Br^-
XeF_6	XeF_5^+ (sp^3d^2)	F^-
N_2O_5	NO_2^+ (sp)	NO_3^- (sp^2)
N_2O_3(s)	NO^+	NO_2^- (sp^2)
N_2O_4(s)	NO^+	NO_3^- (sp^2)
I_2Cl_6 (liquid)	ICl_2^+ (sp^3)	ICl_4^- (sp^3d^2)
I_2(liquid)	I_3^+ (sp^3)	I_3^- (sp^3d)
Cl_2O_6	ClO_2^+ (sp^2)	ClO_4^- (sp^3)

PF_5(s) exist in form of trigonal bipyramidal geometry.

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 localised orbitals. These orbitals arange themselves in so as to minimize the mutual electronic repulsions.

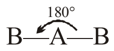
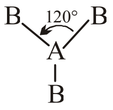
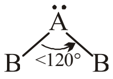
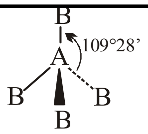
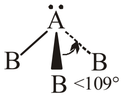
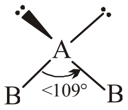
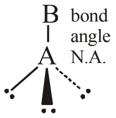
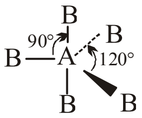
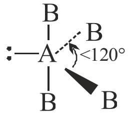
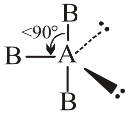
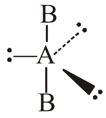
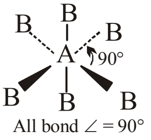
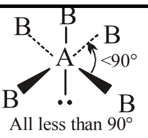
(ii) The magnitude of the different types of electronic repulsions follows the order given below:

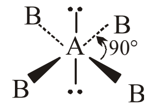
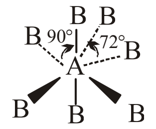
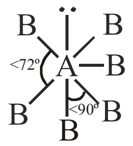
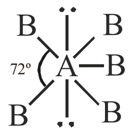
lone pair-lone pair > lone pair - bonded pair > bonded pair - bonded pair

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

(iv) The actual shape of the molecules containing lone pairs is a little distorted from the basic shape as in the NH_3 and H_2O molecules, the bond angles are not 109°28' but 107° and 104.5° respectively due to presence of one lone pair in NH_3 and two lone pairs in H_2O.

SHAPES OF MOLECULES BASED ON VSEPR THEORY

Total no. of hybrid orbitals	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	BCl_3, NO_3^- GaF_3, CO_3^{--}
3	2	1	AB_2	sp^2		V or Bent or angular	$SnCl_2$, O_3,SO_2
4	4	0	AB_4	sp^3		Tetrahedron	CH_4, SiF_4, NH_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	PF_5, SF_5^+, $SbBr_5$, XeO_3F_2
5	4	1	AB_4	sp^3d		Seesaw	SF_4
5	3	2	AB_3	sp^3d		T-shaped	ClF_3, BrF_3
5	2	3	AB_2	sp^3d		Linear	ICl_2^-, XeF_2, I_3^-
6	6	0	AB_6	sp^3d^2		Octahedral or Square bipyramidal	SF_6, IF_6^+
6	5	1	AB_5	sp^3d^2		Square pyramidal	IF_5, $XeOF_4$, BrF_5

6	4	2	AB_4	sp^3d^2		Square planar	IF_4^-, XeF_4, ICl_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^-

BOND PARAMETERS

(I) Bond order *(II) Bond Length (Bond distance)*

(III) Bond Angle *(IV) Bond Enthalpy*

(I) Bond order :

The Bond Order is given by the number of bonds between the two atoms in a molecule.
The bond order, for example in H_2 (with a single shared electron pair), in O_2 (with two shared electron pairs) and in N_2 (with three shared electron pairs) is 1,2,3 respectively.

Note : Isoelectronic molecules and ions have identical bond orders; for example, F_2 and O_2^{2-} have bond order 1. N_2, CO and NO^+ have bond order 3.

Note : A general correlation useful for understanding the stablities of molecules is that: with increase in bond order, bond enthalpy increases and bond length decreases.

(II) Bond Length :-

Bond length is defined as the equilibrium distance between the nuclei of two bonded atoms in a molecule. Bond lengths are measured by spectroscopic, X-ray diffraction and electron-diffraction techniques about which you will learn in higher classes.

Factors affecting bond length

(a) Size of atoms

(b) Effect of bond order or number of bonds

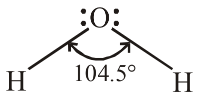
(c) Effect of Resonance

(d) Effect of Electronegativity difference

(e) Effect of Hybridisation

(III) Bond angle :

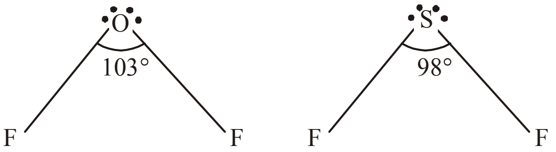
It is defined as the angle between the orbitals containing bonding electron pairs around the central atom in a molecule/complex ion. Bond angle is expressed in degree which can be experimentally determined by spectroscopic methods. For example $H-\hat{O}-H$ bond angle in water can be represented as under :



Comparison of bond angles.

(a) If central atoms are in different hybridisations then it can be compared.

(b) If same hybridisation but different central atoms then bond angle would be more of the molecule in which central atom is more E.N. eg. OF_2 , SF_2



(c) Molecules having same C.A. but different substituent then bond angle increases as the size of attached atom increases except in symmetrical molecules and H_2O / F_2O , NH_3 / NF_3

Factors affecting bond angle

(a) State of Hybridisation

(b) Presence of lone pair

(c) Electronegativity of central atom

(d) Electronegativity of surrounding atom

(e) Size of surrounding atom

(f) Lone pairs may sometimes be transferred from a filled shell of one atom to an unfilled shell of another bonded atom, causing less repulsion.

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

(IV) Bond Enthalpy

It is defined as the amount of energy required to break one mole of bonds of a particular type between two atoms in a gaseous state. The unit of bond enthalpy is kJ mol^{-1}. For example, the H – H bond enthalpy in hydrogen molecule is 435.8 kJ mol^{-1}.

$H_2(g) \longrightarrow H(g) + H(g); \Delta_a H^\ominus = 435.8 \text{ kJ mol}^{-1}$

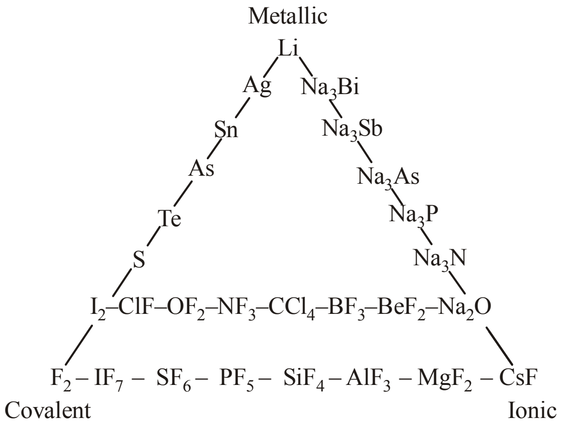
⇒ In polyatomic molecules the **term mean or average bond enthalpy** is used. It is obtained by dividing total bond dissociation enthalpy by the number of bonds broken as explained below in case of water molecule,

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

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

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

SUMMARY OF THE THREE MAIN TYPES OF BONDS



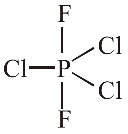
BENT'S RULE

(i) A lone pair of electron prefers to occupy that hybrid orbitals which has greater percentage of s-character.

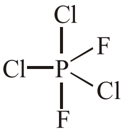
(ii) A more electronegative atom/group prefers to occupy that hybrid orbital which has smaller percentage of s-character.

Ex. Draw the geometry of PCl_3F_2

Sol.



Correct Structure



Wrong Structure

Because highly electronegative atom occupy axial position (axial position has smaller percentage of s-character).

DRAGO'S RULE

On the basis of experimental bond angles of certain molecules fulfilling the following three conditions,

(i) Central atom belongs to third or lower period in periodic table

(ii) Central atom must contain atleast one lone pair of electron, and

(iii) Electronegativity of surrounding atom is $\leqslant 2.5$

Drago generalised that in such molecules justification of experimental bond angle can be made satisfactorily if one considers no hybridisation, i.e., overlapping of almost pure atomic orbitals from central atom.

In such molecules bond angle is approximately 90°.

Group 15	**Bond angle**	**Group 16**	**Bond angle**
NH_3	107°48'	H_2O	104°28'
PH_3	93°36'	H_2S	92°
AsH_3	91°48'	H_2Se	91°
SbH_3	91°18'	H_2Te	90.5°

- Right order of bond angle.

  (a) $H_2O > H_2S > H_2Se > H_2Te$ (b) $NH_3 > PH_3 > AsH_3 > SbH_3$

MOLECULES THAT DO NOT EXIST

(1) SF_4, SF_6 & PF_5 exist while. OF_4, OF_6, NF_5 do not exist

(2) (a) PI_5(vap) & SCl_6 do not exist

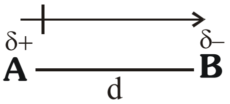
(b) SCl_6 does not exist while $TeCl_6$ exist

(c) PI_5 (Solid) exist

(3) SF_6, PF_5, XeF_6, XeF_4 & XeF_2 exist while SH_6, PH_5, XeH_6, XeH_4, XeH_2 do not exist

DIPOLE MOMENT

- The degree of polarity of covalent bond is given by the dipole moment (μ)
- It is the product of the either charge and the distance between them.



Electronegativity of A < Electronegativity of B

$$\mu = \delta \times d$$

- Dipole moment is a vector quantity.
  The direction of dipole moment is represented by $+\!\!\!\longrightarrow$
- Units = Cm (S.I.) or esu cm(CGS) or Debye (common unit)
- 1 D = 10^{-18} esu cm = 3.33×10^{-30} coulomb m

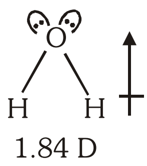
Dipole moment depends on

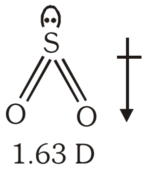
- ✦ Electronegativity difference between bonded atoms
- ✦ Direction of bond dipole moment
- ✦ Angle between various bonds
- ✦ Influence of unshared e^- pairs
- ✦ Magnitude of polarity of the molecule
- ✦ Symmetrical / Unsymmetrical shape.

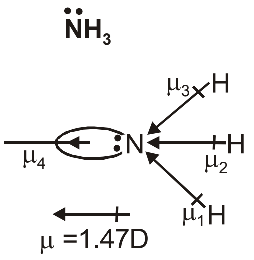
Application of dipole moment

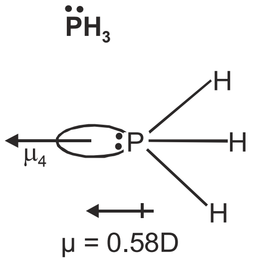
- To determine the polarity and geometry of molecules

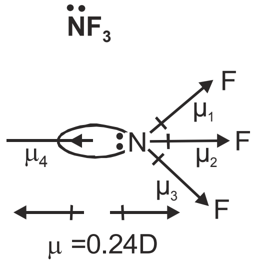
Example :











- To the calculate the percentage of ionic character

$$\%\text{ ionic character} = \frac{\text{observed }\mu}{\text{calculated }\mu\text{ (for 100 \% ionic)}} \times 100\ \%$$

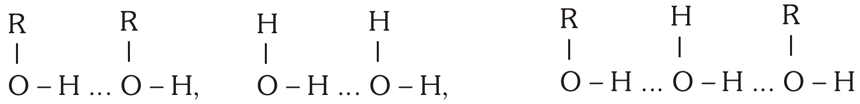
HYDROGEN BONDING

✦ **Hydrogen bonding:** When a hydrogen atom is bonded to a highly electronegative atom (like F, O or N) comes under the influence of another strongly electronegative atom, then a weak electrostatic force of attraction is developed between them, which is called as hydrogen bond.

Types of H-bonding:

✦ Intermolecular H-bond

(i) This type of H-bonding takes place between two moleules. **Ex.** ROH, H_2O, R - OH & H_2O



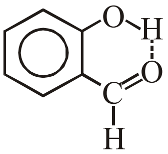
$$\overset{\overset{R}{|}}{O}-H\ldots\overset{\overset{R}{|}}{O}-H,\quad \overset{\overset{H}{|}}{O}-H\ldots\overset{\overset{H}{|}}{O}-H,\quad \overset{\overset{R}{|}}{O}-H\ldots\overset{\overset{H}{|}}{O}-H\ldots\overset{\overset{R}{|}}{O}-H$$

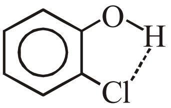
(ii) In such compounds molecular wt., M.P, & B.P. are high.

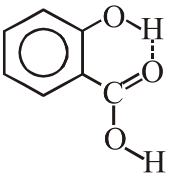
(iii) Extent of Inter molecular H-bonding ↑ viscosity & density ↑.

✦ Intramolecular H-bond

Normally when 2 hydroxyl groups are present on the same carbon atom i.e. gem diols are unstable, but "chloralhydrate" is a stable molecule due to formation of H-bond.







Properties influenced by hydrogen bonding

(a) Abnormal behaviour of water.

(b) Association of molecules eg. dimersiation of CH_3COOH, $HCOOH$

(c) Dissociation of a polar species.

(d) Abnormal melting point & boiling point.

(e) Enhanced solubility in water.

✦ **Metallic bonds :**

Electron gas model or sea model, with metal atom existing as kernels along with less firmly held valence electrons & bonds between various kernels (at the lattice site) & valence electrons are known as metallic bonds.

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 HCl, 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 KHF_2 is possible but not $KHBr_2$ or KHI_2. Why?

Q.11 O – Nitrophenol is less soluble in H_2O 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 CH_4 and H_2O have nearly same molecular weight. Yet CH_4 has a boiling point 112 K and water 373 K. Explain.

Q.15 The experimental molecular weight of acetic acid in just double than theoretical molecular weight of acetic acid. Why?

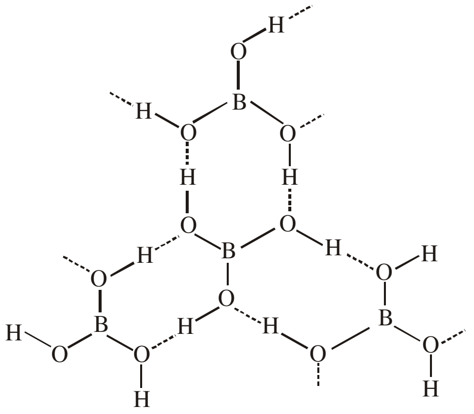
Q.16 Although chlorine has same electronegativity as nitrogen but the former does not form effective H-bonding. Explain.

