Chapter

3

Chemical Bonding

Atoms of different elements *excepting* noble gases donot have complete octet so they combine with other atoms to form chemical bond. *The force which holds the atoms or ions together within the molecule is called a* ***chemical bond*** and the process of their combination is called ***Chemical Bonding***. It depends on the valency of atoms.

Cause and Modes of chemical combination

Chemical bonding takes place due to *acquire a state of minimum energy and maximum stability* and to *convert atoms into molecule to acquire stable configuration of the nearest noble gas*. We divide atoms into three classes,

(1) Electropositive elements which give up one or more electrons easily. They have low ionisation potentials.

(2) Electronegative elements, which can gain electrons. They have higher value of electronegativity.

(3) Elements which have little tendency to lose or gain electrons.

Different types of bonds are formed from these types of atoms.

Atoms involved	**Type**
$A + B$	Electrovalent
$B + B$	Covalent
$A + A$	Metallic
Electrons deficient molecule or ion (Lewis acid) and electrons rich molecule or ion (Lewis base)	Coordinate
H and electronegative element (F, N, O)	Hydrogen

Electrovalent bond

An electrovalent bond is formed when a metal atom transfers one or more electrons to a non-metal atom.

$$\dot{Na} + \cdot\overset{\cdot\cdot}{\underset{\cdot\cdot}{Cl}}: \rightarrow \left[Na\right]^{+}\left[:\overset{\cdot\cdot}{\underset{\cdot\cdot}{Cl}}:\right]^{-} \quad \text{or} \quad Na^{+}Cl^{-}$$

Some other examples are: $MgCl_2$, $CaCl_2$, MgO, Na_2S, CaH_2, AlF_3, NaH, KH, K_2O, KI, $RbCl$, $NaBr$, CaH_2 etc.

(1) **Conditions for formation of electrovalent bond**

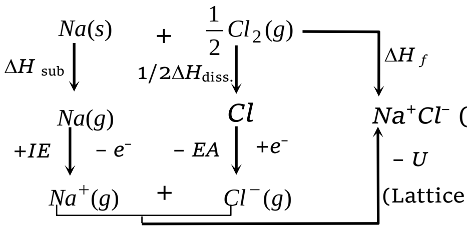
(i) The atom which changes into cation (+ ive ion) should possess 1, 2 or 3 valency electrons. The other atom which changes into anion (–*ve* ion) should possess 5, 6 or 7 electrons in the valency shell.

(ii) A high difference of electronegativity (about 2) of the two atoms is necessary for the formation of an electrovalent bond. *Electrovalent bond is not possible between similar atoms.*

(iii) *There must be overall decrease in energy i.e., energy must be released. For this an atom should have low value of* ***Ionisation potential*** *and the other atom should have high value of* ***electron affinity***.

(iv) *Higher the lattice energy, greater will be the case of forming an ionic compound. The amount of energy released when free ions combine together to form one mole of a crystal is called* ***lattice energy (U).*** Lattice energy $= \frac{K}{r^+ + r^-}$; $r^+ + r^-$ is internuclear distance.

The energy changes involved in the formation of ionic compounds from their constituent elements can be studied with the help of a thermochemical cycle called **Born Haber cycle.**



(Born Haber

According to Hess's law of constant heat summation, heat of formation of an ionic solid is net resultant of the above changes.

$$\Delta H_f = \Delta H_{\text{Subl.}} + \frac{1}{2}\Delta H_{\text{diss.}} + IE - EA - U$$

(2) **Characteristics of electrovalent compounds**

(i) Electrovalent compounds are generally crystalline is nature. The constituent ions are arranged in a regular way in their lattice.

(ii) Electrovalent compounds possess high melting and boiling points. Order of melting and boiling points in halides of sodium and oxides of II$^{\text{nd}}$ group elements is as,

$NaF > NaCl > NaBr > NaI,\ MgO > CaO > BaO$

(iii) Electrovalent compounds are hard and brittle in nature.

(iv) Electrovalent solids do not conduct electricity. While electrovalent compounds in the molten state or in solution conduct electricity.

(v) Electrovalent compounds are fairly soluble in polar solvents and insoluble in non-polar solvents.

(vi) The electrovalent bonds are non-rigid and non-directional. Thus these compound do not show space isomerism e.g. geometrical or optical isomerism.

(vii) Electrovalent compounds furnish ions in solution. *The chemical reaction of these compounds are known as ionic reactions, which are fast.*

$$K^+Cl^- + \overset{+}{Ag}\,\overset{-}{NO_3} \longrightarrow \underset{\text{(Precipitate)}}{\overset{+}{Ag}\,\overset{-}{Cl}}\downarrow + \overset{+}{K}\,\overset{-}{NO_3}$$

(viii) Electrovalent compounds show isomorphism.

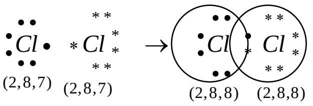
(ix) Cooling curve of an ionic compound is not smooth, it has two break points corresponding to time of solidification.

(x) Ionic compounds show variable electrovalency due to unstability of core and inert pair effect.

Covalent bond

Covalent bond was first proposed by **Lewis** in 1916. *The bond formed between the two atoms by mutual sharing of electrons so as to complete their octets or duplets (in case of elements having only one shell) is called* ***covalent bond or covalent linkage.*** A covalent bond between two similar atoms is non-polar covalent bond while it is polar between two different atom having different electronegativities. Covalent bond may be single, double or a triple bond. We explain covalent bond formation by Lewis octet rule.

Chlorine atom has seven electrons in the valency shell. In the formation of chlorine molecule, each chlorine atom contributes one electron and the pair of electrons is shared between two atoms. both the atoms acquire stable configuration of argon.



or $Cl - Cl$

Some other examples are : $H_2S, NH_3, HCN, PCl_3, PH_3,$ $C_2H_2, H_2, C_2H_4, SnCl_4, FeCl_3, BH_3,$ graphite, $BeCl_2$ etc.

(1) **Conditions for formation of covalent bond**

(i) The combining atoms should be short by 1, 2 or 3 electrons in the valency shell in comparison to stable noble gas configuration.

(ii) Electronegativity difference between the two atoms should be zero or very small.

(iii) The approach of the atoms towards one another should be accompanied by decrease of energy.

(2) **Characteristics of covalent compounds**

(i) These exist as gases or liquids under the normal conditions of temperature and pressure. Some covalent compounds exist as soft solids.

(ii) Diamond, Carborandum (SiC), Silica (SiO_2), AlN etc. have giant three dimensional network structures; therefore have exceptionally high melting points otherwise these compounds have relatively low melting and boiling points.

(iii) In general covalent substances are bad conductor of electricity. Polar covalent compounds like HCl in solution conduct electricity. Graphite can conduct electricity in solid state since electrons can pass from one layer to the other.

(iv) These compounds are generally insoluble in polar solvent like water but soluble in non-polar solvents like benzene etc. some covalent compounds like alcohol, dissolve in water due to hydrogen bonding.

(v) The covalent bond is rigid and directional. These compounds, thus show isomerism (structural and space).

(vi) Covalent substances show molecular reactions. The reaction rates are usually low.

(vii) *The number of electrons contributed by an atom of the element for sharing with other atoms is called covalency of the element.* Covalency = 8 – [Number of the group to which element belongs]. *The variable covalency of an element is equal to the total number of unpaired electrons in s, p and d-orbitals of its valency shell.*

The element such as *P*, *S*, *Cl*, *Br*, *I* have vacant *d*-orbitals in their valency shell. These elements show variable covalency by increasing the number of unpaired electrons under excited conditions. The electrons from paired orbitals get excited to vacant *d*-orbitals of the same shell.

Four elements, H, N, O and F do not possess d-orbitals in their valency shell. Thus, such an excitation is not possible and variable valency is not shown by these elements. This is reason that NCl_3 *exists while* NCl_5 *does not.*

(3) **The Lewis theory :** The tendency of atoms to achieve eight electrons in their outermost shell is known as lewis octet rule.

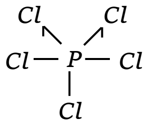
Lewis symbol for the representative elements are given in the following table,

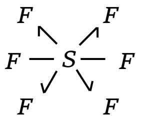
	1	2	13	14	15	16	17
Group	IA	IIA	IIIA	IVA	VA	VIA	VIIA
Lewis symbol	$X\bullet$	$\bullet X\bullet$	$\overset{\bullet}{\bullet X \bullet}$	$\underset{\bullet}{\overset{\bullet}{\bullet X \bullet}}$	$\underset{\bullet\bullet}{\overset{\bullet}{\bullet X \bullet}}$	$\underset{\bullet\bullet}{\overset{\bullet\bullet}{\bullet X \bullet}}$	$\underset{\bullet\bullet}{\overset{\bullet\bullet}{:X \bullet}}$

(4) **Failure of octet rule :** There are several stable molecules known in which the octet rule is violated *i.e.*, atoms in these molecules have number of electrons in the valency shell either short of octet or more than octet.

BeF_2, BF_3, AlH_3 are electron- deficients (Octet incomplete) hence are Lewis acid.

In PCl_5, P has 10 electrons in valency shell while in SF_6, S has 12 electrons in valence shell. **Sugden** introduced singlet linkage in which one electron is donated (Instead of one pair of electrons) to the electron deficient atom so that octet rule is not violated. This singlet is represented as ($\rightarrow$). Thus, PCl_5 and SF_6 have structures as,





(5) **Construction of structures for molecules and poly atomic ions :** The following method is applicable to species in which the octet rule is not violated.

(i) Determine the total number of valence electrons in all the atoms present, including the net charge on the species (n_1).

(ii) Determine n_2 = [2 × (number of H atoms) + 8 × (number of other atoms)].

(iii) Determine the number of bonding electrons, n_3, which equals $n_2 - n_1$. No. of bonds equals $n_3/2$.

(iv) Determine the number of non-bonding electrons, n_4, which equals $n_1 - n_3$. No. of lone pairs equals $n_4/2$.

(v) Knowing the central atom (you'll need to know some chemistry here, math will not help!), arrange and distribute other atoms and $n_3/2$ bonds. Then complete octets using $n_4/2$ lone pairs.

(vi) Determine the 'formal charge' on each atom.

(vii) Formal Charge = [valence electrons in atom) – (no. of bonds) – (no. of unshared electrons)]

(viii) Other aspects like resonance etc. can now be incorporated.

Illustrative examples

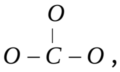
(i) $CO_3^{2-}; n_1 = 4 + (6 \times 3) + 2 = 24$ [2 added for net charge]

n_2 = (2 × 0) + (8 × 4) = 32 (no. *H* atom, 4 other atoms (1'*C*' and 3 '*O*')

n_3 = 32 – 24 = 8, hence 8/2 = 4 bonds

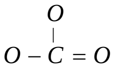
n_4 = 24 – 8 = 16, hence 8 lone pairs.

Since carbon is the central atom, 3 oxygen atoms are to be arranged around it, thus,

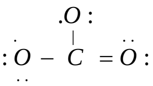


$O - \overset{\overset{O}{|}}{C} - O$, but total bonds are equal to 4.

Hence, we get



$O - \overset{\overset{O}{|}}{C} = O$. Now, arrange lone pairs to complete octet



$:\underset{..}{\overset{.}{O}} - \overset{\overset{.\ddot{O}:}{|}}{C} = \overset{..}{O}:$

(ii) CO_2; n_1 = 4 + (6 × 2) = 16

n_2 = (2 × 0) + (8 × 3) = 24

n_3 = 24 – 16 = 8, hence 4 bonds

n_4 = 16 – 8 = 8, hence 4 lone-pairs

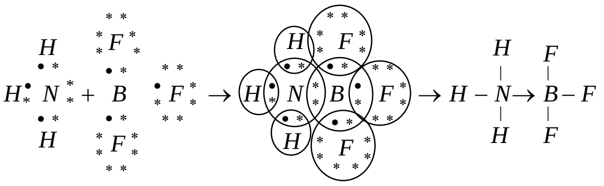
Since C is the central atom, the two oxygen atoms are around to be arranged it thus the structure would be; $O – C – O$, but total no. of bonds = 4

Thus, $O = C = O$. After arrangement of lone pairs to complete octets, we get, $:\ddot{O}=C=\ddot{O}:$ and thus final structure is $:\ddot{O}=C=\ddot{O}:$

Co-ordinate covalent or Dative bond

This is a special type of covalent bond where the shared pair of electrons are contributed by one species only but shared by both. The atom which contributes the electrons is called the **donor** (Lewis base) while the other which only shares the electron pair is known as **acceptor** (Lewis acid). This bond is usually represented by an arrow (→) pointing from donor to the acceptor atom.

BF_3 molecule, boron is short of two electrons. So to complete its octet, it shares the lone pair of nitrogen in ammonia forming a dative bond.



Formation of a co-ordinate

Examples : CO, N_2O, H_2O_2, N_2O_3, N_2O_4, N_2O_5, HNO_3, NO_3^-, SO_2, SO_3, H_2SO_4, SO_4^{2-}, SO_2^{2-}, H_3PO_4, $H_4P_2O_7$, $H_3PO_3, Al_2Cl_6\text{(Anhydrous)}, O_3, SO_2Cl_2, SOCl_2, HIO_3, HClO_4$, $HClO_3, CH_3NC, N_2H_5^+$, $CH_3NO_2, NH_4^+, [Cu(NH_3)_4]^{2+}$ etc.

Characteristics of co-ordinate covalent compound

(1) Their melting and boiling points are higher than purely covalent compounds and lower than purely ionic compounds.

(2) These are sparingly soluble in polar solvent like water but readily soluble in non-polar solvents.

(3) Like covalent compounds, these are also bad conductors of electricity. Their solutions or fused masses do not allow the passage to electricity.

(4) The bond is rigid and directional. Thus, coordinate compounds show isomerism.

Dipole moment

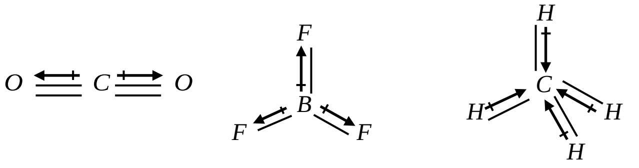
"*The product of magnitude of negative or positive charge (q) and the distance (d) between the centres of positive and negative charges is called dipole moment*".

μ = Electric charge × bond length

As q is in the order of 10^{-10} *esu* and d is in the order of 10^{-8} *cm*, μ is in the order of 10^{-18} *esu cm*. Dipole moment is measured in "*Debye*" (D) unit. $1D = 10^{-18}$ *esu cm* = 3.33×10^{-30} *coulomb metre* (In S.I. unit).

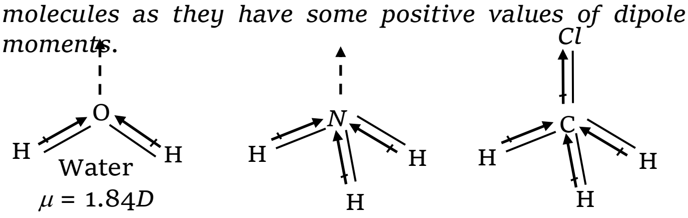
Dipole moment is indicated by an arrow having a symbol ( ) pointing towards the negative end. Dipole moment has both magnitude and direction and therefore it is a vector quantity.

***Symmetrical polyatomic molecules** are not polar so they do not have any value of dipole moment.*



μ = 0 due to symmetry

***Unsymmetrical polyatomic molecules** always have net value of dipole moment, thus such molecules are polar in nature. H_2O, CH_3Cl, NH_3, etc are polar molecules as they have some positive values of dipole moments.*



Water
μ = 1.84D

Ammonia
μ = 1.46D

Methyl chloride

$\mu \neq 0$ due to unsymmetry

(1) Dipole moment is an important factor in determining the geometry of molecules.

Table : 3.1 Molecular geometry and dipole moment

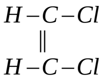
General formula	Molecular geometry	Dipole moment	Example
AX	Linear	May be non zero	HF, HCl
AX_2	Linear	Zero	CO_2, CS_2
	Bent or V-shape	Non zero	H_2O, NO_2
AX_3	Triangular planar	Zero	BF_3
	Pyramidal	Non zero	NH_3, PCl_3
	T-shape	Non zero	ClF_3
AX_4	Tetrahedral	Zero	CH_4, CCl_4
	Square planar	Zero	XeF_4
	See saw	Non zero	$SF_4, TeCl_4$
AX_5	Trigonal bipyramidal	Zero	PCl_5
	Square pyramidal	Non zero	$BrCl_5$
AX_6	Octahedral	Zero	SF_6
	Distorted octahedral	Non zero	XeF_6

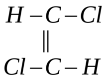
AX_7	Pentagonal bipyramidal	Zero	IF_7

(2) Every ionic compound having some percentage of covalent character according to Fajan's rule. The percentage of ionic character in compound having some covalent character can be calculated by the following equation.

The % ionic character $= \frac{\text{Observed } \mu}{\text{Theoretical } \mu} \times 100$.

(3) The trans isomer usually possesses either zero dipole moment or very low value in comparison to *cis*–form


$$\begin{array}{c} H-C-Cl \\ \| \\ H-C-Cl \end{array}$$


$$\begin{array}{c} H-C-Cl \\ \| \\ Cl-C-H \end{array}$$

Fajan’s rule

The magnitude of polarization or increased covalent character depends upon a number of factors. These factors are,

(1) **Small size of cation :** *Smaller size of cation greater is its polarizing power i.e. greater will be the covalent nature of the bond.*

(2) **Large size of anion :** *Larger the size of anion greater is its polarizing power i.e. greater will be the covalent nature of the bond.*

(3) **Large charge on either of the two ions :** *As the charge on the ion increases, the electrostatic attraction of the cation for the outer electrons of the anion also increases with the result its ability for forming the covalent bond increases.*

(4) **Electronic configuration of the cation :** For the two ions of the same size and charge, one with a pseudo noble gas configuration (i.e. 18 electrons in the outermost shell) will be more polarizing than a cation with noble gas configuration (i.e., 8 electron in outer most shell).

Valence bond theory or VBT

It was developed by Heitler and London in 1927 and modified by Pauling and Slater in 1931.

(1) To form a covalent bond, two atoms must come close to each other so that orbitals of one overlaps with the other.

(2) Orbitals having unpaired electrons of anti spin overlaps with each other.

(3) After overlapping a new localized bond orbital is formed which has maximum probability of finding electrons.

(4) Covalent bond is formed due to electrostatic attraction between radii and the accumulated electrons cloud and by attraction between spins of anti spin electrons.

(5) *Greater is the overlapping, lesser will be the bond length, more will be attraction and more will be bond energy and the stability of bond will also be high.*

(6) The extent of overlapping depends upon: Nature of orbitals involved in overlapping, and nature of overlapping.

(7) More closer the valence shells are to the nucleus, more will be the overlapping and the bond energy will also be high.

(8) Between two sub shells of same energy level, the sub shell more directionally concentrated shows more overlapping. Bond energy : $2s-2s <$ $2s-2p <$ $2p-2p$

(9) s-orbitals are spherically symmetrical and thus show only head on overlapping. On the other hand, p-orbitals are directionally concentrated and thus show either head on overlapping or lateral overlapping.Overlapping of different type gives sigma (σ) and pi (π) bond.

Sigma (σ) bond	***Pi* (π) bond**
It results from the end to end overlapping of two *s*-orbitals or two *p*-orbitals or one *s* and one *p*-orbital.	It result from the sidewise (lateral) overlapping of two *p*-orbitals.
Stronger	Less strong
Bond energy 80 *kcals*	Bond energy 65 *kcals*
More stable	Less stable
Less reactive	More reactive
Can exist independently	Always exist along with a σ-bond
The electron cloud is symmetrical about the internuclear axis.	The electron cloud is above and below the plane of internuclear axis.

Hybridization

The concept of hybridization was introduced by **Pauling** and **Slater**. Hybridization is defined as the intermixing of dissimilar orbitals of the same atom but having slightly different energies to form same number of new orbitals of equal energies and identical shapes. The new orbitals so formed are known as **hybrid orbitals**.