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

ANSWER OF HYDROGEN BONDING

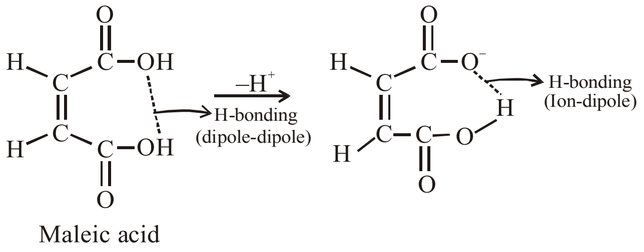
1.

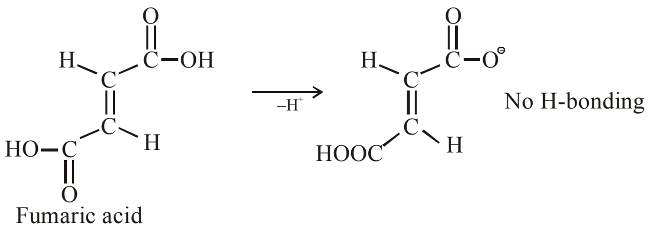


Structure of boric acid; the dotted lines represent hydrogen bonds

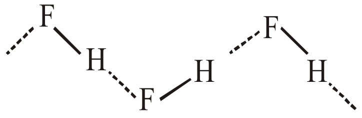
2. Inter molecular H-Bonding in case of para nitro phenol is strong enough to increase boiling point which is not favoured in o-Nitro phenol.

3. Maleic acid anion gets stabilize due to intra molecular H-bonding which is not possible in anion of Fumaric acid. So H^+ releasing tendency is more in case of maleic acid





4. Due to strong H-Bonding in H–F



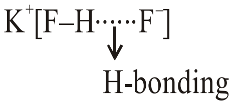
5. Due to H-Bonding in NH_3.

6. Density of ice is higher than that of water due to cage like structure of ice volume of ice increases and density decreases.

7. On heating ice in temperature range 0–4°C H-bonds of ice break down, which decreases volume, hence density of H_2O increases. On heating ice after 4°C thermal vibrations of H_2O molecules increases which increases effective volume of ice, so density of ice again decreases.

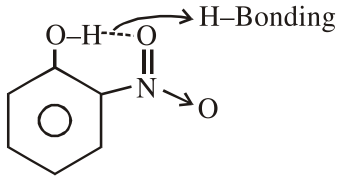
8. H-I bond is weak as compare to H-F so it can be dissociated easily and can give H^+ easily.

9. The organic matter in wood participate in H-bonding with water molecules in ice-cream.

10. 

$K^+[F\text{–}\underset{\text{H-bonding}}{\underset{\downarrow}{H\cdots\cdots}}F^-]$ But $KHBr_2$ & KHI_2 can't form H-Bond.

11. In o-Nitrophenol intra molecular H-bond is present which decreases it's solubility in water.



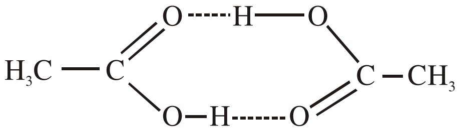
Ortho Nitro-phenol

12. In o-hydroxy benzeldehyde intramolecular H-bond is present which is less stronger than intermolecular H-bond in p-hydroxy benzeldehyde.

13. Extent of H-bonding in glycerol is more as compare to ethanol so it is more viscous.

14. Due to H-bonding in H_2O

15. Due to H-bonding in acetic acid it forms dimer so overall molecular weight is just double of original



Dimer of CH_3COOH

16. Due to bigger size of 'Cl' atom it's interaction is not enough to evolve the aomount of energy which lies in the range of H-bond.

17. $\underset{\text{liquid}}{(AcOH)_n} \xrightarrow{\text{on vapour}} \frac{n}{2}(AcOH)_2$

} Not completely converted

But in $\underset{\text{liquid}}{(H_2O)_n} \xrightarrow{\text{on vapour}} n(H_2O)$

Here all H_2O molecule gets vapourised. So entropy change is more

18. As extent of H-bond is more in H_2O as compare to HF, heat of vaporisation of water is higher than HF.

VANDER WAAL'S FORCES

⇒ These are the weakest type of inter molecular forces that exist among the chemical species which being significant change in physical properties.

⇒ These are non-directional, non-valence cohesive forces. These attractive forces being played between the two molecules are independent of the presence of other molecules.

⇒ Solid, liquid or gaseous states of many molecules are explained on the basis of inter molecular forces other than covalent, ionic or metallic bonds. Although inert gases do not form any type of bond but may exist in liquid and solid states. This shows that the atoms of inert gases are attracted by each other through some type of inter molecular forces. These intermolecular forces are called Vander Waals forces.

Types of Vander Waal's Forces

(1) ***Dipole-dipole interaction (Keesom forces) :*** The force of attraction between the oppositely charged poles of two polar molecules (for example : H_2S, HCl, PH_3 etc.) is called dipole-dipole attraction.

(2) ***Dipole-induced dipole interaction (Debye forces) :*** This type of cohesive forces occurs in a mixture of polar and non polar molecules. The former induce polarity in non polar molecules by disturbing their electron system. for example force of attraction between Cl_2 and H_2O.

(3) ***Instantaneous dipole-Induced dipole interaction (Dispersion forces/London forces) :*** The weak intermolecular forces operating in similar non polar gaseous molecules are called London forces. These forces are very weak in nature and exists only at low temperature. For example weak intermolecular forces in F_2, Cl_2, N_2, molecules and in noble gasses.

(Note :- London forces present in both polar and non polar species)

Other Weak Interactions

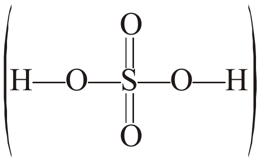
(1) ***Ion-dipole interaction :*** Polar molecules are attracted by ions. The negative pole is attracted by cation and positive pole attracted by the anion. This type of attraction is called ion dipole attraction, ion-dipole attraction is observed generally in the process of solvation when sodium chloride (Na^+ Cl^-) is dissolved in water because negative poles of water aggregate around Na^+ ions and positive poles around Cl^- ions.

(2) ***Ion-induced dipole interaction :*** When non polar molecules come in contact with ions, its electron cloud gets polarised and the oppositely charged end of it is attracted by the ion. For example attraction between I^- and I_2 molecule.

☐ OXY-ACIDS

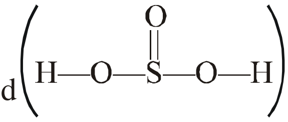
Those compounds which contain X–O–H bond are called oxy-acids. Where X is usually a non-metal. But sometimes X may also be a metal.

H_2SO_4
Sulfuric acid



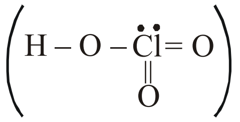
$$\left(\mathrm{H{-}O{-}\overset{O}{\overset{\|}{\underset{\underset{O}{\|}}{S}}}{-}O{-}H}\right)$$

H_2SO_3
Sulphurous acid



$$\left(\mathrm{H{-}O{-}\overset{O}{\overset{\|}{S}}{-}O{-}H}\right)$$

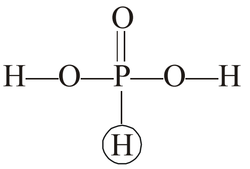
$HClO_3$
Chloric acid



$$\left(\mathrm{H-O-\underset{\underset{O}{\|}}{\ddot{Cl}}=O}\right)$$

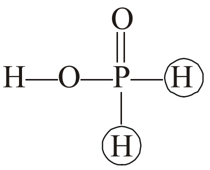
In oxy acids, all the hydrogens are attached with oxygen. Although there are a very few exceptions (as given below), in which all hydrogens are not attached with oxygen.

H_3PO_3
Phosphorus acid



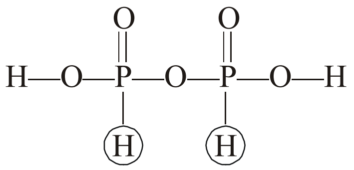
$$\mathrm{H{-}O{-}\overset{O}{\overset{\|}{\underset{\underset{Ⓗ}{|}}{P}}}{-}O{-}H}$$

H_3PO_2
Hypophosphorus acid



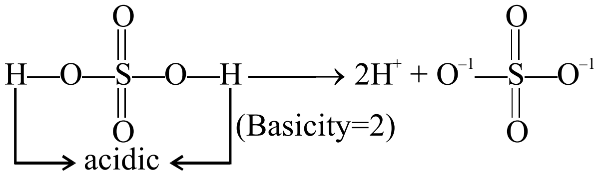
$$\mathrm{H{-}O{-}\overset{O}{\overset{\|}{\underset{\underset{Ⓗ}{|}}{P}}}{-}Ⓗ}$$

$H_4P_2O_5$
Pyrophosphorus acid



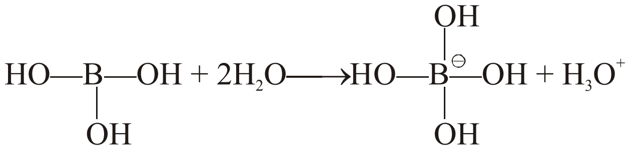
$$\mathrm{H{-}O{-}\overset{O}{\overset{\|}{\underset{\underset{Ⓗ}{|}}{P}}}{-}O{-}\overset{O}{\overset{\|}{\underset{\underset{Ⓗ}{|}}{P}}}{-}O{-}H}$$

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 ionise in solution.



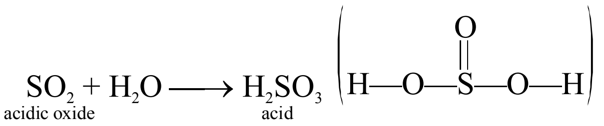
$$\mathrm{H{-}O{-}\overset{O}{\overset{\|}{\underset{\underset{O}{\|}}{S}}}{-}O{-}H} \xrightarrow[\text{(Basicity=2)}]{} 2H^+ + O^{-1}{-}\overset{O}{\overset{\|}{\underset{\underset{O}{\|}}{S}}}{-}O^{-1}$$

No. 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 soluion. In fact, H_3BO_3 when dissolved in water, it behaves as a monobasic acid.*



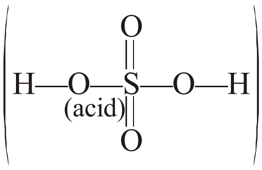
$$\mathrm{HO{-}\underset{\underset{OH}{|}}{B}{-}OH} + 2H_2O \longrightarrow \mathrm{HO{-}\overset{OH}{\overset{|}{\underset{\underset{OH}{|}}{B^{\ominus}}}}{-}OH} + H_3O^+$$

Oxyacids are actually aqueous solutions of acidic oxides.



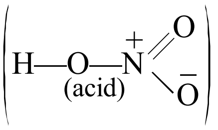
$$\underset{\text{acidic oxide}}{SO_2} + H_2O \longrightarrow \underset{\text{acid}}{H_2SO_3}\left(\mathrm{H{-}O{-}\overset{O}{\overset{\|}{S}}{-}O{-}H}\right)$$

$SO_3 + H_2O \longrightarrow H_2SO_4$
acidic oxide



$$\left(H{-}O{-}\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}{-}O{-}H\right)$$

$N_2O_5 + H_2O \longrightarrow 2HNO_3$
acidic oxide



- Some acids have suffix-ic acid and some has-ous acid. Usually, when the central atom in oxy acid is in higher 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

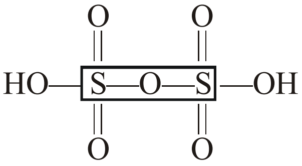
☐ **PYRO ACIDS :**

When one mole of water is removed from two moles of an oxyacid, the resultant oxy acid is known as pyro acid. In general pyro acids contain X—O—X bonds.

Oxy acid (2 moles) $\xrightarrow{-H_2O}$ Oxy acid [Pyro acid]

- H_2SO_4 (2 moles) = $H_4S_2O_8 \xrightarrow{-H_2O} H_2S_2O_7$ [Pyrosulphuric acid]
  [Sulphuric acid]
  In general Pyro acids contain X–O–X bond.

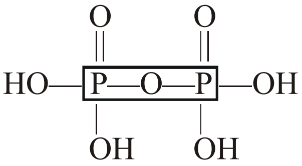
$H_2S_2O_7$



$$HO{-}\boxed{\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}{-}O{-}\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}}{-}OH$$

(S—O—S bond)

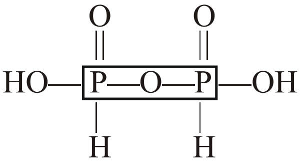
- H_3PO_4 (2 moles) = $H_6P_2O_8 \xrightarrow{-H_2O} H_4P_2O_7$ [Pyrophosphoric acid]
  [Orthophosphoric acid]



$$HO{-}\boxed{\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}{-}O{-}\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}}{-}OH$$

(P—O—P bond)

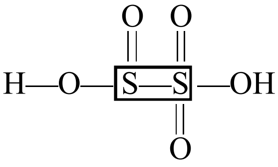
- $2H_3PO_3$ (phosphorus acid) $\xrightarrow[-H_2O]{}$ $H_4P_2O_5$ (pyrophosphorus acid)



$$HO{-}\boxed{\overset{\overset{O}{\|}}{\underset{\underset{H}{|}}{P}}{-}O{-}\overset{\overset{O}{\|}}{\underset{\underset{H}{|}}{P}}}{-}OH$$

- $2H_2SO_3 \xrightarrow{-H_2O} H_2S_2O_5$(Pyrosulfurous acid)

Exception : $H_2S_2O_5$ [Pyrosulfurous acid] does not contain S–O–S linkage.



$$H{-}O{-}\boxed{\overset{\overset{O}{\|}}{S}{-}\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}}{-}OH$$

Pyrosulfurous acid

❑ HYPO ACID :

Hypo prefix is added to those oxy acids which is obtained when one oxygen atom is removed from ous form of (usually) acids.

Oxy acid(-ous form) $\xrightarrow{-\text{O}}$ Oxy acid (Hypo -ous acid)

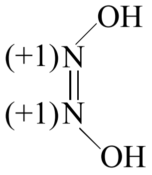
- H_3PO_3 [Phosphorous acid] – O $\longrightarrow$ H_3PO_2 [Hypophosphorous acid] monobasic acid

- $\underset{\substack{\text{Halousacid}\\(x=\text{Cl,Br,I})}}{\overset{+3}{HXO_2}} -[O] \longrightarrow \underset{\text{Hypohalous acid}}{\overset{+1}{HOX}}$

HOCl - Hypochlorous acid
HOBr - Hypobromous acid
HOI - Hypoiodous acid

- $\underset{\text{Nitrous acid}}{\overset{+3}{HNO_2}} -[O] \longrightarrow \overset{+1}{HNO}$

HNO exist in dimeric from i.e. as $(HNO)_2 = H_2N_2O_2$

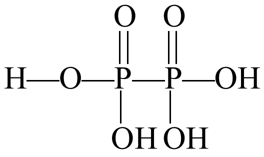


Hyponitrous acid

If one O is removed from pyro 'ic' acid it produce hypo 'ic' acid

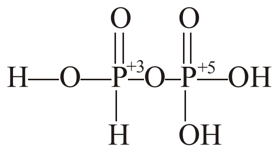
$\underset{\text{Pyrosulphuric acid}}{H_2S_2O_7} \xrightarrow{-\text{"O"}} \underset{\text{Hyposulphuric acid}}{H_2S_2O_6}$

$\underset{\text{Pyrophosphoricacid}}{H_4\overset{(+5)}{P_2}O_7} \xrightarrow{\text{"}-\text{O"}} \underset{\text{Hypophosphoricacid}}{H_4\overset{(+4)}{P_2}O_6}$



$$H-O-\underset{OH}{\overset{O}{\overset{\|}{\underset{|}{P}}}}-\underset{OH}{\overset{O}{\overset{\|}{\underset{|}{P}}}}-OH$$

Exception : ***(It may be exist as isohypophosphoric acid)***



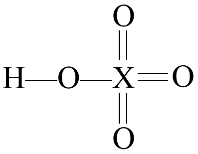
$$H-O-\underset{H}{\overset{O}{\overset{\|}{\underset{|}{\overset{+3}{P}}}}}-O-\underset{OH}{\overset{O}{\overset{\|}{\underset{|}{\overset{+5}{P}}}}}-OH$$

Isohypophosphoric acid

❑ PER ACID AND PEROXY ACID :

When one oxygen in 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.