Characteristics of hybridization

(1) Only orbitals of almost similar energies and belonging to the same atom or ion undergoes hybridization.

(2) Hybridization takes place only in orbitals, electrons are not involved in it.

(3) The number of hybrid orbitals produced is equal to the number of pure orbitals, mixed during hybridization.

(4) In the excited state, the number of unpaired electrons must correspond to the oxidation state of the central atom in the molecule.

(5) Both half filled orbitals or fully filled orbitals of equivalent energy can involve in hybridization.

(6) Hybrid orbitals form only sigma bonds.

(7) Orbitals involved in π bond formation do not participate in hybridization.

(8) Hybridization never takes place in an isolated atom but it occurs only at the time of bond formation.

(9) The hybrid orbitals are distributed in space as apart as possible resulting in a definite geometry of molecule.

(10) Hybridized orbitals provide efficient overlapping than overlapping by pure s, p and d-orbitals.

(11) Hybridized orbitals possess lower energy.

***How to determine type of hybridization* :** The structure of any molecule can be predicted on the basis of hybridization which in turn can be known by the following general formulation,

$$H = \frac{1}{2}(V + M - C + A)$$

Where H = Number of orbitals involved in hybridization viz. 2, 3, 4, 5, 6 and 7, hence nature of hybridization will be sp, sp^2, sp^3, sp^3d, sp^3d^2, sp^3d^3 respectively.

V = Number electrons in valence shell of the central atom,

M = Number of monovalent atom

C = Charge on cation,

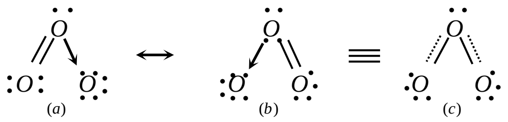
A = Charge on anion

Resonance

The phenomenon of resonance was put forward by **Heisenberg** to explain the properties of certain molecules.

In case of certain molecules, a single Lewis structure cannot explain all the properties of the molecule. The molecule is then supposed to have many structures, each of which can explain most of the properties of the molecule but none can explain all the properties of the molecule. The actual structure is in between of all these contributing structures and is called **resonance hybrid** and the different individual structures are called **resonating structures** or **canonical forms**. This phenomenon is called **resonance**.

To illustrate this, consider a molecule of ozone O_3. Its structure can be written as



As a resonance hybrid of above two structures (*a*) and (*b*). For simplicity, ozone may be represented by structure (*c*), which shows the resonance hybrid having equal bonds between single and double.

Resonance is shown by benzene, toluene, O_3*, allenes* ($>C = C = C<$), CO, CO_2, CO_3^-, SO_3, NO, NO_2 *while it is not shown by* H_2O_2, H_2O, NH_3, CH_4, SiO_2.

As a result of resonance, the bond lengths of single and double bond in a molecule become equal e.g. *O–O* bond lengths in ozone or *C–O* bond lengths in CO_3^{2-} ion.

The resonance hybrid has lower energy and hence greater stability than any of the contributing structures.

Greater is the number of canonical forms especially with nearly same energy, greater is the stability of the molecule.

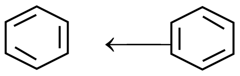
Difference between the energy of resonance hybrid and that of the most stable of the resonating structures (having least energy) is called resonance energy. Thus,

Resonance energy = Energy of resonance hybrid – Energy of the most stable of resonating structure.

In the case of molecules or ions having resonance, the bond order changes and is calculated as follows,

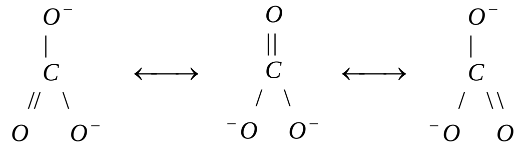
$$\text{Bond order} = \frac{\text{Total no. of bonds between two atoms in all the structures}}{\text{Total no. of resonating structures}}$$

In benzene



$$\text{Bond order} = \frac{\text{double bond} + \text{single bond}}{2} = \frac{2+1}{2} = 1.5$$

In carbonate ion



$$\text{Bond order} = \frac{2+1+1}{3} = 1.33$$

Bond characteristics

(1) **Bond length**

"The average distance between the centre of the nuclei of the two bonded atoms is called bond length".

It is expressed in terms of Angstrom (1 Å = 10^{-10} *m*) or picometer (1pm = 10^{-12} *m*).

In an ionic compound, the bond length is the sum of their ionic radii ($d = r_+ + r_-$) and in a covalent compound, it is the sum of their covalent radii (e.g., for *HCl*, $d = r_H + r_{Cl}$).

Factors affecting bond length

(i) The bond length increases with increase in the size of the atoms. For example, bond length of $H-X$ are in the order, $HI > HBr > HCl > HF$.

(ii) The bond length decreases with the multiplicity of the bond. Thus, bond length of carbon–carbon bonds are in the order, $C \equiv C < C = C < C - C$.

(iii) As an s-orbital is smaller in size, greater the s-character shorter is the hybrid orbital and hence shorter is the bond length.

For example, $sp^3\, C-H > sp^2\, C-H > sp\, C-H$

(iv) Polar bond length is usually smaller than the theoretical non-polar bond length.

(2) **Bond energy**

"The amount of energy required to break one mole of bonds of a particular type so as to separate them into gaseous atoms is called **bond dissociation energy** or simply **bond energy**". Greater is the bond energy, stronger is the bond. Bond energy is usually expressed in $kJ\, mol^{-1}$.

Factors affecting bond energy

(i) Greater the size of the atom, greater is the bond length and less is the bond dissociation energy i.e. less is the bond strength.

(ii) For the bond between the two similar atoms, greater is the multiplicity of the bond, greater is the bond dissociation energy.

(iii) Greater the number of lone pairs of electrons present on the bonded atoms, greater is the repulsion between the atoms and hence less is the bond dissociation energy.

(iv) The bond energy increases as the hybrid orbitals have greater amount of *s* orbital contribution. Thus, *bond energy decreases in the following order*, $sp > sp^2 > sp^3$

(v) *Greater the electronegativity difference, greater is the bond polarity and hence greater will be the bond strength i.e., bond energy,* $H-F > H-Cl > H-Br > H-I$,

(vi) Among halogens *Cl – Cl > F – F > Br – Br > I – I,* (Decreasing order of bond energy) Resonance increases bond energy.

(3) **Bond angle**

In case of *molecules made up of three or more atoms, the average angle between the bonded orbitals (i.e., between the two covalent bonds) is known as bond angle θ.*

Factors affecting bond angle

(i) *Repulsion between atoms or groups attached to the central atom may increase or decrease the bond angle.*

(ii) In hybridisation *as the s character of the s hybrid bond increases, the bond angle increases*.

Bond type	sp^3	sp^2	sp
Bond angle	109°28′	120°	180°

(iii) *By increasing lone pair of electron, bond angle decreases approximately by* 2.5%.

	CH_4	NH_3	H_2O
Bond angle	109°	107°	105°

(iv) *If the electronegativity of the central atom decreases, bond angle decreases.*

	H_2O	$> H_2S$	$> H_2Se$	$> H_2Te$
Bond angle	104.5°	92.2°	91.2°	89.5°

In case the central atom remains the same, bond angle increases with the decrease in electronegativity of the surrounding atom.

	PCl_3	PBr_3	PI_3 ,	$AsCl_3$	$AsBr_3$	AsI_3
Bond angle	100°	101.5°	102°	98.4°	100.5°	101°

Valence shell electron pair repulsion theory (VSEPR)

The basic concept of the theory was suggested by **Sidgwick** and **Powell** (1940). It provides useful idea for predicting shapes and geometries of molecules. The concept tells that, the arrangement of bonds around the central atom depends upon the repulsion's operating between electron pairs(bonded or non bonded) around the central atom. **Gillespie** and **Nyholm** developed this concept as VSEPR theory.

The main postulates of VSEPR theory are

(1) For polyatomic molecules containing 3 or more atoms, *one of the atoms is called the central atom to which other atoms are linked.*

(2) The geometry of a molecule depends upon the total number of valence shell electron pairs (bonded or not bonded) present around the central atom and their repulsion due to relative sizes and shapes.

(3) If the central atom is surrounded by bond pairs only. It gives the symmetrical shape to the molecule.

(4) If the central atom is surrounded by lone pairs (lp) as well as bond pairs (bp) of e^- then the molecule has a distorted geometry.

(5) *The relative order of repulsion between electron pairs is as follows : lp – lp > lp – bp > bp – bp.*

A lone pair is concentrated around the central atom while a bond pair is pulled out between two bonded atoms. As such repulsion becomes greater when a lone pair is involved.

Table : 3.2 Geometry of Molecules/Ions having bond pair as well as lone pair of electrons

Type of molecule	No. of bond pairs of electron	No. of lone pairs of electrons	Hybridization	Bond angle	Expected geometry	Actual geometry	Examples
AX_3	2	1	sp^2	$< 120^\circ$	Trigonal planar	V-shape, Bent, Angular	SO_2, $SnCl_2$, NO_2^-
AX_4	2	2	sp^3	$< 109^\circ 28'$	Tetrahedral	V-shape, Angular	H_2O, H_2S, SCl_2, OF_2, NH_2^-, ClO_2^-
AX_4	3	1	sp^3	$< 109^\circ 28'$	Tetrahedral	Pyramidal	NH_3, NF_3 , PCl_3, PH_3, AsH_3, ClO_3^- , H_3O^+
AX_5	4	1	sp^3d	$< 109^\circ 28'$	Trigonal bipyramidal	Irregular tetrahedron	SF_4, SCl_4, $TeCl_4$
AX_5	3	2	sp^3d	90°	Trigonal bipyramidal	T-shaped	ICl_3, IF_3, ClF_3
AX_5	2	3	sp^3d	180°	Trigonal bipyramidal	Linear	XeF_2, I_3^-, ICl_2^-
AX_6	5	1	sp^3d^2	$< 90^\circ$	Octahedral	Square pyramidal	ICl_5, BrF_5, IF_5
AX_6	4	2	sp^3d^2	–	Octahedral	Square planar	XeF_4, ICl_4^-
AX_7	6	1	sp^3d^3	–	Pentagonal pyramidal	Distorted octahedral	XeF_6

Molecular orbital theory or MOT

Molecular orbital theory was given by **Hund** and **Mulliken** in 1932.

The main ideas of this theory are,

(1) When two atomic orbitals combine or overlap, they lose their identity and form new orbitals. The new orbitals thus formed are called **molecular orbitals**.

(2) Molecular orbitals are the energy states of a molecule in which the electrons of the molecule are filled just as atomic orbitals are the energy states of an atom in which the electrons of the atom are filled.

(3) In terms of probability distribution, a molecular orbital gives the electron probability distribution around a group of nuclei just as an atomic orbital gives the electron probability distribution around the single nucleus.

(4) Only those atomic orbitals can combine to form molecular orbitals which have comparable energies and proper orientation.

(5) The number of molecular orbitals formed is equal to the number of combining atomic orbitals.

(6) When two atomic orbitals combine, they form two new orbitals called bonding molecular orbital and antibonding molecular orbital.

(7) The bonding molecular orbital has lower energy and hence greater stability than the corresponding antibonding molecular orbital.

(8) The bonding molecular orbitals are represented by σ, π etc, whereas the corresponding antibonding molecular orbitals are represented by σ^*, π^* etc.

(9) The shapes of the molecular orbitals formed depend upon the type of combining atomic orbitals.

(10) The filling of molecular orbitals in a molecule takes place in accordance with **Aufbau principle, Pauli's exclusion principle** and **Hund's rule**. The general order of increasing energy among the molecular orbitals formed by the elements of second period and hydrogen and their general electronic configurations are given below.

(11) Electrons are filled in the increasing energy of the *MO* which is in order

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

$\pi 2p_z, \quad \pi^* 2p_z$

Increasing energy (for electrons > 14)

$$\xrightarrow{\hspace{6cm}}$$

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

$\pi^* 2p_z$

Increasing energy (for electrons ≤ 14)

$$\xrightarrow{\hspace{6cm}}$$

(12) Number of bonds between two atoms is called **bond order** and is given by

$$\text{Bond order } = \left(\frac{N_B - N_A}{2}\right)$$

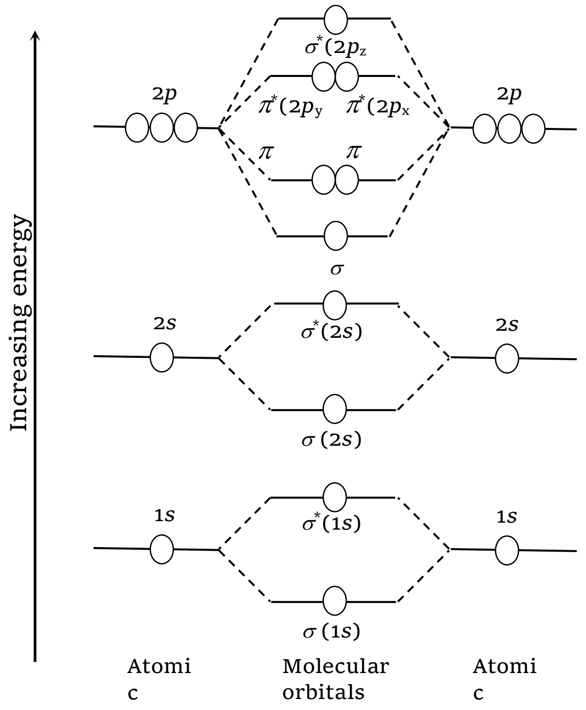
where $N_B =$ number of electrons in bonding *MO*.

$N_A =$ number of electrons in antibonding *MO*.

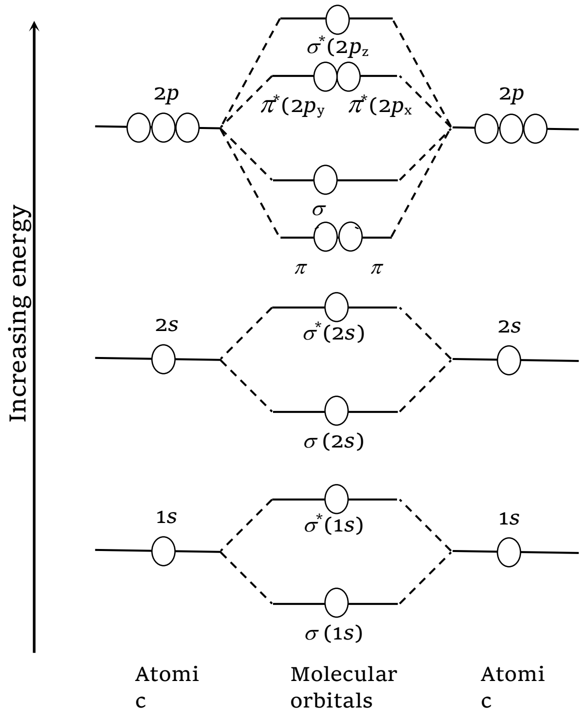
For a stable molecule/ion, $N_B > N_A$

(13) *Bond order* $\propto$ *Stability of molecule* $\propto$ *Dissociation energy* $\propto \frac{1}{\text{Bond length}}$.

(14) If all the electrons in a molecule are paired then the substance is a diamagnetic on the other hand if there are unpaired electrons in the molecule, then the substance is paramagnetic. More the number of unpaired electron in the molecule greater is the paramagnetism of the substance.



Molecular orbital energy level diagram (Applicable for elements with Z > 7)



Molecular orbital energy level diagram obtained by the overlap of 2*s* and 2p_z atomic orbitals after mixing (Applicable for elements with *Z* < 7)

Hydrogen bonding

In 1920, **Latimer** and **Rodebush** introduced the idea of "**hydrogen bond**".

For the formation of H-bonding the molecule should contain an atom of high electronegativity such as F, O or N bonded to hydrogen atom and the size of the electronegative atom should be quite small.

Types of hydrogen bonding

(1) **Intermolecular hydrogen bond :** Intermolecular hydrogen bond is formed between two different molecules of the same or different substances.

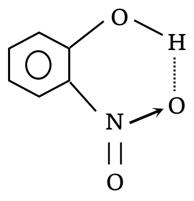
(i) Hydrogen bond between the molecules of hydrogen fluoride.

(ii) Hydrogen bond in alcohol and water molecules

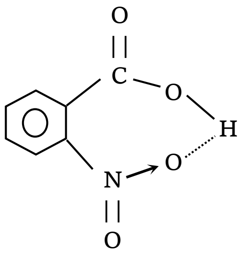
(2) **Intramolecular hydrogen bond** (Chelation)

Intramolecular hydrogen bond is formed between the hydrogen atom and the highly electronegative atom (F, O or N) present in the same molecule. Intramolecular hydrogen bond results in the cyclisation of the molecules and prevents their association. Consequently, the effect of intramolecular hydrogen bond on the physical properties is negligible.

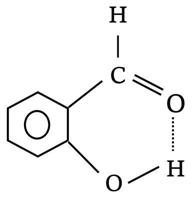
For example : Intramolecular hydrogen bonds are present in molecules such as o-nitrophenol, o-nitrobenzoic acid, etc.



Ortho nitrophenol



Ortho nitrobenzoic acid



Salicyldehyde (o-hydroxy

The extent of both intramolecular and intermolecular hydrogen bonding depends on temperature.

Effects of hydrogen bonding

Hydrogen bond helps in explaining the abnormal physical properties in several cases. Some of the properties affected by H-bond are given below,

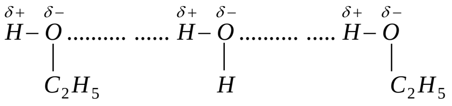
(1) **Dissociation :** In aqueous solution, hydrogen fluoride dissociates and gives the difluoride ion (HF_2^-) instead of fluoride ion (F^-). This is due to H-bonding in HF. This explains the existence of KHF_2. H-bond formed is usually longer than the covalent bond present in the molecule (e.g. in H_2O, $O–H$ bond = 0.99 $Å$ but H-bond = 1.77 $Å$).

(2) **Association :** The molecules of carboxylic acids exist as dimers because of the hydrogen bonding. The molecular masses of such compounds are found to be double than those calculated from their simple formulae. For example, molecular mass of acetic acid is found to be 120.

(3) **High melting and boiling point :** The compounds having hydrogen bonding show abnormally high melting and boiling points.

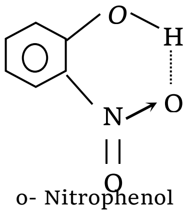
The high melting points and boiling points of the compounds $(H_2O, HF$ and $NH_3)$ containing hydrogen bonds is due to the fact that some extra energy is needed to break these bonds.

(4) **Solubility :** The compound which can form hydrogen bonds with the covalent molecules are soluble in such solvents. For example, *lower alcohols are soluble in water because of the hydrogen bonding which can take place between water and alcohol molecules* as shown below,



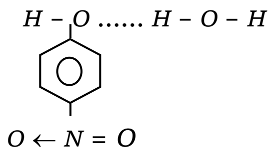
$$\underset{\displaystyle C_2H_5}{\overset{\delta+\;\;\delta-}{H-O}}\;..........\;......\;\underset{\displaystyle H}{\overset{\delta+\;\;\delta-}{H-O}}\;..........\;.....\;\underset{\displaystyle C_2H_5}{\overset{\delta+\;\;\delta-}{H-O}}$$

The intermolecular hydrogen bonding increases solubility of the compound in water while, the intramolecular hydrogen bonding decreases.



o- Nitrophenol

Due to chelation, – OH group is not available to form hydrogen bond with water hence it is sparingly



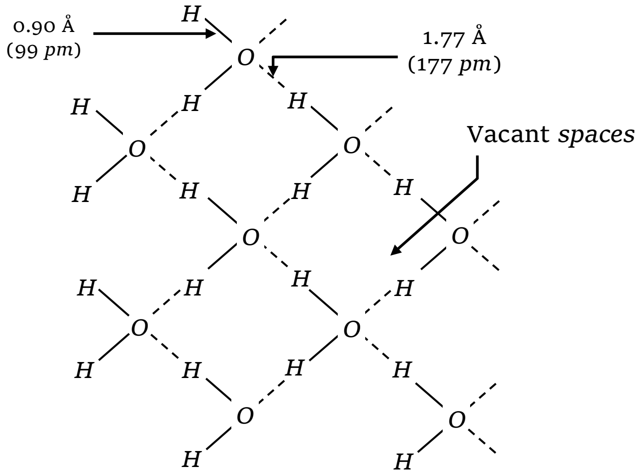
p- Nitrophenol

– OH group available to form hydrogen bond with water, hence it is completely soluble in

(5) As the compounds involving hydrogen bonding between different molecules (intermolecular hydrogen bonding) have higher boiling points, so they are less volatile.