- $\underset{\substack{(X=\text{Cl,Br,I})\\\text{Halic acid}}}{\overset{(+5)}{HXO_3}}+ O \longrightarrow \underset{\text{Perhalic acid}}{\overset{(+7)}{HXO_4}}$

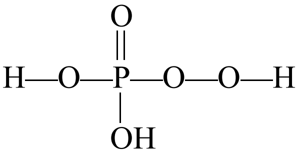


$$H-O-\underset{O}{\overset{O}{\overset{\|}{\underset{\|}{X}}}}=O$$

$HClO_4$ perchloric acid $HBrO_4$ - Perbromic acid.

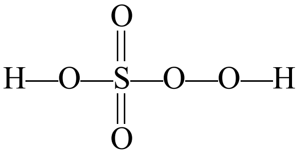
Peroxy prefix is added to those oxy acids which are obtained when one oxygen is added to –ic from of acid and the oxidation number of central atom remains the same. Peroxy acids contain peroxy linkage (—O—O—).

- $\overset{+5}{H_3PO_4} + O \longrightarrow \overset{+5}{H_3PO_5}$
  Orthophosphoric acid → Peroxyphosphoric acid



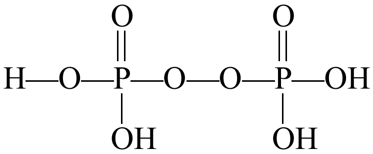
$H-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-O-O-H$

- $\overset{+6}{H_2SO_4} + O \longrightarrow \overset{+6}{H_2SO_5}$
  Peroxysulfuric acid (caro's acid)



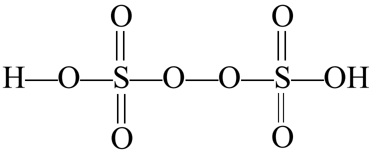
$H-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-O-H$

- $\overset{+5}{H_4P_2O_7} + O \longrightarrow \overset{+5}{H_4P_2O_8}$
  diphosphoric acid pyrophosphoric acid → Peroxy diphosphoric acid



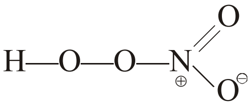
$H-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-O-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-OH$

- $\overset{+6}{H_2S_2O_7} + O \longrightarrow \overset{+6}{H_2S_2O_8}$
  Pyrosulphuric acid disulphuric acid → Peroxydisulphuric acid (Marshall acid)



$H-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-OH$

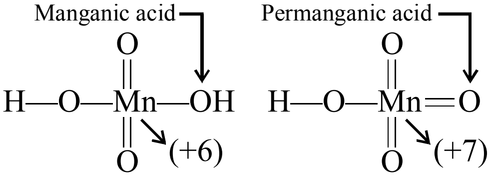
- $\overset{+5}{HNO_3} + O \longrightarrow \overset{+5}{HNO_4}$
  (nitric acid) → (peroxy nitric acid)



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

Exception : $\overset{+6}{H_2MnO_4}$ is manganic acid when one hydrogen is removed from H_2MnO_4, $HMnO_4$ is formed which is named as permanganic acid.

$\overset{(+6)}{H_2MnO_4}-H \longrightarrow \overset{(+7)}{HMnO_4}$



❑ 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 X–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.

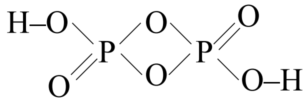
$$\underset{(ortho)}{\text{Oxy acid(1 mol)}} \xrightarrow{-H_2O} \underset{meta}{\text{Oxy acid}}$$

- $\underset{(ortho - phosphoric\ acid)}{H_3PO_4} \xrightarrow{-H_2O} HPO_3$ Meta phosphoric acid *(It forms Cyclic polymetaphosphoric acids)*

◆ **Cyclic polymetaphosphoric acids :**

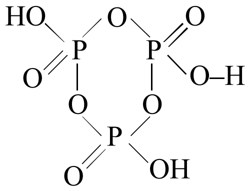
$(HPO_3)_2$ - Dimetaphosphorsphoric acid

$(H_2P_2O_6)$



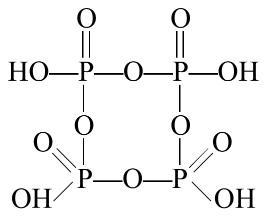
(expected)

$(HPO_3)_3$

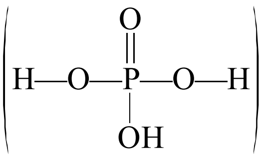


Trimetaphosphoric acid

$(HPO_3)_4$



Tetrametaphosphoric acid



$$\left(H-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-O-H\right)$$

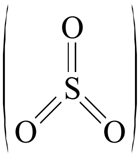
Orthophosphoric acid

An ortho acid must contain at least three hydrogens.

- $H_3BO_3 \xrightarrow[-H_2O]{} HBO_2$

  Ortho-boric acid   Meta boric acid

- H_2SO_4(~~ortho~~ -sulphuric acid) $\xrightarrow{-H_2O}$ SO_3 sulfur trioxide(anhydride of H_2SO_4)

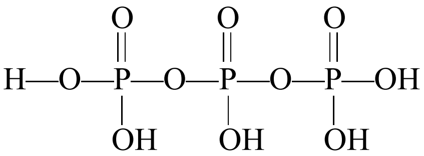


As SO_3 does not contain any hydrogen (i.e., X–OH/S–OH bond), so SO_3 is not an oxy acid rather it is anhydride of sulphuric acid (H_2SO_4) so, H_2SO_4 can't be prefixed with ortho, and its name does not contain any prefix and it is named as sulphuric acid.

❑ POLYPHOSPHORIC ACID :

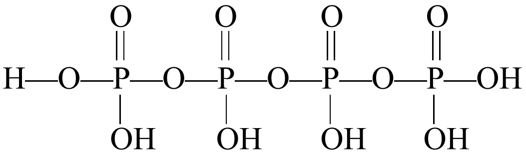
Oxy acids having general formula $H_{(n+2)}P_nO_{(3n+1)}$ are known as polyphosphoric acids. These contain (n–1) P–O–P bonds.

$H_5P_3O_{10}$ - Tripolyphosphoric acid



$$H-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-OH$$

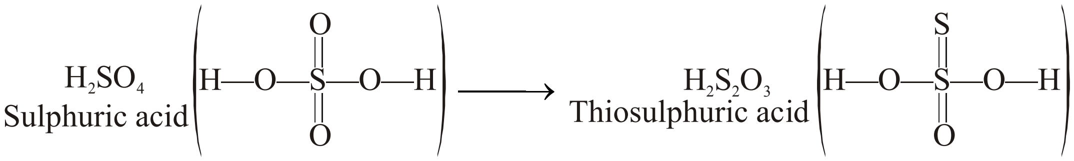
$H_6P_4O_{13}$ - Tetrapolyphosphoric acid



$$H-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-O-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-OH$$

❑ THIO ACID :

- **1.** Oxy acids in which one oxygen atom are replaced by sulphur are considered as thio acid. For example :-



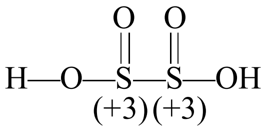
$$H_2SO_4 \text{ Sulphuric acid} \left(H—O—\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}—O—H \right) \longrightarrow H_2S_2O_3 \text{ Thiosulphuric acid} \left(H—O—\overset{\overset{S}{\|}}{\underset{\underset{O}{\|}}{S}}—O—H \right)$$

HOCN $\longrightarrow$ HSCN

Cyanic acid — Thiocyanic acid (Hydrothionic acid)

- **2.** Oxy acids of sulphur containing S—S bonds are known as thio acids.

$H_2S_2O_4$

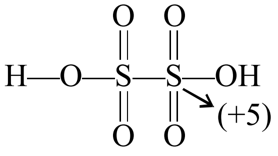


$$H—O—\overset{\overset{O}{\|}}{\underset{(+3)}{S}}—\overset{\overset{O}{\|}}{\underset{(+3)}{S}}—OH$$

dithionous acid.

Thionic acids : Oxy acids of sulphur containing S—S bond and having general formula $H_2S_{(n+2)}O_6$ are known as thionic acids

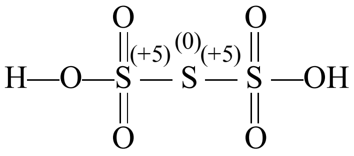
$H_2S_2O_6$ –



$$H—O—\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}—\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}—OH \;(+5)$$

Dithionic acid (hyposulphuric acid)

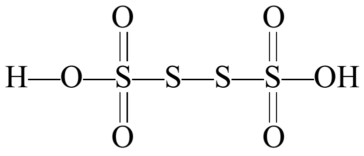
$H_2S_3O_6$ –



$$H—O—\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{\overset{(+5)}{S}}} — \overset{(0)}{S} — \overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{\overset{(+5)}{S}}} —OH$$

Trithionic acid

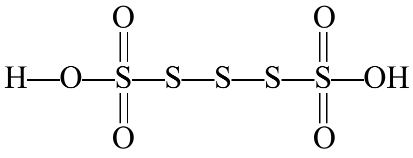
$H_2S_4O_6$ –



$$H—O—\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}—S—S—\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}—OH$$

Tetrathionic acid

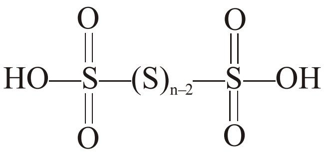
$H_2S_5O_6$ –



$$H—O—\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}—S—S—S—\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}—OH$$

Pentathionic acid

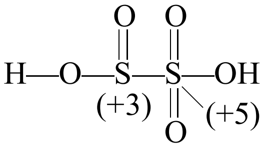
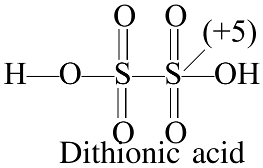
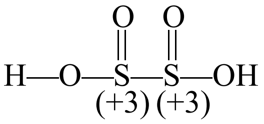
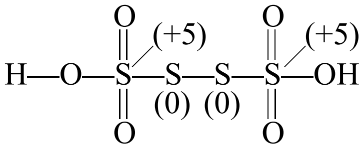
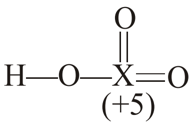
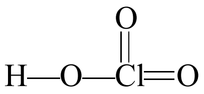
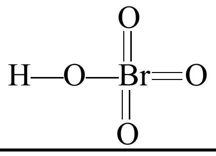
$H_2S_{(n)}O_6$ –



$$HO—\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}—(S)_{n-2}—\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}—OH$$

Polythionic acid

☐ TABLE OF OXIDATION STATE OF OXY-ACIDS :

Element	–Ous acid	–ic acid
P	**(+3**, H_3PO_3, $H_4P_2O_5$) **(+2**, H_3PO_2)	**(+4)** $H_4P_2O_6$ (Hypophosphoric acid) $+5 \rightarrow H_{n+2}P_nO_{3n+1}$ - polyphosphoric acid $+5 \rightarrow H_3PO_4$, $H_4P_2O_7$, $H_4P_2O_8$ $+5 \rightarrow H_3PO_5$ - peroxymonophosphoric acid
S	**(+4)** H_2SO_3 Sulfurous acid  $H{-}O{-}\underset{(+3)}{\overset{\overset{O}{\Vert}}{S}}{-}\underset{\underset{O}{\Vert}}{\overset{\overset{O}{\Vert}}{S}}{-}OH\ (+5)$ Pyrosulfurous acid	**(+6)** Sulphuric acid (H_2SO_4) $H_2S_2O_7$ - Pyrosulphuric acid $H_2S_{(n+2)}O_6$- Thionic acids e.g :  $H{-}O{-}\underset{\underset{O}{\Vert}}{\overset{\overset{O}{\Vert}}{S}}{-}\underset{\underset{O}{\Vert}}{\overset{\overset{O}{\Vert}}{S}}{-}OH\ (+5)$ Dithionic acid
	$H_2S_2O_4$  $H{-}O{-}\underset{(+3)}{\overset{\overset{O}{\Vert}}{S}}{-}\underset{(+3)}{\overset{\overset{O}{\Vert}}{S}}{-}OH$ dithionous acid	 $H{-}O{-}\underset{\underset{O}{\Vert}}{\overset{\overset{O}{\Vert}}{S}}{-}\underset{(0)}{S}{-}\underset{(0)}{S}{-}\underset{\underset{O}{\Vert}}{\overset{\overset{O}{\Vert}}{S}}{-}OH$ (+5) (+5) Tetrathionic acid $\overset{(+6)}{H_2SO_5}$- Peroxymonosulfuric acid $\overset{(+6)}{H_2S_2O_8}$- Peroxydisulfuric acid
X (X=Cl,Br,I)	**(+1)** H–O–X Hypohalous acid e.g. H–O–Cl - Hypochlorous acid H–O–I - Hypoiodous acid **(+3)** HXO_2 ; H–O–X=O Halous acid H–O–I=O - Iodous acid	**(+5)** Halic acid (HXO_3)  $H{-}O{-}\underset{(+5)}{\overset{\overset{O}{\Vert}}{X}}{=}O$  $H{-}O{-}\overset{\overset{O}{\Vert}}{Cl}{=}O$ [Chloric acid] **(+7)** Perhalic acid (HXO_4) e.g.  $H{-}O{-}\underset{\underset{O}{\Vert}}{\overset{\overset{O}{\Vert}}{Br}}{=}O$ [Perbromic acid]
Others		(+3) H_3BO_3 Orthoboric acid (+3) HBO_2 - Metaboric acid (+4) Orthosilicic acid H_4SiO_4 H_2SiO_3 - Metasilicic acid $H_6Si_2O_7$ - Pyrosilicic acid

- **Naming of salts of oxy acids : The name of salt ends with – "ate" if the name of the oxy acid ends with - ic acid and all prefix remain same eg. :-**