(6) The substances which contain hydrogen bonding have higher viscosity and high surface tension.

(7) **Explanation of lower density of ice than water and maximum density of water at 277*K* :** In case of *solid ice, the hydrogen bonding gives rise to a cage like structure of water molecules* as shown in following figure. As a matter of fact, *each water molecule is linked tetrahedrally to four other water molecules. Due to this structure ice has lower density than water at* $273\,K$. *That is why ice floats on water*. On heating, the hydrogen bonds start collapsing, obviously the molecules are not so closely packed as they are in the liquid state and thus the molecules start coming together resulting in the decrease of volume and hence increase of density. This goes on upto 277*K*. *After 277 K, the increase in volume due to expansion of the liquid water becomes much more than the decrease in volume due to breaking of H-bonds. Thus, after* $277\,K$*, there is net increase of volume on heating which means decrease in density. Hence density of water is maximum* $277\,K$.



Cage like structure of H_2O in the ice

Tips & Tricks

- A chemical bond is expected to be formed when the energy of the aggregate formed is about 40 *kJ mole*$^{-1}$ lower than the separate particles.
- Formation of a chemical bond is always an exothermic process.
- Lattice energies of bi-bivalent solids > bi-univalent solids > uni-univalent solids. For example, lattice energy of $Mg^{2+}O^{2-}(3932\ kJ\ mole^{-1}) > Ca^{2+}(F^-)_2\ (2581\ kJ\ mole^{-1}) > Li^+F^-(1034\ kJ\ mole^{-1})$.
- When co-ordination number increases, the coulombic forces of attraction increases and hence stability increases.
- Ionic solids have negative vapour pressure.
- As a general rule, atomic crystals are formed by the lighter elements of the middle columns of the periodic table.
- $FeCl_3$ is more covalent than $FeCl_2$ because polarising power of Fe^{3+} is more than that of Fe^{2+}. Similarly $SnCl_4$ is more covalent than $SnCl_2$.
- Boron forms the maximum number of electron deficient compounds than any other elements in the periodic table.
- Roughly each lone pair decreases the bond angle by 2.5°.
- Greater the number of the lone pairs at the two bonding atoms, greater is the repulsion between them and weaker is the bond.
- The actual number of *s*- and *p*-electrons present in the outermost shell of the element is called maximum covalency of that atom.
- The hydrogen bonds are tetrahedral in their directions and not planar.
- The hydrogen bond is stronger in *HF* and persists even in vapour state. Such bonds account for the fact that gaseous hydrogen fluoride is largely polymerised into the molecular species $H_2F_2, H_3F_3,\ H_4F_4, H_5F_5$ and H_6F_6.
- Hydrogen bonding is strongest when the bonded structure is stabilised by resonance.
- Critical temperature of water is higher than that of O_2 because H_2O molecule has dipole moment.

Ordinary Thinking

Objective Questions

Electrovalent bonding

1. Which forms a crystal of $NaCl$ **[CPMT 1972; NCERT 1976; DPMT 1996]**

(a) $NaCl$ molecules (b) Na^+ and Cl^- ions

(c) Na and Cl atoms (d) None of the above

2. When sodium and chlorine reacts then **[NCERT 1973]**

(a) Energy is released and ionic bond is formed

(b) Energy is released and a covalent bond is formed

(c) Energy is absorbed and ionic bond is formed

(d) Energy is absorbed and covalent bond is formed

3. Which one is least ionic in the following compounds **[CPMT 1976; BHU 1998]**

(a) $AgCl$ (b) KCl

(c) $BaCl_2$ (d) $CaCl_2$

4. The electronic configuration of four elements *L, P, Q* and *R* are given in brackets

$L(1s^2,\ 2s^2\ 2p^4);\ Q(1s^2,\ 2s^2\ 2p^6,\ 3s^2\ 3p^5)$

$P(1s^2,\ 2s^2\ 2p^6,\ 3s^1);\ R(1s^2,\ 2s^2\ 2p^6,\ 3s^2)$

The formulae of ionic compounds that can be formed between these elements are **[NCERT 1983]**

(a) $L_2P,\ RL,\ PQ$ and R_2Q (b) $LP,\ RL,\ PQ$ and RQ

(c) $P_2L,\ RL,\ PQ$ and RQ_2 (d) $LP,\ R_2L,\ P_2Q$ and RQ

5. Electrovalent compound's **[MP PMT 1984]**

(a) Melting points are low

(b) Boiling points are low

(c) Conduct current in fused state

(d) Insoluble in polar solvent

6. A electrovalent compound is made up of **[CPMT 1978, 81; MNR 1979]**

(a) Electrically charged molecules

(b) Neutral molecules

(c) Neutral atoms

(d) Electrically charged atoms or group of atoms

7. Electrovalent bond formation depends on

(a) Ionization energy (b) Electron affinity
(c) Lattice energy (d) All the three above

8. In the following which substance will have highest boiling point **[NCERT 1973; MP PMT 1990]**
(a) He (b) CsF
(c) NH_3 (d) $CHCl_3$

9. An atom of sodium loses one electron and chlorine atom accepts one electron. This result the formation of sodium chloride molecule. This type of molecule will be **[MP PMT 1987]**
(a) Coordinate (b) Covalent
(c) Electrovalent (d) Metallic bond

10. Formula of a metallic oxide is MO. The formula of its phosphate will be **[CPMT 1986, 93]**
(a) $M_2(PO_4)_2$ (b) $M(PO_4)$
(c) M_2PO_4 (d) $M_3(PO_4)_2$

11. From the following which group of elements easily forms cation
(a) F, Cl, Br (b) Li, Na, K
(c) O, S, Se (d) N, P, As

12. Which type of compounds show high melting and boiling points **[CPMT 1996]**
(a) Electrovalent compounds
(b) Covalent compounds
(c) Coordinate compounds
(d) All the three types of compounds have equal melting and boiling points

13. Lattice energy of an ionic compound depends upon **[AIEEE 2005]**
(a) Charge on the ion only
(b) Size of the ion only
(c) Packing of ions only
(d) Charge on the ion and size of the ion

14. In the given bonds which one is most ionic **[EAMCET 1980]**
(a) $Cs-Cl$ (b) $Al-Cl$
(c) $C-Cl$ (d) $H-Cl$

15. Element x is strongly electropositive and y is strongly electronegative. Both element are univalent, the compounds formed from their combination will be **[IIT 1980]**
(a) x^+y^- (b) x^-y^+
(c) $x-y$ (d) $x \rightarrow y$

16. In the formation of $NaCl$ from Na and Cl **[CPMT 1985]**
(a) Sodium and chlorine both give electrons
(b) Sodium and chlorine both accept electrons
(c) Sodium loses electron and chlorine accepts electron
(d) Sodium accepts electron and chlorine loses electron

17. Which of the following is an electrovalent linkage **[CPMT 1974; DPMT 1984, 91; AFMC 1988]**
(a) CH_4 (b) $MgCl_2$
(c) $SiCl_4$ (d) BF_3

18. Electrovalent compounds do not have **[CPMT 1991]**
(a) High M.P. and Low B.P. (b) High dielectric constant
(c) High M.P. and High B.P. (d) High polarity

19. Many ionic crystals dissolve in water because **[NCERT 1982]**
(a) Water is an amphiprotic solvent
(b) Water is a high boiling liquid
(c) The process is accompanied by a positive heat of solution
(d) Water decreases the interionic attraction in the crystal lattice due to solvation

20. The electronic structure of four elements A, B, C, D are
(A) $1s^2$ (B) $1s^2, 2s^2\,2p^2$
(C) $1s^2, 2s^2\,2p^5$ (D) $1s^2, 2s^2\,2p^6$
The tendency to form electrovalent bond is largest in **[MNR 1987, 95]**
(a) A (b) B
(c) C (d) D

21. Chloride of metal is MCl_2. The formula of its phosphate will be **[CPMT 1979]**
(a) M_2PO_4 (b) $M_3(PO_4)_2$
(c) $M_2(PO_4)_3$ (d) MPO_4

22. The phosphate of a metal has the formula MPO_4. The formula of its nitrate will be
(a) MNO_3 (b) $M_2(NO_3)_2$
(c) $M(NO_3)_2$ (d) $M(NO_3)_3$

23. In the transition of Zn atoms to Zn^{++} ions there is a decrease in the **[CPMT 1972]**
(a) Number of valency electrons
(b) Atomic weight
(c) Atomic number
(d) Equivalent weight

24. Phosphate of a metal M has the formula $M_3(PO_4)_2$. The formula for its sulphate would be **[CPMT 1973; MP PMT 1996]**
(a) MSO_4 (b) $M(SO_4)_2$

(c) $M_2(SO_4)_3$ (d) $M_3(SO_4)_2$

25. The molecular formula of chloride of a metal M is MCl_3. The formula of its carbonate would be **[CPMT 1987]**

(a) MCO_3 (b) $M_2(CO_3)_3$

(c) M_2CO_3 (d) $M(CO_3)_2$

26. Sodium chloride easily dissolves in water. This is because

[NCERT 1972; BHU 1973]

(a) It is a covalent compound

(b) Salt reacts with water

(c) It is a white substance

(d) Its ions are easily solvated

27. When $NaCl$ is dissolved in water the sodium ion becomes

[NCERT 1974; CPMT 1989; MP PMT 1999]

(a) Oxidized (b) Reduced

(c) Hydrolysed (d) Hydrated

28. Solid $NaCl$ is a bad conductor of electricity since

[AFMC 1980]