H_2SO_4	Na_2SO_4 - Sodium sulfate
Sulphuric acid	K_2SO_4 - Potassium sulfate
	$BaSO_4$ - Barium sulfate
	$FeSO_4$ - Ferrous sulfate
	$Al_2(SO_4)_3$ - Aluminium sulfate
H_3PO_4	Na_3PO_4 - Sodium orthophosphate
Orthophosphoric acid	K_3PO_4 - Potassium orthophosphate
	$Ca_3(PO_4)_2$ - Calcium Orthophosphate
	$AlPO_4$ - Aluminium orthophosphate
HPO_3	$NaPO_3$ - Sodium metaphosphate
meta phosphoric acid	KPO_3 - Potassium metaphosphate
	$Ca(PO_3)_2$ - Calcium metaphosphate
	$Al(PO_3)_3$ - Aluminium metaphosphate
$HClO_3$	$KClO_3$ - Potassium chlorate
chloric acid	$NaClO_3$ - Sodium chlorate
	$Ca(ClO_3)_2$ - Calcium chlorate
$HClO_4$	$NaClO_4$ - Sodium perchlorate
Perchloric acid	$KClO_4$- Potassium perchorate
	NH_4ClO_4- Ammonium perchlorate
	$Ca(ClO_4)_2$ - Calcium perchlorate
H_3PO_4	KH_2PO_4 potassium dihydrogen orthophosphate
Orthophosphoric acid	$Ca(H_2PO_4)_2$ calcium dihydrogen orthophosphate
$(HPO_3)_6 = H_6P_6O_{18}$	$Na_6P_6O_{18}$
Hexametaphosphoric acid	Sodium hexametaphosphate
HBO_2	$NaBO_2$ sodium metaborate
metaboric acid	
H_2SO_5	Na_2SO_5. Sodium peroxysulfate
Peroxysulphuric acid	
$H_4P_2O_7$	$Na_4P_2O_7$ - Sodium pyrophosphate
Pyrophosphoric acid	

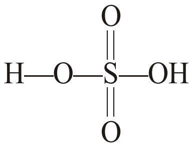
If the name of the oxy acid ends with ous acid then the name of the salt ends with "ite"

$HClO_2$	$NaC1O_2$ sodium chlorite
chlorous acid	$KCIO_2$ potassium chlorite
	$Ca(ClO_2)_2$ calcium chlorite
H_3PO_3	Na_2HPO_3 sodium phosphite
Phosphorous acid	K_2HPO_3 Potassium phosphite
(dibasic acid)	$CaHPO_3$ calcium phosphite
H_2SO_3	Na_2SO_3 sodium sulfite
sulfurous acid	K_2SO_3 potassium sulfite
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 Hypophosphorous acid (monobasic acid)	NaH_2PO_2 sodium hypophosphite $Ba(H_2PO_2)_2$ Barium hypophosphite

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 (H attached with oxygen)

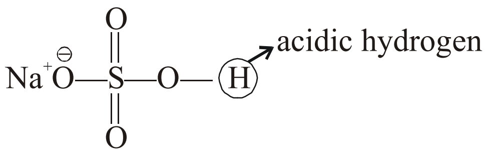
Ex.1



$$H-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-OH$$

Sulphuric acid

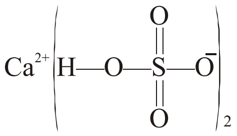
$NaHSO_4$



$$Na^{+}\overset{\ominus}{O}-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-Ⓗ$$

Sodium hydrogen sulphate

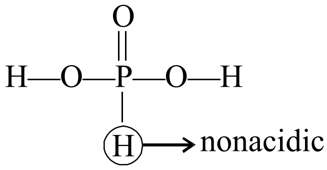
Ex.2 $Ca(HSO_4)_2$ calcium hydrogensulphate



$$Ca^{2+}\left(H-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-\bar{O}\right)_2$$

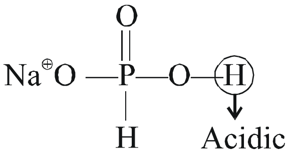
Ex.3 H_3PO_3

Phosphorous acid



$$H-O-\overset{\overset{O}{\|}}{\underset{\underset{Ⓗ}{|}}{P}}-O-H$$

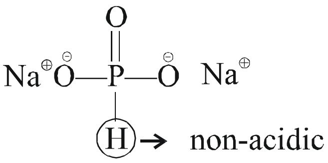
NaH_2PO_3



$$Na^{\oplus}O-\overset{\overset{O}{\|}}{\underset{\underset{H}{|}}{P}}-O-Ⓗ$$

sodium hydrogen phosphite

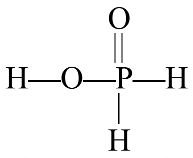
Na_2HPO_3



$$Na^{\oplus}\overset{\ominus}{O}-\overset{\overset{O}{\|}}{\underset{\underset{Ⓗ}{|}}{P}}-\overset{\ominus}{O}\ Na^{\oplus}$$

sodium phosphite

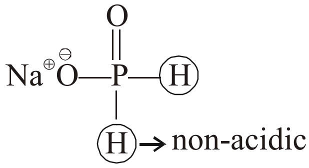
Ex.4 H_3PO_2



$$H-O-\overset{\overset{O}{\|}}{\underset{\underset{H}{|}}{P}}-H$$

Hypophosphorous acid
(monobasic)

NaH_2PO_2



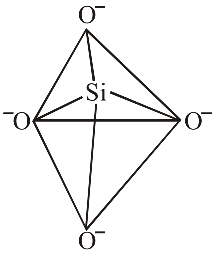
$$Na^{\oplus}\overset{\ominus}{O}-\overset{\overset{O}{\|}}{\underset{\underset{Ⓗ}{|}}{P}}-Ⓗ$$

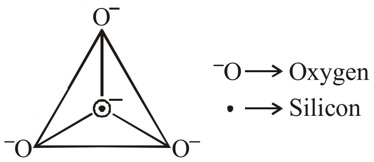
sodium hypophosphite but not sodium dihydrogen phosphite as H is not acidic.

SILICATES

Silicates are metal derivatives of silicic acid, H_4SiO_4 or $Si(OH)_4$. Silicates are formed by heating metal oxide or metal carbonates with sand, e.g.,

$$Na_2CO_3 \xrightarrow[SiO_2]{\text{Fused with sand}} Na_4SiO_4,\ Na_2(SiO_3)_n,\ \text{etc.}$$





Plane projection of silicate ion

Silicates have basic unit of SiO_4^{4-}, each silicon atom is bonded with four oxide ions tetrahedrally. There are following types of silicates

Silicates	**Sharing of O-atom / Basic Tetrahedral unit**	**Contribution of O-atom/Basic Tetrahedral unit**	**General formula**
Ortho	0	4	SiO_4^{4-}
Pyro	1	3.5	$Si_2O_7^{-6}$
Cyclic	2	3	$(SiO_3)_n^{2n-}$
Simple chain (pyroxene)	2	3	$(SiO_3)_n^{2n-}$
Double chain (Amphibole)	(3, 2) av = 2.5	$\frac{11}{4} = \left(\frac{5.5}{2}\right)$	$(Si_4O_{11})_n^{6n-}$
2D or (Sheet)	3	2.5	$(Si_2O_5)_n^{2n-}$
3D	4	2	$(SiO_2)_n$

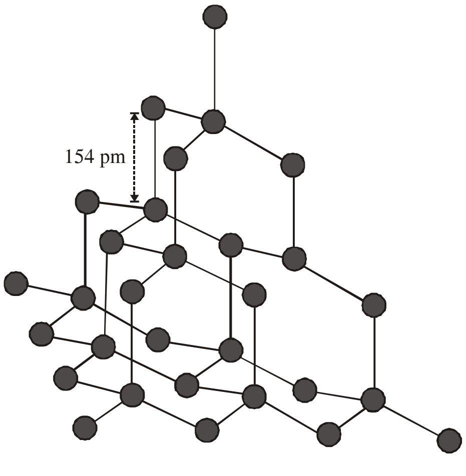
ALLOTROPES OF CARBON FAMILY

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

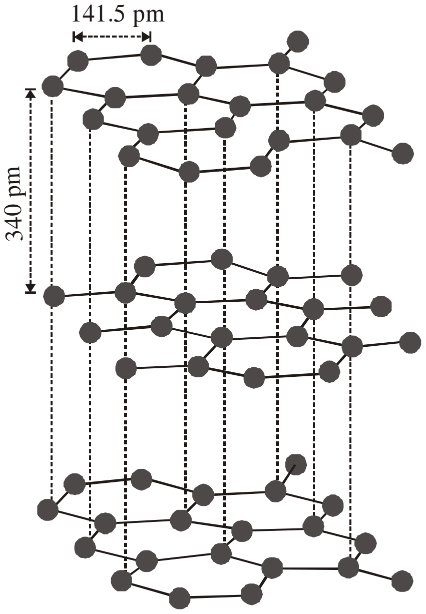
- It has a **crystalline lattice**. A rigid three dimensional network of carbon atoms.
- Each carbon atom undergoes **sp^3 hybridisation** and linked to four other carbon atoms by using hybridised orbitals in tetrahedral fashion.
- **C–C bond length is 154 pm**.
- It is very difficult to break **extended covalent bonding** and, therefore, diamond is a **very hard** substance.

Uses :-

- Used as an abrasive for sharpening hard tools, in making dyes and in the manufacture of tungsten filaments for electric light bulbs.
- Diamond is a precious stone and used in jewellery. It is measured in **carats** (1 carat = 200 mg).



The structure of diamond



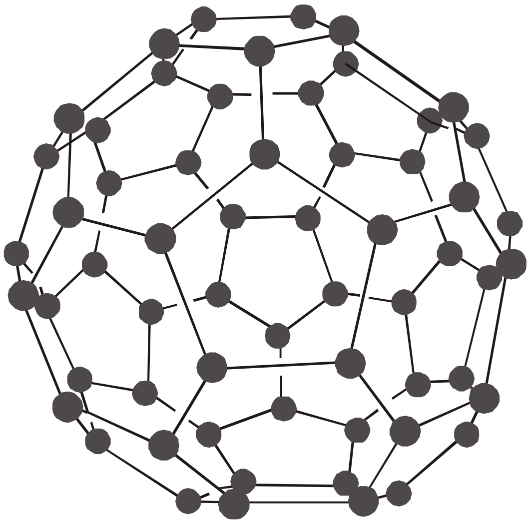
The structure of graphite

⇒ **Graphite** ***(Thermodynamically most stable allotrope of carbon)***

- Layered structure. **Layers are held by van der Waals forces** and distance between two **layers is 340 pm.**
- Each layer is composed of **planar hexagonal rings of** carbon atoms. C—C bond length within the **layer is 141.5 pm.**
- 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.
- **Uses :-** Due to slippery nature graphite is used as **a dry lubricant** in machines running at high temperature, where oil cannot be used as a lubricant.
- **Being good conductor, graphite is used for electrodes in batteries and industrial electrolysis.**

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 C_n 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 are cage like molecules.**
- **Fullerene C_{60} :-** molecule has **a shape like soccer ball** and **called Buckminsterfullerene**. **It contains 20, six- membered rings and 12, five membered rings.**
- 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 143.5 pm and 138.3 pm respectively. **Spherical fullerenes are also called *bucky balls* in short.**
- 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 delocalised 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.



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

IMPORTANT POINTS FOR CARBON

- **Thermodynamic stability order :** Graphite > Diamond > Fullerene C_{60}
- **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.
- **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 contaminators 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.

ALLOTROPES OF OXYGEN FAMILY

- ***Oxygen***

  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 :

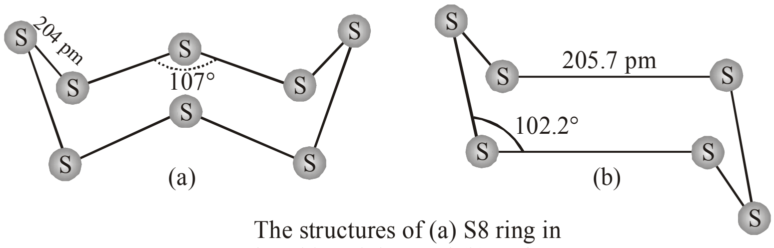
- Sulphur forms numerous allotropes of which the **yellow rhombic** (α-sulphur) and **monoclinic** (β -sulphur) forms are the most important.
- The **stable form** at room temperature is **rhombic sulphur**, which transforms to monoclinic sulphur when heated above 369 K.

⇒ **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) S8 ring in rhombic sulphur and (b) S_6 form

EXTRA POINTS

- Several other modifications of sulphur containing 6-20 sulphur atoms per ring have been synthesised 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.
- **Engel's sulphur** (ε-sulphur) is unstable and contains S_6 rings arranged in the chair conformation. It is made by pouring $Na_2S_2O_3$ solution into concentrated HCl and extracting the S with toluene.
- Plastic sulphur-(χ) is obtained by pouring liquid sulphur into water.

Allotropes 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.

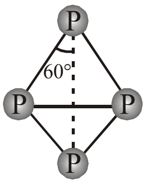
PHOSPHORUS ALLOTROPIC FORMS

Phosphorus is found in many allotropic forms, the important ones being white, red and black.

⇒ ***White phosphorus***

- 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.

$$P_4 + 3NaOH + 3H_2O \longrightarrow PH_3 + \underset{\text{(Sodium hypophosphite)}}{3NaH_2PO_2}$$



Discrete tetrahedral P_4 unit of White Phosphorus

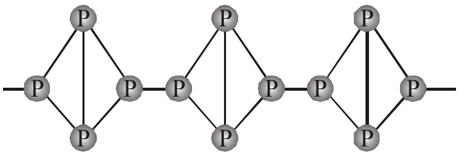
- White phosphorus is **less stable** and therefore, **more reactive** than the other solid phases under normal conditions **because of angular strain** in the P_4 molecule where the angles are only 60°. It readily catches fire in air to give dense white fumes of P_4O_{10}.

$$P_4 + 5O_2 \rightarrow P_4O_{10}$$

⇒ **Red phosphorus**

- Obtained by heating white phosphorus at 573K 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.**

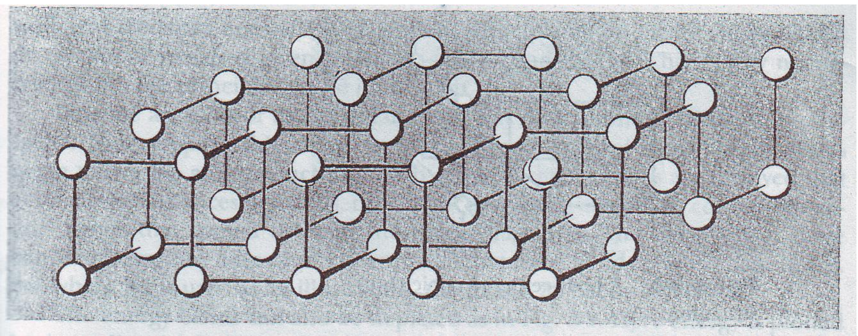
It is polymeric, consisting of chains of P_4 tetrahedra linked together in the manner as shown in Fig.



Red Phosphorus

⇒ **Black phosphorus**

- Two forms α-black phosphorus and β-black phosphorus.
- α-Black phosphorus is formed when red phosphorus is heated in a sealed tube at 803K. It can be sublimed in air and has opaque monoclinic or rhombohedral crystals. It does not oxidise 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

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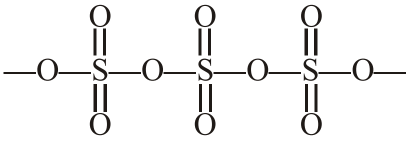
ALLOTROPIC FORM OF SO_3

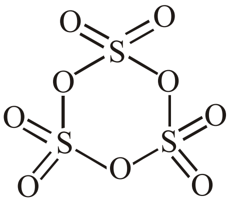
SO_3 have three allotropic forms α-SO_3 , β-SO_3 and γ-SO_3

α-SO_3
Cross linked solid ,



$$-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-$$

Polymeric chain structure
β-SO_3 ,



γ-SO_3
(S_3O_9)
cylic trimer

NOTE:- 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.

$$\underset{\substack{\text{grey tin}\\\text{(Diamond structure)}}}{\alpha-Sn} \overset{13.2°C}{\rightleftharpoons} \underset{\substack{\text{white tin}\\\text{(metallic)}}}{\beta-Sn}$$

EXERCISE # O–1

IONIC BOND

(Only one option is correct)

1. The compound which contains ionic as well as covalent bonds is

(A) $C_2H_4Cl_2$ (B) CH_3I (C) KCN (D) H_2O_2

CBO0001

2. A bond formed between two like atoms cannot be

(A) ionic (B) covalent (C) coordinate (D) metallic

CBO0002

3. An ionic bond A^+B^- is most likely to be formed when :

(A) the ionization energy of *A* is high and the electron gain enthalpy of *B* is low

(B) the ionization energy of *A* is low and the electron gain enthalpy of *B* is high

(C) the ionization energy of *A* and the electron gain enthalpy of *B* both are high

(D) the ionization energy of *A* and the electron gain enthalpy of *B* both are low

CBO0003

COVALENT BOND , CO-ORDINATE BOND & LEWIS STRUCTURE

4. Which of the following species are hypervalent?

(1) PCl_5, (2) BF_3, (3) XeF_2 , (4) CO_3^{2-}

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

CBO0004

5. The types of bond present in $N_2O_{5(g)}$ are

(A) only covalent (B) only ionic (C) ionic and covalent (D) covalent & coordinate

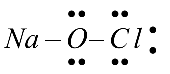
CBO0005

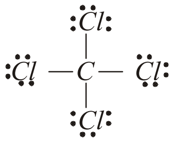
6. Which of the following molecule does not have coordinate bonds?

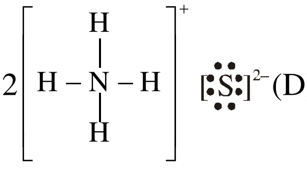
(A) CH_3–NC (B) CO (C) O_3 (D) CO_3^{2-}

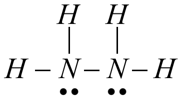
CBO0006

7. Which of the following Lewis dot diagrams is(are) incorrect ?

(A)


(B)


(C)


(D)


CBO0007

V.B.T., HYBRIDISATION & VSEPR THEORY

8. Which of the following has a geometry different from the other three species (having the same geometry)?

(A) BF_4^- (B) SO_4^{2-} (C) XeF_4 (D) PH_4^+

CBO0008

9. Maximum bond energy is in :

(A) F_2 (B) N_2 (C) O_2 (D) equal

CBO0009

10. The hybridisation and shape of BrF_3 molecule are :

(A) sp^3d and bent *T* shape (B) sp^2d^2 and tetragonal

(C) sp^3d and bent (D) none of these

CBO0010

11. The shape of methyl cation (CH_3^+) is likely to be:

(A) linear (B) pyramidal (C) planar (D) spherical

CBO0011

12. The structure of XeF_2 involves hybridization of the type :

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

CBO0012

13. Which of the following has been arranged in increasing order of length of the hybrid orbitals ?

(A) $sp < sp^2 < sp^3$ (B) $sp^3 < sp^2 < sp$ (C) $sp^2 < sp^3 < sp$ (D) $sp^2 < sp < sp^3$

CBO0013

14. In the context of carbon, which of the following is arranged in the correct order of electronegativity :

(A) $sp > sp^2 > sp^3$ (B) $sp^3 > sp^2 > sp$ (C) $sp^2 > sp > sp^3$ (D) $sp^3 < sp < sp^2$

CBO0014

15. When 2s–2s, 2p–2p and 2p–2s orbitals overlap, the bond strength decreases in the order :

(A) $p - p > s - s > p - s$ (B) $p - p > p - s > s - s$

(C) $s - s > p - p > p - s$ (D) $s - s > p - s > p - p$

CBO0015

16. Carbon atoms in $C_2(CN)_4$ are :

(A) *sp*-hybridized (B) sp^2-hybridized

(C) *sp*- and sp^2 hybridized (D) *sp*, sp^2 and sp^3- hybridized

CBO0016

17. The structure of XeF_6 in vapour phase is

(A) pentagonal bipyramidal (B) trigonal bipyramidal

(C) capped octahedron (D) square bipyramidal

CBO0017

BENT'S RULE AND DRAGO'S RULE

18. C–H bond distance is the longest in:

(A) C_2H_2 (B) C_2H_4 (C) C_2H_6 (D) $C_2H_2Br_2$

CBO0018

19. The bond angle and hybridization in ether (CH_3OCH_3) is :

(A) 106°51', sp^3 (B) 104°31', sp^3 (C) 110°, sp^3 (D) 109°28', sp^3

CBO0019

20. Which of the following has been arranged in order of decreasing bond length ?

(A) P–O > Cl–O > S–O (B) P–O > S–O > Cl–O

(C) S–O > Cl–O > P–O (D) Cl–O > S–O > P–O

CBO0020

21. Select the **CORRECT** set of statements :
As the s-character of a hybrid orbital decreases
(I) The bond angle decreases (II) The bond strength increases
(III) The bond length increases (IV) Size of orbital increases
(A) (I), (III) and (IV) (B) (II), (III) and (IV) (C) (I) and (II) (D) All are **CORRECT**

CBO0021

22. Among the following, the **CORRECT** statement is :
(A) Between NH_3 and PH_3, NH_3 is a better electron donor because the lone pair of electrons occupies spherical 's' orbital and is less directional
(B) Between NH_3 and PH_3, PH_3 is a better electron donor because the lone pair of electrons occupies sp^3orbital and is more directional
(C) Between NH_3 and PH_3, NH_3 is a better electron donor because the lone pair of electrons occupies sp^3 orbital and is more directional
(D) Between NH_3 and PH_3, PH_3 is a better electron donor because the lone pair of electrons occupies spherical 's' orbital and is less directional

CBO0022

23. In which of the following molecule C—C bond length will be highest ?
(A) $CF_3 - CF_3$ (B) $F_2CH - CHF_2$ (C) $FCH_2 - CH_2F$ (D) $CH_3–CF_3$

CBO0023

24. In BClBr I molecule the maximum % s-character provided from the central atom is in bond :
(A) B – I (B) B – Cl (C) B – Br (D) Can not predict

CBO0024

25. Which of the following order is **CORRECT** for increasing p-character in orbital used for bonding by central atom
(A) $SiH_4 > CH_4$ (B) $H_2S > H_2O$ (C) $PH_4^+ > PH_3$ (D) $NH_3 > PH_3$

CBO0025

MOLECULE DOES NOT EXIST

26. PCl_5 exists but NCl_5 does not because :
(A) Nitrogen has no vacant 2*d*-orbitals (B) NCl_5 is unstable
(C) Nitrogen atom is much smaller than P (D) Nitrogen is highly inert

CBO0026

27. Which of the following molecules do not exist.
(A) BF_6^{3-} (B) NCl_3 (C) NOF_3 (D) XeF_5^-

CBO0027

28. Select non existing species
(A) PH_3 (B) PH_4^+ (C) $[PF_6]^-$ (D) None of these

CBO0028

29. Among the fluorides below, the one which does not exist is -
(A) XeF_4 (B) BeF_4 (C) SF_4 (D) CF_4

CBO0029

30. Which of the following compound exist -
(A) XeH_2 (B) ClF_7 (C) PH_5 (D) ICl_3

CBO0030

DIPOLE MOMENT & HYDROGEN BONDING

31. Which of the following has been arranged in order of decreasing dipole moment ?

(A) $CH_3Cl > CH_3F > CH_3Br > CH_3I$ (B) $CH_3F > CH_3Cl > CH_3Br > CH_3I$

(C) $CH_3Cl > CH_3Br > CH_3I > CH_3F$ (D) $CH_3F > CH_3Cl > CH_3I > CH_3Br$

CBO0031

32. The experimental value of the dipole moment of *HCl* is 1.03 *D*. The length of the *H–Cl* bond is 1.275 Å. The percentage of ionic character in *HCl* is nearly :

(A) 43 (B) 21 (C) 17 (D) 7

CBO0032

33. Ethanol has a higher boiling point than dimethyl ether though they have the same molecular weight. This is due to :

(A) resonance (B) coordinate bonding

(C) hydrogen bonding (D) ionic bonding

CBO0033

34. Which of the following compounds would have significant intermolecular hydrogen bonding ?
HF, CH_3OH, N_2O_4, CH_4

(A) HF, N_2O_4 (B) HF, CH_4, CH_3OH (C) HF, CH_3OH (D) CH_3OH, CH_4

CBO0034

35. For H_2O_2, H_2S, H_2O and HF, the correct order of decreasing strength of hydrogen bonding is :

(A) $H_2O > HF > H_2O_2 > H_2S$ (B) $HF > H_2O_2 > H_2O > H_2S$

(C) $HF > H_2O > H_2O_2 > H_2S$ (D) $H_2O_2 > H_2O > HF > H_2S$

CBO0035

36. Which one of the following does not have intermolecular H-bonding?

(A) H_2O (B) *o*-nitro phenol (C) HF (D) CH_3COOH

CBO0036

37. The order of strength of hydrogen bonds is:

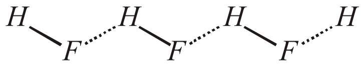
(A) NH...N > OH...O > FH...F (B) NH...N < OH...O < FH...F

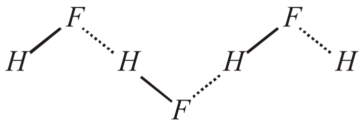
(C) NH...N > OH...O < FH...F (D) NH...N < OH...O > FH...F

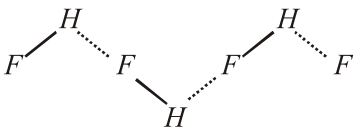
CBO0037

38. The *H* bond in solid *HF* can be best represented as:

(A) H – F....H – F....H – F

(B) 

(C) 

(D) 

CBO0038

VANDERWAAL FORCES

39. **Statement-1 :** The melting point of noble gases increases as its atomic mass increases.

Statement-2 : Instantaneous dipole induced dipole attraction increases with increase in atomic mass of noble gases.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

CBO0039

40. The critical temperature of water is higher than that of O_2 because the H_2O molecule has :

(A) fewer electrons than O_2 (B) two ionic bonds

(C) V–shape (D) dipole moment

CBO0040

41. Which of the following boiling point order is correct -

(A) He > T_2 > D_2 (B) He < T_2 < D_2 (C) T_2 > He > D_2 (D) He < D_2 < T_2

CBO0041

42. Which is the incorrect match for the energy distance function for following interaction -

(A) Debye force : r^{-6} (B) Ion-induced dipole interaction : r^{-2}

(C) London force : r^{-6} (D) Keesom force : r^{-3}

CBO0042

43. Identify the incorrect order of boilng point in the following pair.

(A) $B(OH)_3 < B(OCH_3)_3$ (B) $NF_3 < N(CH_3)_3$

(C) $BF_3 < B(CH_3)_3$ (D) $C_2H_6 < C_2F_6$

CBO0043

SILICATE

44. The number of corners or O-atoms shared per tetrahedron for pyroxene chain silicate is -

(A) 3 (B) 2 (C) 2.5 (D) 1

CBO0044

45. The mineral $Na_2Fe_3^{II}Fe_2^{III}\left[Si_8O_{22}\right](OH)_2$ (chrocidolite) is a :

(A) Pyroxene chain silicate (B) Sheet silicate

(C) Amphiboles chain silicate (D) 3D-silicate

CBO0045

46. The silicate anion in the mineral kinoite is a chain of three SiO_4 tetrahedra that share corners with adjacent tetrahedra. The mineral also contains Ca^{2+} ions, Cu^{2+} ions, and water molecules in a 1:1:1 ratio mineral is represented as :

(A) $CaCuSi_3O_{10}.H_2O$ (B) $CaCuSi_3O_{10}.2H_2O$

(C) $Ca_2Cu_2Si_3O_{10}.2H_2O$ (D) none of these

CBO0046

47. Silicate thortveitite ($Sc_2Si_2O_7$) is an example of -

(A) Ortho silicate (B) Pyro silicate (C) Cyclic silicate (D) Chain silicate

CBO0047

48. Name of the structure of silicates in which three oxygen atoms of SiO_4^{4-} are shared is -

(A) Pyro silicate (B) Sheet silicate

(C) Linear chain silicate (D) Three dimensional silicate

CBO0048

MISCELLEANEOUS

49. The formal charges on the three O-atoms in O_3 molecule are

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

CBO0049

50. The types of bonds present in $CuSO_4 \cdot 5H_2O$ are

(A) electrovalent and covalent

(B) electrovalent , coordinate covalent & H-bond

(C) covalent, coordinate covalent & H-bonds

(D) electrovalent, covalent, coordinate covalent & H-bond

CBO0050

51. If ethylene molecule lies in X-Y plane then nodal planes of the π-bond will lie in

(A) XZ plane (B) YZ plane

(C) In a plane that bisects C–C axis (D) XY plane

CBO0051

52. Two ice cubes are pressed over each other and unite to form one cube. Which force is responsible for holding them together :

(A) van der Waal's forces (B) Covalent attraction

(C) Hydrogen bond formation (D) Dipole-dipole attraction

CBO0052

EXERCISE # O–2

IONIC BOND , COVALENT BOND & COORDINATE BOND

1. Which of the following compounds contain ionic, covalent and co-ordinate bonds?

(A) NH_4Cl (B) KCN (C) $NaBF_4$ (D) NaOH

CBO0053

2. Which of the following statements is/are true?

(A) Covalent bonds are directional

(B) Ionic bonds are nondirectional

(C) A polar bond is formed between two atoms which have the same electronegativity value.