(a) In solid $NaCl$ there are no ions

(b) Solid $NaCl$ is covalent

(c) In solid $NaCl$ there is no motion of ions

(d) In solid $NaCl$ there are no electrons

29. Favourable conditions for electrovalency are

(a) Low charge on ions, large cation, small anion

(b) High charge on ions, small cation, large anion

(c) High charge on ions, large cation, small anion

(d) Low charge on ions, small cation, large anion

30. The sulphate of a metal has the formula $M_2(SO_4)_3$. The formula for its phosphate will be

[DPMT 1982; CPMT 1972; MP PMT 1995]

(a) $M(HPO_4)_2$ (b) $M_3(PO_4)_2$

(c) $M_2(PO_4)_3$ (d) MPO_4

31. Ionic bonds are usually formed by combination of elements with **[CBSE PMT 1993; MP PMT 1994]**

(a) High ionisation potential and low electron affinity

(b) Low ionisation potential and high electron affinity

(c) High ionisation potential and high electron affinity

(d) Low ionisation potential and low electron affinity

32. Molten sodium chloride conducts electricity due to the presence of **[IIT 1981]**

(a) Free electrons

(b) Free ions

(c) Free molecules

(d) Atoms of sodium and chlorine

33. The phosphate of a metal has the formula $MHPO_4$. The formula of its chloride would be

[NCERT 1974; CPMT 1977]

(a) MCl (b) MCl_2

(c) MCl_3 (d) M_2Cl_3

34. A number of ionic compounds *e.g.* $AgCl, CaF_2, BaSO_4$ are insoluble in water. This is because **[NCERT 1984]**

(a) Ionic compounds do not dissolve in water

(b) Water has a high dielectric constant

(c) Water is not a good ionizing solvent

(d) These molecules have exceptionally high alternative forces in the lattice

35. What is the nature of chemical bonding between Cs and F

[MP PMT 1987; CPMT 1976]

(a) Covalent (b) Ionic

(c) Coordinate (d) Metallic

36. Which one of the following compound is ionic

[MNR 1985]

(a) KCl (b) CH_4

(c) Diamond (d) H_2

37. Which of the following compound has electrovalent linkage

[CPMT 1983, 84, 93]

(a) CH_3Cl (b) $NaCl$

(c) CH_4 (d) Cl_2

38. An ionic compound is generally a **[MADT Bihar 1981]**

(a) Good electrolyte (b) Weak electrolyte

(c) Non-electrolyte (d) Neutral

39. What metals combine with non-metals, the metal atom tends to **[AMU 1982]**

(a) Lose electrons

(b) Gain electrons

(c) Remain electrically neutral

(d) None of these

40. Chemical formula for calcium pyrophosphate is $Ca_2P_2O_7$. The formula for ferric pyrophosphate will be **[NCERT 1977]**

(a) $Fe_3(P_2O_7)_3$ (b) $Fe_4P_4O_{14}$

(c) $Fe_4(P_2O_7)_3$ (d) Fe_3PO_4

41. Among the bonds formed by a chlorine atom with atoms of hydrogen, chlorine, sodium and carbon, the strongest bond is formed between **[EAMCET 1988; MP**

(a) $H-Cl$ (b) $Cl-Cl$

(c) $Na-Cl$ (d) $C-Cl$

42. Which of the following is least soluble **[CPMT 1989]**

(a) BeF_2 (b) SrF_2

(c) CaF_2 (d) MgF_2

43. Which of the following halides has maximum melting point

(a) $NaCl$ (b) $NaBr$

(c) NaI (d) NaF

44. The high melting point and insolubility in organic solvents of sulphanilic acid are due to its ...... structure. **[IIT 1994]**

(a) Simple ionic (b) Bipolar ionic

(c) Cubic (d) Hexagonal

45. Out of the following, which compound will have electrovalent bonding

(a) Ammonia (b) Water

(c) Calcium chloride (d) Chloromethane

46. The force which holds atoms together in an electrovalent bond is

(a) Vander Waal's force

(b) Dipole attraction force

(c) Electrostatic force of attraction

(d) All the above

47. The main reaction during electrovalent bond formation is

(a) Redox reaction (b) Substitution reaction

(c) Addition reaction (d) Elimination reaction

48. Electrovalent compounds are **[CPMT 1996]**

(a) Good conductor of electricity

(b) Polar in nature

(c) Low M.P. and low B.P.

(d) Easily available

49. Ionic compounds do not have **[RPMT 1997]**

(a) Hard and brittle nature

(b) High melting and boiling point

(c) Directional properties

(d) Soluble in polar solvents

50. Highest melting point would be of

(a) He (b) $CsCl$

(c) NH_3 (d) $CHCl_3$

51. What is the effect of more electronegative atom on the strength of ionic bond

(a) Decreases (b) Increases

(c) Decreases slowly (d) Remains the same

52. An element X with the electronic configuration $1s^2, 2s^2 2p^6, 3s^2$ would be expected to form the chloride with the formula

(a) XCl_3 (b) XCl_2

(c) XCl (d) X_2Cl

53. Two element have electronegativity of 1.2 and 3.0. Bond formed between them would be **[CPMT 1982; DCE**

(a) Ionic (b) Polar covalent

(c) Co-ordinate (d) Metallic

54. Which of the following is least ionic **[MP PET 2002]**

(a) C_2H_5Cl (b) KCl

(c) $BaCl_2$ (d) $C_6H_5N^+H_3Cl^-$

55. Which type of bonding exists in Li_2O and CaF_2 respectively **[RPET 2000]**

(a) Ionic, ionic (b) Ionic, covalent

(c) Covalent, ionic (d) Coordinate, ionic

56. An atom with atomic number 20 is most likely to combine chemically with the atom whose atomic number is

[BHU 2000]

(a) 11 (b) 14

(c) 16 (d) 10

57. Bond formed in crystal by anion and cation is

[CBSE PMT 2000]

(a) Ionic (b) Metallic

(c) Covalent (d) Dipole

58. Atoms or group of atoms which are electrically charged are known **[UPSEAT 2001]**

(a) Anions (b) Cations

(c) Ions (d) Atoms

59. Which one is the strongest bond **[Pb. PMT 2001]**

(a) $Br-F$ (b) $F-F$

(c) $Cl-F$ (d) $Br-Cl$

60. The interionic attraction depends on interaction of

[Kerala CET (Med.) 2002]

(a) Solute-Solute (b) Solvent-Solvent

(c) The charges (d) Molecular properties

61. Which of the following compounds is ionic

[UPSEAT 2002]

[RPMT 1999]

(a) KI (b) CH_4

(c) Diamond (d) H_2

62. Which of the following pairs of species has same electronic configuration **[UPSEAT 2002]**

[AMU 1999]

(a) Zn^{2+} and Ni^{2+} (b) Co^{+3} and Ni^{4+}

(c) Co^{2+} and Ni^{2+} (d) Ti^{4+} and V^{3+}

63. The energy that opposes dissolution of a solvent is

[CPMT 2002]

(a) Hydration energy (b) Lattice energy

[JIPMER 2000]

(c) Internal energy (d) Bond energy

64. Which of the following has highest melting point

[RPET 2003]

(a) $BeCl_2$ (b) $MgCl_2$

(c) $CaCl_2$ (d) $BaCl_2$

65. Which of the following statements is not true for ionic compounds **[RPET 2003]**

(a) High melting point

(b) Least lattice energy

(c) Least solubility in organic compounds

(d) Soluble in water

66. Electrolytes are compound containing**[MADT Bihar 1981]**

(a) Electrovalent bond (b) Covalent bond

(c) Coordinate bond (d) Hydrogen bond

67. Which of the following hydrides are ionic**[Roorkee 1999]**

(a) CaH_2 (b) BaH_2

(c) SrH_2 (d) BeH_2

68. Which of the following conduct electricity in the fused state

[Roorkee 2000]

(a) $BeCl_2$ (b) $MgCl_2$

(c) $SrCl_2$ (d) $BaCl_2$

Covalent bonding

1. The valency of sulphur in sulphuric acid is **[NCERT 1974]**

(a) 2 (b) 4

(c) 6 (d) 8

2. The number of electrons involved in the bond formation of N_2 molecule

[IIT 1980; CPMT 1983, 84, 85; CBSE PMT 1992]

(a) 2 (b) 4

(c) 6 (d) 10

3. The electronic configuration of four elements are given in brackets

$L(1s^2,\ 2s^2 2p^1)$; $M(1s^2,\ 2s^2\ 2p^5)$

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

The element that would most readily form a diatomic molecule is

[NCERT 1983]

(a) Q (b) M

(c) R (d) L

4. In covalency **[CPMT 1974, 76, 78, 81; AFMC 1982]**

(a) Electrons are transferred

(b) Electrons are equally shared

(c) The electron of one atom are shared between two atoms

(d) None of the above

5. Which compound is highest covalent

(a) $LiCl$ (b) LiF

(c) $LiBr$ (d) LiI

6. The nature of bonding in graphite is

[DPMT 1986; CPMT 1986]

(a) Covalent (b) Ionic

(c) Metallic (d) Coordinate

7. Which of the following substances has giant covalent structure **[DPMT 1985, 86; NCERT 1975]**

(a) Iodine crystal (b) Solid CO_2

(c) Silica (d) White phosphorus

8. With which of the given pairs CO_2 resembles**[BHU 2005]**

(a) $HgCl_2$, C_2H_2 (b) $HgCl_2$, $SnCl_4$

(c) C_2H_2, NO_2 (d) N_2O and NO_2

9. The electron pair which forms a bond between two similar non-metallic atoms will be **[IIT 1986]**

(a) Dissimilar shared between the two

(b) By complete transfer from one atom to other

(c) In a similar spin condition

(d) Equally shared in between the two

10. For the formation of covalent bond, the difference in the value of electronegativities should be**[EAMCET 1982**

(a) Equal to or less than 1.7 (b) More than 1.7

(c) 1.7 or more (d) None of these

11. Which type of bond is formed between similar atoms

(a) Ionic (b) Covalent

(c) Coordinate (d) Metallic

12. Covalent compounds are generally ...... in water

[CPMT 1987]