(D) The presence of polar bonds in a polyatomic molecule suggests that it has zero dipole moment

CBO0054

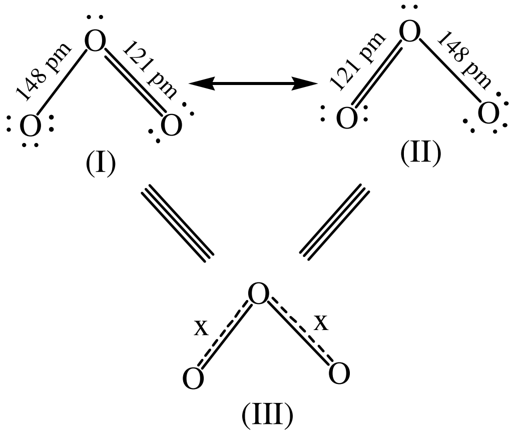
3. To which of the following species octet rule is not applicable :

(A) BrF_5 (B) SF_6 (C) IF_7 (D) CO

CBO0055

LEWIS STRUCTURE & BOND LENGTH

4. O_3(ozone) molecule can be equally represented by the structures I and II shown below



which of the following values of x are not correct

(A) 148 pm (B) 121 pm (C) less than 121 pm (D) more than 148 pm

CBO0056

5. Select the correct statement -

(A) C–O bond length of CO molecule is higher than the C–O bond length of CO_2

(B) C–O bond length of CO molecule is lower than the C–O bond length of CO_2

(C) N–O bond length of NO_3^- ion is higher than the N–O bond length of NO_2^-

(D) N–O bond length of NO_3^- ion is lower than the N–O bond length of NO_2^-

CBO0057

VBT, HYBRIDISATION & VSEPR THEORY

6. Which of the following statement(s) is / are not correct?

(A) Hybridization is the mixing of atomic orbitals of large energy difference.

(B) sp^2–hybrid orbitals are formed from two *p* - atomic orbitals and one *s*- atomic orbital

(C) sp^3d^2–hybrid orbitals are all at 90º to one another

(D) sp^3–hybrid orbitals are directed towards the corners of a regular tetrahedron

CBO0058

7. Which of the following species are linear ?

(A) ICl_2^- (B) I_3^- (C) N_3^- (D) ClO_2^+

CBO0059

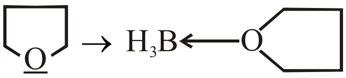
8. Which of the following molecules have bent shape.
Where A is central atom , B is surrounding atom and E is lone pair -

(A) AB_2E_2 (B) AB_2E (C) AB_3E (D) AB_2

CBO0060

9. In which of the following process(s) hybridisation of underlined atom does not change –

(A) $\underline{N}H_3 + BF_3 \rightarrow H_3N.BF_3$ (B) $\underline{Si}F_4 + 2F^{\ominus} \rightarrow [SiF_6]^{2-}$

(C) BH_3 + 

(D) $H_3\underline{B}O_3 \xrightarrow{OH^-} [B(OH)_4]^-$

CBO0061

10. Which of the following 'd' orbital(s) participate in the hybridistaion for Xe in the cationic part of XeF_6(s) :-

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

CBO0062

11. Select the **CORRECT** statement if internuclear axis is y-axis :-

(A) d_{xy} and d_{xy} orbital of two atoms form π-bond

(B) p_z and p_z orbital of two atoms form σ-bond

(C) $d_{x^2-y^2}$ and $d_{x^2-y^2}$ orbital of two atoms form π-bond

(D) p_y and d_{zx} orbital of two atoms form π-bond

CBO0063

12. What is the hybridisation state of Cl in cationic part of solid Cl_2O_6 ?

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

CBO0064

13. **INCORRECT** order of bond angle is:-

(A) $OCl_2 > SF_2$ (B) $H_2O > OF_2$ (C) $SO_4^{2-} > CF_4$ (D) $NF_3 > NH_3$

CBO0065

14. Select the **CORRECT** statement(s) ?

(A) Bond angle order : $CH_4 > CF_4$
(B) Bond length order : $d_{N-O}(NO_2^-) < d_{N-O}(NO_3^-)$
(C) Bond order of S–O : $SO_4^{2-} > SO_3^{2-}$
(D) Bond angle order : $NH_3 < PH_3$

CBO0066

MOLECULE DOES NOT EXIST

15. Which of the following molecules do not exist ?

(A) Br_2O (B) SF_6 (C) NCl_5 (D) OF_4

CBO0067

16. Which of the following do not exists ?

(A) SH_6 (B) HFO_4 (C) $SiCl_6^{-2}$ (D) $HClO_3$

CBO0068

17. Which of the following molecule exist-

(A) SF_6 (B) IH_3 (C) SH_2 (D) PCl_5

CBO0069

18. Which of the following molecules does not exist and non-existence reason is same as that of SH_6

(A) OF_4 (B) SH_4 (C) PBr_6^- (D) XeH_4

CBO0070

DIPOLE MOMENT & HYDROGEN BOND

19. Which of the following compounds possesses zero dipole moment?

(A) Water
(B) Benzene
(C) Carbon tetrachloride
(D) Boron trifluoride

CBO0071

20. Which of the following statements are correct?

(A) The crystal lattice of ice is formed by covalent as well as hydrogen bonds
(B) The density of water increases when heated from *0°C* to *4°C*
(C) Above 4° *C* the thermal agitation of water molecules increases. Therefore, intermolecular distance increases and water starts expanding
(D) The density of water decreases from 0° *C* to a maximum at 4° *C*

CBO0072

21. In which of the following chemical species hydrogen bonding takes places -

(A) $Na_2HPO_3(s)$ (B) $K_2HPO_4(s)$ (C) $KHCO_3(s)$ (D) $NaHCO_3(s)$

CBO0073

22. If IF_x^n, types species are planar and non-polar, then which of the following match is correct- (where X is number of F atoms and n is charge an species)

(A) x = 2 and n = +1 (B) x = 3 and n = 0 (C) x = 2 and n = –1 (D) x = 5 and n = 0

CBO0074

23. The correct order/s of boiling point is/are -

(A) $H_2O > CH_3OH$ (B) $H_3PO_4 > Me_3PO_4$ (C) $NH_3 < H_2O$ (D) $H_2O > HF$

CBO0075

VANDERWAAL FORCES

24. Which of the following factors are responsible for origination of vander Waals forces ?

(A) Instantaneous dipole-induced dipole interaction

(B) Dipole-induced dipole interaction

(C) Dipole-dipole interaction

(D) Size of molecule

CBO0076

25. Which of the following are true ?

(A) Vander Waals forces are responsible for the formation of molecular crystals

(B) Branching lowers the boiling points of isomeric organic compounds due to decrease in Vander Waals forces of attraction

(C) In graphite, vander Waals forces act between the carbon layers

(D) In diamond, vander Waals forces act between the carbon layers

CBO0077

26. Iodine molecules are held in solid lattice by _______.

(A) London forces (B) Dipole-dipole attraction

(C) Covalent bonds (D) Coulombic force

CBO0078

27. Which of the following inert gas liquefies easily as compare to others -

(A) Kr (B) He (C) Ne (D) Ar

CBO0079

SILICATE

28. In which of the following cases the number of corner shared per tetrahedron is '2' -

(A) Pyroxene chain silicate (B) Amphibole chain silicate

(C) 5-membered cyclic silicate (D) None of these

CBO0080

29. Which of the following minerals contain three oxygen corners shared per silicate unit ?

(A) $CaMg[(SiO_3)_2]$ (B) $BaTi[Si_3O_9]$

(C) $Ca_2Mg_5[(Si_4O_{11})_2](OH)_2$ (D) $Al_2(OH)_4[Si_2O_5]$

CBO0081

30. In Silica (SiO_2), each silicon atom is bonded to -

(A) Two oxygen atoms (B) Four oxygen atoms

(C) One silicon and two oxyen atoms (D) One silicon and four oxyen atoms

31. The ratio of 'Si' atom to monovalent 'O' atom in amphibole silicate is -

(A) 2 : 3 (B) 4 : 5 (C) 4 : 11 (D) 1 : 3

CBO0083

32. In which of the following silicate/s, 'Si' atoms are sp^3 hybrid -

(A) Pyro silicate (B) Sheet silicate (C) Pyroxene (D) Amphiboles

CBO0084

MISCELLEANEOUS & STRUCTURE

33. Which of the following oxyacids of sulphur contain $S-S$ bonds ?

(A) $H_2S_2O_8$ (B) $H_2S_2O_6$ (C) $H_2S_2O_4$ (D) $H_2S_2O_5$

CBO0085

34. Molecule(s) having both polar and non polar bonds is / are

(A) O_2F_2 (B) S_2Cl_2 (C) N_2H_4 (D) S_2F_{10}

CBO0086

35. Which of the following molecule is/are planar -

(A) CH_2Cl_2 (B) XeF_4 (C) SO_3 (D) NF_3

CBO0087

EXERCISE # S–1

Integer Type Answer :

1. In solid $\overset{+}{Na}Cl^{-}$ one Na^+ is surrounded by six Cl^- ions find out total number of directional bonds formed by each Na^+ with Cl^- ions.

CBO0088

2. Find out total number of pπ–dπ bonds present in SO_2 molecule

CBO0089

3. Find out total number of pπ–pπ bonds present in SO_4^{2-}

CBO0090

4. How many number of atomic orbitals are required, so that their mixing produces hybrid orbitals each having % of s-character nearly equal to 17%.

CBO0091

5. Calculate the maximum number of atoms lying in one plane of PCl_3F_2.

CBO0092

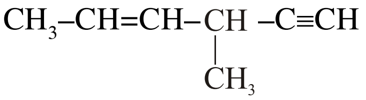
6. Find the total number of following molecule(s) which have all bond lengths are same.
XeF_4, SF_4, SH_2, NO_3^-, SiF_4, ClF_3, PF_2Cl_3, XeO_3F_2

CBO0093

7. A diatomic molecule has a dipole moment of 1.2 D. If bond length is 1.0 Å, what percentage of an electronic charge exists on each atom.
[Add the digits untill you are getting single digit. e.g. If the answer is 537, then 5 + 3 + 7 = 15] again 1 + 5 = 6 and 6 is to be written as answer.

CBO0094

8. Total number of sp^3 hybridised atom(s) in given hydrocarbon.



$CH_3–CH=CH–\underset{\underset{CH_3}{|}}{CH}–C{\equiv}CH$

CBO0095

9. Find the number of lone pair on central atom of ICl_4^-

CBO0096

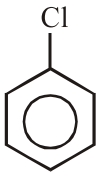
10. Find the number of acid(s) which are having hypo prefix in it's name from the following.
H_3PO_4, H_3BO_3, H_3PO_3, H_3PO_2, $HClO_3$, $HClO$, $(HNO)_2$, $H_4P_2O_6$

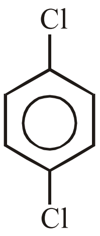
CBO0097

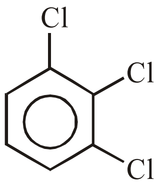
11. Find the number of planar molecules/ions which are cyclic –
$B_3N_3H_6$, $C_3N_3Cl_3$, $(BO_2^-)_3$, $S_2O_8^{2-}$

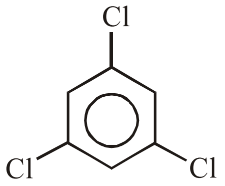
CBO0098

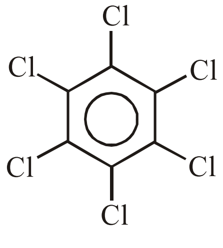
12. Find the number of molecule having dipole moment less than the dipole moment of











CBO0099

13. Find the number of molecules having intramolecular hydrogen bonding in the following :
ice, o-boric acid, o-nitrophenol, o-chlorophenol, chloral hydrate, o-salicyaldehyde

CBO0100

14. Calculate the value of "n" in $Zn_nCa_2(Si_3O_{10}).2H_2O$

CBO0101

15. In which of the following silicates structure, the number of corner/oxygen atoms shared per tetrahedron is ‘2’.
Pyrosilicate , pyroxene chain silicate ,
2D-silicate , 3D-silicate , 4-membered cyclic silicate

CBO0102

EXERCISE # S–2

(Comprehension) (Q.1 to Q.2)

Bond angle and bond polarity are important parameters associated for bonding in molecule.

1. Which of the following bond angle order is incorrect.

(A) $NH_3 > PH_3$ (B) $BF_3 < BH_3$

(C) $O(CH_3)_2 < O(C_2H_5)_2$ (D) $CO_3^{2-} < CO_2$

CBO0103

2. Which of the following molecule is polar and non-planar

(A) CH_2Cl_2 (B) PCl_5 (C) SO_2 (D) XeF_4

CBO0103

(Comprehension) (Q.3 to Q.4)

During the formation of a covalent bond each participating atom usually acquires electronic configuration to that of nearest noble gas, and the shared electron pair remains localized between the bonded nuclei. Besides these shared electrons there are certain electron pairs which remains localized on C.A. or on substituent or both and are called non bonding or lone pair electrons.

3. Which of the following species does / do not follow octet rule:

(A) Hypovalent (B) Hypervalent

(C) Odd electron molecules (D) All

CBO0104

4. In SO_3^{2-} the total number of lone pairs and bond pairs are respectively

(A) 18 and 4 (B) 9 and 8 (C) 9 and 4 (D) 7 and 4

CBO0104

(Comprehension) (Q.5 to Q.7)

Hybridisation is a theoretical concept, as state of hybridisation cannot be detected even by spectroscopically; unlike intermediates or transition state in various reactions. but it corrects the predictions which are based simple on overlapping of pure atomic orbitals. VSEPR theory predicts precisely shape and bond angle in a given molecule.

5. In which pair of molecules bond angles are not same:

(A) CCl_4 & $SiCl_4$ (B) NH_4^+ & $\overset{+}{N}F_4$ (C) ClF_6^+ & SF_6 (D) None

CBO0105

6. The molecules / ions which are planar as well as polar.

(A) BF_3 , H_2O, H F , NH_2^- (B) $SnCl_2$, I_3^+ , NH_2^- , IF_3

(C) CO_3^{2-} , I_3^-, SF_2, XeF_2 (D) NO_2^-, XeF_4, ICl_4^-, NH_2^+

CBO0105

7. The correct order of energy levels of hybrid orbitals.

(A) $sp > sp^2 > sp^3$ (B) $sp < sp^2 < sp^3$ (C) $sp^2 > sp^3 > sp$ (D) $sp^3 > sp > sp^2$

CBO0105

(Comprehension) (Q.8 to Q.10)

As one moves from sp hybridisation to sp^3. % of s-character in hybrid orbital decreases from 50% to 25% and p-character increases from 50% to 75% and in any hybrid orbital total % of s & p- character remains 100%. By increasing p-character the hybrid orbitals become elongated hence, their overlapping extent decreases that is results into weak bond energy also bond angle decreases.

8. **Statement-1 :** On decreasing s-character in hybrid orbitals, bond angle decreases.

Statement-2 : p-orbitals are at 90° to one another.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

CBO0106

9. The type of overlapping which produces bond of maximum bond energy is:

(A) $sp^3 - 1s$ (B) $sp^2 - 1s$
(C) $sp - 1s$ (D) All have same bond energy

CBO0106

10. The molecule having bond pair in which % of s character is minimum for the central atom's hybrid orbital.

(A) SiF_4 (B) BCl_3 (C) CH_3^+ (D) CO_2

CBO0106

Match the Column :

11. Match the column

Column-I (molecules)	**Column-II (correct about molecule)**
(A) $\underline{P}Cl_5(\theta = 120^o), (\theta' = 90^o)$	(P) Number of the given bond angle (θ or θ') is = One
(B) $\underline{N}H_3(\theta = 107^o)$	(Q) Number of the given bond angle (θ or θ') is = Three
(C) $\underline{Si}H_4(\theta = 109^o\ 28')$	(R) Number of the given bond angle (θ or θ') is = Six
(D) $\underline{S}O_2(\theta = 116^o)$	(S) d-orbital(s) is/are involved in hybrdisation of central atom
	(T) Lone pair at underlined atom is present

CBO0107

12.

Column I	**Column II**
(A) BrF_3	(P) Atleast one angle ≤ 90°
(B) TeF_5^-	(Q) Central atom is sp^3d^2 hybridised
(C) IF_7	(R) Non planar
(D) XeF_4	(S) Polar

CBO0108

13.

Column I	**Column II**
(A) $I(CN)_2^-$	(P) Having $p\pi-p\pi$ bond & $\mu_D = 0$
(B) CO_3^{2-}	(Q) Having $p\pi-d\pi$ bond & $\mu_D \neq 0$
(C) XeO_2F_2	(R) Planar
(D) SOF_4	(S) Central atom is sp^3d

CBO0109

14.

Column I	**Column II**
(A) $H_2S_2O_5$	(P) Central atom is sp^3 hybridised
(B) $H_6B_2O_7^{2-}$	(Q) M–O–M i.e. oxo linkage is present
(C) $H_4P_2O_6$(tetrabasic)	(R) M–M linkage is present
(D) $H_6Si_2O_7$	(S) Non planar

CBO0110

15.

Column–I	**Column–II**
(P) XeF_4	(1) sp^3d hybridised with 2 lone pair on central atom
(Q) BrF_5	(2) sp^3d^2 hybridised with 2 lone pair on central atom
(R) ClF_3	(3) sp^3 hybridised with 1 lone pair on central atom
(S) SO_3^{2-}	(4) sp^3d^2 hybridised with 1 lone pair on central atom

Code :

	P	**Q**	**R**	**S**
(A)	1	2	3	4
(B)	2	4	1	3
(C)	2	4	3	1
(D)	3	1	4	2

CBO0111

16.

Column–I	**Column–II**
(P) NH_4Cl	(1) diamond like structure
(Q) $K[HF_2]$	(2) Benzene like structure
(R) $B_3N_3H_6$	(3) Both hydrogen bond and ionic bond exist
(S) SiC	(4) Both covalent bond and ionic bond exist

Code :

	P	**Q**	**R**	**S**
(A)	4	3	2	1
(B)	3	4	2	1
(C)	3	4	1	2
(D)	4	1	3	2

CBO0112

Answer Q.17, Q.18 and Q.19 by appropriately matching the information given in the three columns of the following table.

Column - I	**Column - II**	**Column - III**
(P) d_{yz}	(1) p_y	(i) 1 lobe – 1 lobe overlap
(Q) s	(2) p_x	(ii) 2 lobe – 2 lobe overlap
(R) d_{xz}	(3) d_{yz}	(iii) 4 lobe – 4 lobe overlap
(S) p_z	(4) s	(iv) Zero overlap

17. Which of the following combination results in π-bond formation if internuclear axis is z-axis

(A) (P), (1), (ii) (B) (P), (4), (i) (C) (R), (4), (iv) (D) (R), (3), (ii)

CBO0113

18. Which of the following combination resultsin σ-bond formation if internuclear axis is z-axis

(A) (P), (1), (ii) (B) (Q), (3), (ii) (C) (Q), (4), (i) (D) (R), (2), (ii)

CBO0113

19. Which of the following combination results in δ-bond formation if internuclear axis is x-axis

(A) (P), (1), (i) (B) (P), (3), (iii) (C) (R), (3), (iv) (D) (P), (2), (ii)

CBO0113

20. Match the column

Column-I **(Molecules)**	**Column-I** **(Characteristics)**
(A) CH_4	(P) Molecule is having perfect tetrahedral shape
(B) CH_2F_2	(Q) C-F bond has maximum p-character
(C) CHF_3	(R) C–H bond has maximum s-character
(D) CF_4	(S) Molecule is having maximum number of equal angles
	(T) Molecule has lowest bond angle

CBO0114

EXERCISE # JEE-MAIN

1. The hybridisation of orbitals of N atom in NO_3^-, NO_2^+ and NH_4^+ are respectively:- **[AIEEE-2011]**

(1) sp, sp^3, sp^2 (2) sp^2, sp^3, sp (3) sp, sp^2, sp^3 (4) sp^2, sp, sp^3

CBO0115

2. The structure of IF_7 is :- **[AIEEE-2011]**

(1) octahedral (2) pentagonal bipyramid

(3) square pyramid (4) trigonal bipyramid

CBO0116

3. Which of the following has maximum number of lone pairs associated with Xe **[AIEEE-2011]**

(1) XeO_3 (2) XeF_4 (3) XeF_6 (4) XeF_2

CBO0117

4. The molecule having smallest bond angle is :- **[AIEEE-2012]**

(1) PCl_3 (2) NCl_3 (3) $AsCl_3$ (4) $SbCl_3$

CBO0118

5. In which of the following pairs the two species are not isostructural ? **[AIEEE-2012]**

(1) AlF_6^{3-} and SF_6 (2) CO_3^{2-} and NO_3^- (3) PCl_4^+ and $SiCl_4$ (4) PF_5 and BrF_5

CBO0119

6. 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]

(1) 1, 0, 1, 0 (2) 0, 1, 1, 0 (3) 1, 0, 0, 1 (4) 0, 1, 0, 1 **(On line)**

CBO0120

7. 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^- **(On line)**

(1) II and III (2) III and IV (3) I and IV (4) I and III

CBO0121

8. Which of the following has the square planar structure :- **[JEE-MAINS-2012]**

(1) NH_4^+ (2) CCl_4 (3) XeF_4 (4) BF_4^- **(On line)**

CBO0122

9. The compound of Xenon with zero dipole moment is :- **[JEE-MAINS-2012]**

(1) XeO_3 (2) XeO_2 (3) XeF_4 (4) $XeOF_4$ **(On line)**

CBO0123

10. Among the following the molecule with the lowest dipole moment is :- **[JEE-MAINS-2012]**

(1) $CHCl_3$ (2) CH_2Cl_2 (3) CCl_4 (4) CH_3Cl **(On line)**

CBO0124

11. The formation of molecular complex $BF_3 - NH_3$ results in a change in hybridisation of boron :- **[JEE-MAINS-2012]**

(1) from sp^3 to sp^3d (2) from sp^2 to dsp^2 **(On line)**

(3) from sp^3 to sp^2 (4) from sp^2 to sp^3

CBO0125

12. Trigonal bipyramidal geometry is shown by: **[JEE-MAINS-2013]**

(1) XeO_3F_2 (2) $XeOF_2$ (3) XeO_3 (4) $FXeOSO_2F$ **(On line)**

CBO0126

13. Which one of the following molecules is polar? **[JEE-MAINS-2013]**

(1) CF_4 (2) SbF_5 (3) IF_5 (4) XeF_4 **(On line)**

CBO0127

14. Oxidation state of sulphur in anions SO_3^{2-}, $S_2O_4^{2-}$ and $S_2O_6^{2-}$ increases in the orders : **[JEE-MAINS-2013]**

(1) $S_2O_6^{2-} < S_2O_4^{2-} < SO_3^{2-}$ (2) $SO_3^{2-} < S_2O_4^{2-} < S_2O_6^{2-}$ **(On line)**

(3) $S_2O_4^{2-} < SO_3^{2-} < S_2O_6^{2-}$ (4) $S_2O_4^{2-} < S_2O_6^{2-} < SO_3^{2-}$

CBO0128

15. XeO_4 molecule is tetrahedral having : **[JEE-MAINS-2013]**

(1) Two pπ-dπ bonds (2) Four pπ-dπ bonds **(On line)**

(3) One pπ-dπ bond (4) Three pπ-dπ bonds

CBO0129

16. 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]**

(1) 61.0% (2) 38.0% **(On line)**

(3) 35.5% (4) 41.5%

CBO0130

17. The shape of IF_6^- is : **[JEE-MAINS-2013]**

(1) distorted octahedron (2) Pyramidal **(On line)**

(3) Octahedral (4) Square antiprism

CBO0131

18. Which has trigonal bipyramidal shape ? **[JEE-MAINS-2013]**

(1) $XeOF_4$ (2) XeO_3 (3) XeO_3F_2 (4) $XeOF_2$ **(On line)**

CBO0132

19. The catenation tendency of C, Si and Ge is in the order Ge < Si < C. The bond energies (in kJ mol^{-1}) of C — C, Si —Si and Ge—Ge bonds are respectively : **[JEE-MAINS-2013 (On line)]**

(1) 348, 260, 297 (2) 348, 297, 260 (3) 297, 348, 260 (4) 260, 297, 348

CBO0133

20. In which of the following sets, all the given species are isostructural ? **[JEE-MAINS-2013 (On line)]**

(1) BF_3, NF_3, PF_3, AlF_3 (2) PCl_3, $AlCl_3$, BCl_3, $SbCl_3$

(3) BF_4^-, CCl_4, NH_4^+, PCl_4^+ (4) CO_2, NO_2, ClO_2, SiO_2

CBO0134

21. For which of the following molecule significant $\mu \neq 0$ **[JEE-M-2014]**

(1)


(2)


(3)


(4)


(1) Only (3) (2) (3) and (4) (3) Only (1) (4) (1) and (2)

CBO0135

22. Among the following oxoacids, the correct decreasing order of acid strength is :- **[JEE-M-2014]**

(1) $HClO_4 > HClO_3 > HClO_2 > HOCl$

(2) $HClO_2 > HClO_4 > HClO_3 > HOCl$

(3) $HOCl > HClO_2 > HClO_3 > HClO_4$

(4) $HClO_4 > HOCl > HClO_2 > HClO_3$

CBO0136

23. The number and type of bonds in C_2^{2-} ion in CaC_2 are:

[AIEEE-2005, AIEEE-2011, JEE-MAINS-2014 (On line)]

(1) Two σ bonds and one π – bond

(2) Two σ bonds and two π – bonds

(3) One σ bond and two π – bonds

(4) One σ bond and one π – bond

CBO0137

24. For the compounds **[JEE-MAINS-2014]**

CH_3Cl, CH_3Br, CH_3I and CH_3F, **(On line)**

the correct order of increasing C-halogen bond length is :

(1) $CH_3F < CH_3Br < CH_3Cl < CH_3I$ (2) $CH_3F < CH_3Cl < CH_3Br < CH_3I$

(3) $CH_3Cl < CH_3Br < CH_3F < CH_3I$ (4) $CH_3F < CH_3I < CH_3Br < CH_3Cl$

CBO0138

25. Shapes of certain interhalogen compounds are stated below. Which one of them is not correctly stated?

[JEE-MAINS-2014]

(1) IF_7 : Pentagonal bipyramid (2) BrF_5 : Trigonal bipyramid **(On line)**

(3) ICl_3 : Planar dimeric (4) BrF_3 : Planar T-shaped

CBO0139

26. Which of the following molecules has two sigma(σ) and two pi(π) bonds :- **[JEE-MAINS-2014]**

(1) HCN (2) $C_2H_2Cl_2$ (3) N_2F_2 (4) C_2H_4 **(On line)**

CBO0140

27. Example of a three-dimensional silicate is : **[JEE-MAINS-2014]**

(1) Beryls (2) Zeolites (3) Feldspars (4) Ultramarines **(On-line)**

CBO0141

28. The intermolecular interaction that is dependent on the inverse cube of distance between the molecules is :- **[JEE-M-2015]**

(1) London force (2) Hydrogen bond

(3) ion-ion interaction (4) ion-dipole interaction

CBO0142

29. Which one has the highest boiling point ? **[JEE-M-2015]**

(1) Kr (2) Xe (3) He (4) Ne

CBO0143

30. Which intermolecular force is most responsible in allowing xenon gas to liquefy?

(1) Ionic **[JEE (MAIN) ONLINE 2016]**

(2) Instantaneous dipole- induced dipole

(3) Dipole - dipole

(4) Ion - dipole

CBO0144

31. The pair in which phosphorous atoms have a formal oxidation state of + 3 is :-

(1) Pyrophosphorous and pyrophosphoric acids **[JEE-MAINS(offline)-2016]**

(2) Orthophosphorous and pyrophosphorous acids

(3) Pyrophosphorous and hypophosphoric acids

(4) Orthophosphorous and hypophosphoric acids

CBO0145

32. The group of molecules having identical shape is : **[JEE-MAINS(online)-2016]**

(1) SF_4, XeF_4, CCl_4 (2) ClF_3, $XeOF_2$, XeF_3^+

(3) PCl_5, IF_5, XeO_2F_2 (4) BF_3, PCl_3, XeO_3

CBO0146

33. ***Assertion :*** Among the carbon allotropes, diamond is an insulator, whereas, graphite is a good conductor of electricity. **[JEE-MAINS(online)-2016]**

Reason : Hybridization of carbon in diamond and graphite are sp^3 and sp^2, respectively.

(1) Assertion is incorrect statement, but the reason is correct.

(2)Both assertion and reason are correct, and the reason is the correct explanation for the assertion.

(3) Both assertion and reason are incorrect.

(4) Both assertion and reson are correct, but the reason is not the correct explanation for the assertion.