(a) Soluble (b) Insoluble

(c) Dissociated (d) Hydrolysed

13. Which one is the electron deficient compound**[AIIMS 1982]**

(a) ICl (b) NH_3

(c) BCl_3 (d) PCl_3

14. Which among the following elements has the tendency to form covalent compounds

(a) Ba (b) Be

(c) Mg (d) Ca

15. Silicon has 4 electrons in the outermost orbit. In forming the bonds **[EAMCET 1981]**

(a) It gains electrons (b) It loses electrons

(c) It shares electrons (d) None of these

16. Which of the following occurs when two hydrogen atoms bond with each others

(a) Potential energy is lowered

(b) Kinetic energy is lowered

(c) Electronic motion ceases

(d) Energy is absorbed

17. A bond with maximum covalent character between non-metallic elements is formed**[NCERT 1982]**

(a) Between identical atoms

(b) Between chemically similar atoms

(c) Between atoms of widely different electronegativities

(d) Between atoms of the same size

18. Amongst the following covalent bonding is found in **[CPMT 1973]**

(a) Sodium chloride (b) Magnesium chloride

(c) Water (d) Brass

19. Indicate the nature of bonding in diamond **[EAMCET 1980; BHU 1996; KCET 2000]**

(a) Covalent (b) Ionic

(c) Coordinate (d) Hydrogen

20. Octet rule is not valid for the molecule **[IIT 1979; MP PMT 1995]**

(a) CO_2 (b) H_2O

(c) CO (d) O_2

21. Which of the following compounds are covalent **[IIT 1980; MLNR 1982]**

(a) H_2 (b) CaO

(c) KCl (d) Na_2S

22. Indicate the nature of bonding in CCl_4 and CaH_2 **[NCERT 1973]**

(a) Covalent in CCl_4 and electrovalent in CaH_2

(b) Electrovalent in both CCl_4 and CaH_2

(c) Covalent in both CCl_4 and CaH_2

(d) Electrovalent in CCl_4 and covalent in CaH_2

23. If the atomic number of element X is 7, the best electron dot symbol for the element is **[NCERT 1973; CPMT 2003]**

(a) $X\,.$ (b) $.\,X\,.$

(c) $.\,\underset{\cdot}{\overset{\cdot}{X}}\,:$ (d) $:\,\underset{\cdot\cdot}{\overset{\cdot\cdot}{X}}\,.$

24. Which is the most covalent **[AFMC 1982]**

(a) $C-O$ (b) $C-Br$

(c) $C-S$ (d) $C-F$

25. The covalent compound HCl has the ionic character as **[EAMCET 1980]**

(a) The electronegativity of hydrogen is greater than that of chlorine

(b) The electronegativity of hydrogen is equal to that of chlorine

(c) The electronegativity of chlorine is greater than that of hydrogen

(d) Hydrogen and chlorine are gases

26. The correct sequence of increasing covalent character is represented by **[CBSE PMT 2005]**

(a) $LiCl < NaCl < BeCl_2$ (b) $BeCl_2 < NaCl < LiCl$

(c) $NaCl < LiCl < BeCl_2$ (d) $BeCl_2 < LiCl < NaCl$

27. Bond energy of covalent $O-H$ bond in water is **[EAMCET 1982]**

(a) Greater than bond energy of $H-$bond

(b) Equal to bond energy of $H-$bond

(c) Less than bond energy of $H-$bond

(d) None of these

28. Solid CH_4 is **[DPMT 1983]**

(a) Molecular solid (b) Ionic solid

(c) Pseudo solid (d) Does not exist

29. A covalent bond is likely to be formed between two elements which **[MP PMT 1987]**

(a) Have similar electronegativities

(b) Have low ionization energies

(c) Have low melting points

(d) Form ions with a small charge

30. The bond between two identical non-metal atoms has a pair of electrons **[CPMT 1986]**

(a) Unequally shared between the two

(b) Transferred fully from one atom to another

(c) With identical spins

(d) Equally shared between them

31. The valency of phosphorus in H_3PO_4 is **[DPMT 1984]**

(a) 2 (b) 5

(c) 4 (d) 1

32. Which of the following substances has covalent bonding **[AMU 1985]**

(a) Germanium (b) Sodium chloride

(c) Solid neon (d) Copper

33. The covalency of nitrogen in HNO_3 is **[CPMT 1987]**

(a) 0 (b) 3

(c) 4 (d) 5

34. Hydrogen chloride molecule contains a **[CPMT 1984]**

(a) Covalent bond (b) Double bond

(c) Coordinate bond (d) Electrovalent bond

35. As compared to covalent compounds, electrovalent compounds generally have **[CPMT 1990, 94; MP PMT 1997]**

(a) Low melting points and low boiling points

(b) Low melting points and high boiling points

(c) High melting points and low boiling points

(d) High melting points and high boiling points

36. The interatomic distances in H_2 and Cl_2 molecules are 74 and 198 *pm* respectively. The bond length of HCl is

[MP PET 1993]

(a) 272 *pm* (b) 136 *pm*

(c) 124 *pm* (d) 248 *pm*

37. On analysis, a certain compound was found to contain iodine and oxygen in the ratio of 254 *gm* of iodine and 80 *gm* of oxygen. The atomic mass of iodine is 127 and that of oxygen is 16. Which of the following is the formula of the compound

(a) IO (b) I_2O

(c) I_5O_2 (d) I_2O_5

38. Ionic and covalent bonds are present in

[CBSE PMT 1990; MNR 1990; KCET 2000; UPSEAT 2001]

(a) CCl_4 (b) $CaCl_2$

(c) NH_4Cl (d) H_2O

39. Highest covalent character is found in **[EAMCET 1992]**

(a) CaF_2 (b) $CaCl_2$

(c) $CaBr_2$ (d) CaI_2

40. Among the following which property is commonly exhibited by a covalent compound **[MP PET 1994]**

(a) High solubility in water

(b) High electrical conductance

(c) Low boiling point

(d) High melting point

41. Atoms in the water molecule are linked by **[MP PAT 1996]**

(a) Electrovalent bond

(b) Covalent bond

(c) Coordinate covalent bond

(d) Odd electron bond

42. Which is the correct electron dot structure of N_2O molecule

[MP PET 1996]

(a) $:N = N = \underset{\cdot\cdot}{\overset{\cdot\cdot}{O}}$ (b) $:N \equiv N^+ - \underset{\cdot\cdot}{\overset{\cdot\cdot}{O}}:^-$

(c) $\underset{\cdot\cdot}{\overset{\cdot\cdot}{N}} = \overset{\cdot\cdot}{N} = \underset{\cdot\cdot}{\overset{\cdot\cdot}{O}}$ (d) $:N = N = \underset{\cdot\cdot}{\overset{\cdot\cdot}{O}}:$

43. A covalent bond between two atoms is formed by which of the following **[MP PMT 1996]**

(a) Electron nuclear attraction

(b) Electron sharing

(c) Electron transfer

(d) Electrostatic attraction

44. The electronic configuration of a metal M is $1s^2, 2s^2\, 2p^6, 3s^1$. The formula of its oxides will be

[MP PET/PMT 1998]

(a) MO (b) M_2O

(c) M_2O_3 (d) MO_2

45. Which of the following statements regarding covalent bond is not true **[MP PET/PMT 1998]**

(a) The electrons are shared between atoms

(b) The bond is non-directional

(c) The strength of the bond depends upon the extent of overlapping

(d) The bond formed may or may not be polar

[CPMT 1981]

46. If the electronic configuration of $M = 2, 8, 3$ and that of $A = 2, 8, 7,$ the formula of the compound is

[Bihar MEE 1996]

(a) M_2A_3 (b) MA_2

(c) M_2A (d) MA_3

(e) M_3A

47. The table shown below gives the bond dissociation energies (E_{diss}) for single covalent bonds of carbon (C) atoms with element A, B, C and $D.$ Which element has the smallest atoms **[CBSE PMT 1994]**

Bond	$E_{diss}\ (kJ\ mol^{-1})$
$C-A$	240
$C-B$	328
$C-C$	276
$C-D$	485

(a) A (b) B

(c) C (d) D

48. If a molecule X_2 has a triple bond, then X will have the electronic configuration **[CET Pune 1998]**

(a) $1s^2\ 2s^2\ 2p^5$ (b) $1s^2\ 2s^2\ 2p^3$

(c) $1s^2\ 2s^1$ (d) $1s^2\ 2s^2\ 2p^1$

49. Which of the following compounds does not follow the octet rule for electron distribution **[CET Pune 19**

(a) PCl_5 (b) PCl_3

(c) H_2O (d) PH_3

50. The valency of $A = 3$ and $B = 2$, then the compound is

[Bihar MEE 1997]

(a) A_2B_3 (b) A_3B_2

(c) A_3B_3 (d) A_2B_2

(e) None of these

51. The number of electrons shared by each outermost shell of N_2 is **[AFMC 1998]**

(a) 2 (b) 3

(c) 4 (d) 5

52. Which of the following substances when dissolved in water will give a solution that does not conduct electricity

[JIPMER 1999]

(a) Hydrogen chloride (b) Potassium hydroxide

(c) Sodium acetate (d) Urea

53. Which of the following atoms has minimum covalent radius

[DPMT 2000]

(a) B (b) C

(c) N (d) Si

54. Boron form covalent compound due to **[Pb. PMT 2000]**

(a) Small size (b) Higher ionization energy

(c) Lower ionization energy (d) Both (a) and (b)

55. Two elements X and Y have following electron configurations

$X = 1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2$

and $Y = 1s^2, 2s^2 2p^6, 3s^2 3p^6$

The compound formed by combination of X and Y is

[DPMT 2001]

(a) XY_5 (b) X_2Y_5

(c) X_5Y_3 (d) XY_2

56. Covalent compounds have low melting point because

[KCET 2002]

(a) Covalent bond is less exothermic

(b) Covalent molecules have definite shape

(c) Covalent bond is weaker than ionic bond

(d) Covalent molecules are held by weak Vander Waal's force of attraction

57. p and n-type of semiconductors are formed due to

[UPSEAT 2002]

(a) Covalent bonds (b) Metallic bonds

(c) Ionic bonds (d) Co-ordinate bond

58. Which of the following is Lewis acid **[RPET 2003]**

(a) BF_3 (b) NH_3

(c) PH_3 (d) SO_2

59. Among the species : CO_2, CH_3COO^-, CO, CO_3^{2-}, $HCHO$ which has the weakest carbon- oxygen bond

[Kerala PMT 2004]