CBO0147

34. 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(online)-2016]**

(1) NaCl (2) CaI_2 (3) KBr (4) NaF

CBO0148

35. The correct sequence of decreasing number of π-bonds in the structures of H_2SO_3, H_2SO_4 and $H_2S_2O_7$ is:- **[JEE-MAINS(online)-2017]**

(1) $H_2S_2O_7 > H_2SO_4 > H_2SO_3$ (2) $H_2SO_3 > H_2SO_4 > H_2S_2O_7$

(3) $H_2S_2O_7 > H_2SO_3 > H_2SO_4$ (4) $H_2SO_4 > H_2S_2O_7 > H_2SO_3$

CBO0149

36. The increasing order of the boiling points for the following compounds is :-

(I) C_2H_5OH (II) C_2H_5Cl **[JEE-MAINS(online)-2017]**

(III) $C_2H_5CH_3$ (IV) $C_2H_5OCH_3$

(1) (III) < (II) < (I) < (IV) (2) (II) < (III) < (IV) < (I)

(3) (IV) < (III) < (I) < (II) (4) (III) < (IV) < (II) < (I)

CBO0150

37. The number of P–OH bonds and the oxidation state of phosphorus atom in pyrophosphoric acid ($H_4P_2O_7$) respectively are:- **[JEE-MAINS(online)-2017]**

(1) five and four (2) five and five (3) four and five (4) four and four

CBO0151

38. The group having triangular planar structures is :- **[JEE-MAINS(online)-2017]**

(1) CO_3^{2-}, NO_3^-, SO_3 (2) NCl_3, BCl_3, SO_3 (3) NH_3, SO_3, CO_3^{2-} (4) BF_3, NF_3, CO_3^{2-}

CBO0152

39. The number of S=O and S–OH bonds present in peroxodisulphuric acid and pyrosulphuric acid respectively are : **[JEE-MAINS(online)-2017]**

(1) (2 and 4) and (2 and 4) (2) (4 and 2) and (2 and 4)

(3) (2 and 2) and (2 and 2) (4) (4 and 2) and (4 and 2)

CBO0153

40. The number of P–O bonds in P_4O_6 is :- **[JEE-MAINS(online)-2018]**

(1) 18 (2) 12 (3) 9 (4) 6

CBO0154

41. In XeO_3F_2, the number of bond pair(s), π-bond(s) and lone pair(s) on Xe atom respectively are :- **[JEE-MAINS(online)-2018]**

(1) 4, 2, 2 (2) 4, 4, 0 (3) 5, 2, 0 (4) 5, 3, 0

CBO0155

42. The decreasing order of bond angles in BF_3, NH_3, PF_3 and I_3^- is :- **[JEE-MAINS(online)-2018]**

(1) $I_3^- > BF_3 > NH_3 > PF_3$ (2) $BF_3 > NH_3 > PF_3 > I_3^-$

(3) $I_3^- > NH_3 > PF_3 > BF_3$ (4) $BF_3 > I_3^- > PF_3 > NH_3$

CBO0156

43. Identify the pair in which the geometry of the species is T-shape and square-pyramidal, respectively :- **[JEE-MAINS(online)-2018]**

(1) IO_3^- and $IO_2F_2^-$ (2) $XeOF_2$ and $XeOF_4$ (3) ICl_2^- and ICl_5 (4) ClF_3 and IO_4^-

CBO0157

44. Which of the following is a lewis acid ? **[JEE-MAINS(online)-2018]**

(1) NaH (2) NF_3 (3) PH_3 (4) $B(CH_3)_3$

CBO0158

45. Among the oxides of nitrogen : N_2O_3, N_2O_4 and N_2O_5; the molecule(s) having nitrogen-nitrogen bond is/are :- **[JEE-MAINS(online)-2018]**

(1) N_2O_3 and N_2O_5 (2) N_2O_4 and N_2O_5 (3) N_2O_3 and N_2O_4 (4) Only N_2O_5

CBO0159

46. The incorrect geometry is represented by :- **[JEE-MAINS(online)-2018]**

(1) BF_3 - trigonal planar (2) NF_3 - trigonal planar

(3) AsF_5 - trigonal bipyramidal (4) H_2O - bent

CBO0160

47. Which of the following conversions involves change in both shape and hybridisation ?

[JEE-MAINS(online)-2018]

(1) $BF_3 \rightarrow BF_4^-$ (2) $H_2O \rightarrow H_3O^+$ (3) $CH_4 \rightarrow C_2H_6$ (4) $NH_3 \rightarrow NH_4^+$

CBO0161

48. Which of the following are Lewis acids ? **[JEE-MAINS(offline)-2018]**

(1) $AlCl_3$ and $SiCl_4$ (2) PH_3 and $SiCl_4$ (3) BCl_3 and $AlCl_3$ (4) PH_3 and BCl_3

CBO0162

49. Total number of lone pair of electrons in I_3^- ion is **[JEE-MAINS(offline)-2018]**

(1) 6 (2) 9 (3) 12 (4) 3

CBO0163

50. The element that shows greater ability to form pπ-pπ multiple bonds, is : **[JEE-MAINS(online)-2019]**

(1) Si (2) Ge (3) Sn (4) C

CBO0164

51. The type of hybridisation and number of lone pair(s) of electrons of Xe in $XeOF_4$, respectively, are : **[JEE-MAINS(online)-2019]**

(1) sp^3d and 1 (2) sp^3d and 2 (3) sp^3d^2 and 1 (4) sp^3d^2 and 2

CBO0165

52. The pair that contains two P–H bonds in each of the oxoacids is : **[JEE-MAINS(online)-2019]**

(1) H_3PO_2 nad $H_4P_2O_5$ (2) $H_4P_2O_5$ and $H_4P_2O_6$

(3) H_3PO_3 and H_3PO_2 (4) $H_4P_2O_5$ nad H_3PO_3

CBO0166

53. The ion that has sp^3d^2 hybridization for the central atom, is : **[JEE-MAINS(online)-2019]**

(1) $[ICl_2]^-$ (2) $[IF_6]^-$ (3) $[ICl_4]^-$ (4) $[BrF_2]^-$

CBO0167

54. C_{60}, an allotrope of carbon contains : **[JEE-MAINS(online)-2019]**

(1) 20 hexagons and 12 pentagons. (2) 12 hexagons and 20 pentagons.

(3) 18 hexagons and 14 pentagons. (4) 16 hexagons and 16 pentagons.

CBO0168

55. The oxoacid of sulphur that does not contain bond between sulphur atoms is :

(1) $H_2S_4O_6$ (2) $H_2S_2O_7$ **[JEE-MAINS(online)-2019]**

(3) $H_2S_2O_3$ (4) $H_2S_2O_4$

CBO0169

56. The number of pentagons in C_{60} and trigons (triangles) in white phosphorus, respectively, are:

(1) 12 and 3 (2) 20 and 4 **[JEE-MAINS(online)-2019]**

(3) 12 and 4 (4) 20 and 3

CBO0170

57. The C–C bond length is maximum in **[JEE-MAINS(online)-2019]**

(1) graphite (2) C_{70} (3) diamond (4) C_{60}

CBO0171

58. The dipole moments of CCl_4, $CHCl_3$ and CH_4 are in the order : **[JEE-MAINS(online)-2020]**

(1) $CH_4 = CCl_4 < CHCl_3$ (2) $CH_4 < CCl_4 < CHCl_3$

(3) $CCl_4 < CH_4 < CHCl_3$ (4) $CHCl_3 < CH_4 = CCl_4$

CBO0172

59. The relative strength of interionic/intermolecular forces in decreasing order is :

(1) ion-dipole > ion-ion > dipole-dipole **[JEE-MAINS(online)-2020]**

(2) dipole-dipole > ion-dipole > ion-ion

(3) ion-dipole > dipole-dipole > ion-ion

(4) ion-ion > ion-dipole > dipole-dipole

CBO0173

60. Arrange the following bonds according to their average bond energies in descending order :

C–Cl, C–Br, C–F, C–I **[JEE-MAINS(online)-2020]**

(1) C–I > C–Br > C–Cl > C–F (2) C–Br > C–I > C–Cl > C–F

(3) C–F > C–Cl > C–Br > C–I (4) C–Cl > C–Br > C–I > C–F

CBO0174

61. The predominant intermolecular forces present in ethyl acetate, a liquid, are :

(1) hydrogen bonding and London dispersion **[JEE-MAINS(online)-2020]**

(2) Dipole-dipole and hydrogen bonding

(3) London dispersion and dipole-dipole

(4) London dispersion, dipole-dipole and hydrogen bonding

CBO0175

62. 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 :

(1) 4 and 8 (2) 4 and 6 **[JEE-MAINS(online)-2020]**

(3) 8 and 8 (4) 8 and 6

CBO0176

63. The number of sp^2 hybrid orbitals in a molecule of benzene is : **[JEE-MAINS(online)-2020]**

(1) 24 (2) 6 (3) 12 (4) 18

CBO0177

EXERCISE # JEE-ADVANCED

Integer Type

1. The number of water molecule(s) directly bonded to the metal centre in $CuSO_4.5H_2O$ is **[JEE 2009]**

CBO0178

2. Based on VSEPR theory, the number of 90 degree F–Br–F angles in BrF_5 is **[JEE 2010]**

CBO0179

3. The difference in the oxidation numbers of the two types of sulphur atoms in $Na_2S_4O_6$ is. **[JEE 2011]**

CBO0180

4. The total number of lone-pairs of electrons in melamine is **[JEE Adv. 2013]**

CBO0181

5. The sum of the number of lone pairs of electrons on each central atom in the following species is. **[JEE 2017]**

$[TeBr_6]^{2-}$, $[BrF_2]^+$, SNF_3 and $[XeF_3]^-$

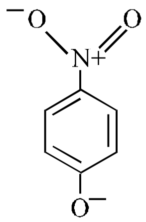
[Atomic number : N = 7, F = 9, S = 16, Br = 35, Te = 52, Xe = 54]

CBO0182

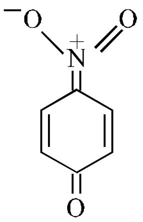
One or more than one correct

6. The most likely representation of resonance structure of p–nitrophenoxide is:

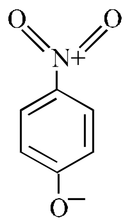
(A)



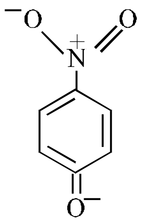
(B)



(C)



(D)



CBO0183

7. 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

CBO0184

8. 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 σ bond at right angle

(D) a plane perpendicular to the molecular plane which contains, the carbon-carbon bond.

CBO0185

9. **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.

CBO0186

10. **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.

CBO0187

11. 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

CBO0188

12. The value of n in the molecular formula $Be_nAl_2Si_6O_{18}$ is **[JEE 2010]**

CBO0189

13. The species having pyramidal shape is/are : **[JEE 2010]**

(A) SO_3 (B) BrF_3 (C) SiO_3^{--} (D) OSF_2

CBO0190

14. Which ordering of compounds is according to the decreasing order of the oxidation state of nitrogen-

(A) HNO_3, NO, NH_4Cl, N_2 (B) HNO_3, NO, N_2, NH_4Cl **[JEE 2012]**

(C) HNO_3, NH_4Cl, NO, N_2 (D) NO, HNO_3, NH_4Cl, N_2

CBO0191

15. The shape of XeO_2F_2 molecule is : **[JEE 2012]**

(A) Trigonal bipyramidal (B) Square planar

(C) tetrahedral (D) see-saw

CBO0192

16. 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

CBO0193

17. The crystalline form of borax has **[JEE 2016]**

(A) Tetranuclear $[B_4O_5(OH)_4]^{2-}$ 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

CBO0194

18. The order of the oxidation state of the phosphorus atom in H_3PO_2, H_3PO_4, H_3PO_3 and $H_4P_2O_6$ is

(A) $H_3PO_4 > H_4P_2O_6 > H_3PO_3 > H_3PO_2$ **[JEE 2017]**

(B) $H_3PO_3 > H_3PO_2 > H_3PO_4 > H_4P_2O_6$

(C) $H_3PO_2 > H_3PO_3 > H_4P_2O_6 > H_3PO_4$

(D) $H_3PO_4 > H_3PO_2 > H_3PO_3 > H_4P_2O_6$

CBO0195

19. Based on the compounds of group 15 elements , the correct statement(s) is (are) **[JEE 2018]**

(A) Bi_2O_5 is more basic than N_2O_5

(B) NF_3 is more covalent than BiF_3

(C) PH_3 boils at lower temperature than NH_3

(D) The N–N single bond is stronger than the P–P single bond

CBO0196

20. The total number of compounds having at least one bridging oxo group among the molecules given below is______. **[JEE 2018]**

N_2O_3, N_2O_5, P_4O_6, P_4O_7, $H_4P_2O_5$, $H_5P_3O_{10}$, $H_2S_2O_3$, $H_2S_2O_5$

CBO0197

ANSWERS KEY

EXERCISE # O–1

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	C	A	B	B	D	D	A	C	B	A
Que.	11	12	13	14	15	16	17	18	19	20
Ans.	C	C	A	A	B	C	C	C	C	B
Que.	21	22	23	24	25	26	27	28	29	30
Ans.	A	C	C	A	B	A	A	D	B	D
Que.	31	32	33	34	35	36	37	38	39	40
Ans.	A	C	C	C	C	B	B	C	A	D
Que.	41	42	43	44	45	46	47	48	49	50
Ans.	D	B	A	B	C	C	B	B	D	D
Que.	51	52								
Ans.	D	C								

EXERCISE # O–2

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	A,C	A,B	A,B,C	A,B,C,D	B,C	A,C	A,B,C	A,B	A,C	B,C
Que.	11	12	13	14	15	16	17	18	19	20
Ans.	A	C	C,D	B,C	C,D	A,B,C	A,C,D	B,D	B,C,D	A,B,C
Que.	21	22	23	24	25	26	27	28	29	30
Ans.	B,C,D	C	A,B,C,D	A,B,C	A,B,C	A	A	A,C	D	B
Que.	31	32	33	34	35					
Ans.	A	A,B,C,D	B,C,D	A,B,C,D	B,C					

EXERCISE # S–1

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	0	1	0	6	4	4	7 (25%)	3	2	4
Que.	11	12	13	14	15					
Ans.	3	3	4	2	2					

EXERCISE # S–2

Que.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Ans.	B	A	D	C	D	B	B	B	C	A
Que.	**11**				**12**					
Ans.	(A)$\rightarrow$Q,R,S;(B)$\rightarrow$Q,T;(C)$\rightarrow$R;(D)$\rightarrow$P,T				(A)$\rightarrow$P,S (B)$\rightarrow$P,Q,R,S (C)$\rightarrow$P,R (D)$\rightarrow$P,Q					
Que.	**13**					**14**				
Ans.	(A) $\rightarrow$ P,R,S (B) $\rightarrow$ P,R (C) $\rightarrow$ Q,S (D) $\rightarrow$ Q,S					(A) $\rightarrow$ P,R,S (B) $\rightarrow$ P,Q,S (C) $\rightarrow$ P,R,S (D) $\rightarrow$ P,Q,S				
Que.	**15**	**16**	**17**	**18**	**19**	**20**				
Ans.	B	A	A	C	B	(A) $\rightarrow$ P,S (B) $\rightarrow$ Q,T (C) $\rightarrow$ R (D) $\rightarrow$ P,S				

EXERCISE # JEE-MAIN

Que.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Ans.	4	2	4	4	4	2	**BONUS**	3	3	3
Que.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Ans.	4	1	3	3	2	4	1	3	2	3
Que.	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Ans.	2	1	3	2	2	1	2,3,4	2	2	2
Que.	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Ans.	2	2	4	4	1	4	3	1	4	2
Que.	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
Ans.	4	1	2	4	3	2	1	3	2	4
Que.	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
Ans.	3	1	3	1	2	3	3	1	4	3
Que.	**61**	**62**	**63**							
Ans.	3	3	4							

EXERCISE # JEE-ADVANCED

1. **Ans. 4**
2. **Ans. 0**
3. **Ans. 5**
4. **Ans. 6**
5. **Ans. 6**

Que.	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Ans.	A	A	A	D	C	A,B,C or A,C	3	D	B
Que.	**15**	**16**	**17**	**18**	**19**	**20**			
Ans.	D	B,C	A,C,D	A	A,B,C	5 or 6			