(a) CO_2 (b) CH_3COO^-

(c) CO (d) CO_3^{2-}

(e) $HCHO$

60. Valency of sulphur in $Na_2S_2O_3$ is **[DPMT 1984]**

(a) Two (b) Three

(c) Four (d) Six

61. The acid having $O-O$ bond is

[IIT JEE Screening 2004]

(a) $H_2S_2O_3$ (b) $H_2S_2O_6$

(c) $H_2S_2O_8$ (d) $H_2S_4O_6$

62. The following salt shows maximum covalent character

[UPSEAT 2004]

(a) $AlCl_3$ (b) $MgCl_2$

(c) $CsCl$ (d) $LaCl_3$

63. Which type of bond is present in H_2S molecule

[MHCET 2003; Pb CET 2001]

(a) Ionic bond (b) Covalent bond

(c) Co-ordinate (d) All of three

64. H_2S is more acidic than H_2O, due to **[BVP 2004]**

(a) O is more electronegative than S

(b) $O-H$ bond is stronger than $S-H$ bond

(c) $O-H$ bond is weaker than $S-H$ bond

(d) None of these

65. Which of the following has covalent bond

[AFMC 1988; DCE 2004]

(a) Na_2S (b) $AlCl_3$

(c) NaH (d) $MgCl_2$

66. The following element forms a molecule with eight its own weight atoms **[MHCET 2004]**

(a) Si (b) S

(c) Cl (d) P

67. In H_2O_2, the two oxygen atoms have

(a) Electrovalent bond (b) Covalent bond

(c) Coordinate bond (d) No bond

68. Carbon has a valency of 2 in CO and 4 in CO_2 and CH_4. Its valency in acetylene (C_2H_2) is **[NCERT 1971]**

(a) 1 (b) 2

(c) 3 (d) 4

69. Number of electrons in the valence orbit of nitrogen in an ammonia molecule are **[MH CET 2004]**

(a) 8 (b) 5

(c) 6 (d) 7

70. Hydrogen atoms are held together to form hydrogen molecules by **[AMU 1982]**

(a) Hydrogen bond (b) Ionic bond

(c) Covalent bond (d) Dative bond

71. Strongest bond is **[AFMC 1987]**

(a) $C-C$ (b) $C-H$

(c) $C-N$ (d) $C-O$

72. The major binding force of diamond, silicon and quartz is

[Kerala CET (Med.) 2002]

(a) Electrostatic force (b) Electrical attraction

(c) Co-valent bond force (d) Non-covalent bond force

73. Multiple covalent bonds exist in a molecule of **[NCERT 1973]**

(a) H_2 (b) F_2

(c) C_2H_4 (d) N_2

74. Which of the following does not obey the octet rule **[EAMCET 1993]**

(a) CO (b) NH_3

(c) H_2O (d) PCl_5

75. Which of the following statements is correct for covalent bond **[BHU 1997]**

(a) Electrons are shared between two atoms

(b) It may be polar or non-polar

(c) Direction is non-polar

(d) Valency electrons are attracted

76. Among CaH_2, NH_3, NaH and B_2H_6, which are covalent hydride **[Orissa JEE 2005]**

(a) NH_3 and B_2H_6 (b) NaH and CaH_2

(c) NaH and NH_3 (d) CaH_2 and B_2H_6

Co-ordinate or Dative bonding

1. Which species has the maximum number of lone pair of electrons on the central atom? **[IIT 2005]**

(a) $[ClO_3]^-$ (b) XeF_4

(c) SF_4 (d) $[I_3]^-$

2. A simple example of a coordinate covalent bond is exhibited by

(a) C_2H_2 (b) H_2SO_4

(c) NH_3 (d) HCl

3. The bond that exists between NH_3 and BF_3 is called **[AFMC 1982; MP PMT 1985; MNR 1994; KCET 2000; MP PET 2001; UPSEAT 2001]**

(a) Electrovalent (b) Covalent

(c) Coordinate (d) Hydrogen

4. Which of the following does not have a coordinate bond **[MADT Bihar 1984]**

(a) SO_2 (b) HNO_3

(c) H_2SO_3 (d) HNO_2

5. Coordinate covalent compounds are formed by **[CPMT 1990, 94]**

(a) Transfer of electrons (b) Sharing of electrons

(c) Donation of electrons (d) None of these process

6. In the coordinate valency **[CPMT 1989]**

(a) Electrons are equally shared by the atoms

(b) Electrons of one atom are shared with two atoms

(c) Hydrogen bond is formed

(d) None of the above

7. Which of the following contains a coordinate covalent bond **[MNR 1990; IIT 1986]**

(a) N_2O_5 (b) $BaCl_2$

(c) HCl (d) H_2O

8. A coordinate bond is formed when an atom in a molecule has

(a) Electric charge on it

(b) All its valency electrons shared

(c) A single unshared electron

(d) One or more unshared electron pair

9. Which has a coordinate bond **[RPMT 1997]**

(a) SO_3^{2-} (b) CH_4

(c) CO_2 (d) NH_3

10. The compound containing co-ordinate bond is **[AFMC 1999; Pb. CET 2002]**

(a) O_3 (b) SO_3

(c) H_2SO_4 (d) All of these

11. The number of dative bonds in sulphuric acid molecules is **[MP PET 2002]**

(a) 0 (b) 1

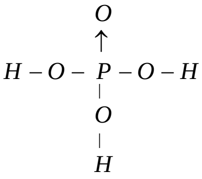
(c) 2 (d) 4

12. **[NCERT 1984]** Which of the following compounds has coordinate (dative) bond **[RPET 2003]**

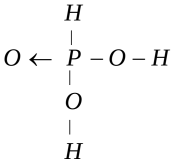
(a) CH_3NC (b) CH_3OH

(c) CH_3Cl (d) NH_3

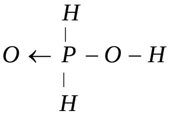
13. The structure of orthophosphoric acid is **[KCET 2003]**

(a) 

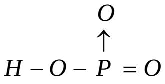
$H-O-\overset{\overset{O}{\uparrow}}{\underset{\underset{\underset{H}{|}}{\underset{O}{|}}}{P}}-O-H$

(b) 

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

(c) 

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

(d) 

$H-O-\overset{\overset{O}{\uparrow}}{P}=O$

14. What is the nature of the bond between B and O in $(C_2H_5)_2OBH_3$ **[Orissa JEE 2003]**

(a) Covalent (b) Co-ordinate covalent

(c) Ionic bond (d) Banana shaped bond

15. Sulphuric acid provides a example of **[Kerala CET (Med.) 2002]**

(a) Co-ordinate bonds

(b) Non-covalent compound

(c) Covalent and co-ordinate bond

(d) Non-covalent ion

Dipole moment

1. Which molecules has zero dipole moment **[AIIMS 1980, 82, 91; Roorkee 2000; MH CET 2001]**

(a) H_2O (b) CO_2

(c) HF (d) HBr

2. In the following which one have zero dipole moment **[DPMT 1985]**

(a) BF_3 (b) CCl_4

(c) $BeCl_2$ (d) All of these

3. Which molecule has the largest dipole moment **[CPMT 1991]**

(a) HCl (b) HI

(c) HBr (d) HF

4. The unequal sharing of bonded pair of electrons between two atoms in a molecule causes **[EAMCET 1986]**

(a) Dipole

(b) Radical formation

(c) Covalent bond

(d) Decomposition of molecule

5. Which of the following will show least dipole character **[NCERT 1975; Kurukshetra CEE 1998]**

(a) Water (b) Ethanol

(c) Ethane (d) Ether

6. Which of the following molecules will show dipole moment **[NCERT 1972, 74; DPMT 1985]**

(a) Methane (b) Carbon tetrachloride

(c) Chloroform (d) Carbon dioxide

7. Which of the following compounds possesses the dipole moment **[NCERT 1978; EAMCET 1983; MP PMT 1995]**

(a) Water (b) Boron trifluoride

(c) Benzene (d) Carbon tetrachloride

8. Which bond angle θ would result in the maximum dipole moment for the triatomic molecule YXY **[AIIMS 1980]**

(a) $\theta = 90^o$ (b) $\theta = 120^o$

(c) $\theta = 150^o$ (d) $\theta = 180^o$

9. Which of the following would have a permanent dipole moment **[CBSE PMT 2005]**

(a) BF_3 (b) SiF_4

(c) SF_4 (d) XeF_4

10. Carbon tetrachloride has no net dipole moment because of **[IIT 1982, 83; MP PMT 1985, 91; EAMCET 1988; AMU 1999]**

(a) Its planar structure

(b) Its regular tetrahedral structure

(c) Similar sizes of carbon and chlorine atoms

(d) Similar electron affinities of carbon and chlorine

11. The molecule which has the largest dipole moment amongst the following **[MNR 1983]**

(a) CH_4 (b) $CHCl_3$

(c) CCl_4 (d) CHI_3

12. Positive dipole moment is present in **[MNR 1986; MP PET 2000]**

(a) CCl_4 (b) C_6H_6

(c) BF_3 (d) HF

13. The polarity of a covalent bond between two atoms depends upon **[AMU 1982]**

(a) Atomic size (b) Electronegativity

(c) Ionic size (d) None of the above

14. Pick out the molecule which has zero dipole moment **[CPMT 1989; EAMCET 1993; MP PMT 1999]**

(a) NH_3 (b) H_2O

(c) BCl_3 (d) SO_2

15. Zero dipole moment is present in **[DPMT 1986; IIT 1987]**

(a) NH_3 (b) H_2O

(c) *cis* 1, 2-dichloroethene (d) *trans* 1, 2-dichloroethene

16. Which of the following is the most polar **[AFMC 1988]**

(a) CCl_4 (b) $CHCl_3$

(c) CH_3OH (d) CH_3Cl

17. Which one has minimum (nearly zero) dipole moment **[IIT Screening 1994; CBSE PMT 1996]**

(a) Butene-1 (b) *cis* butene-2

(c) *trans* butene-2 (d) 2-methyl-1-propene

18. Which one of the following is having zero dipole moment **[RPMT 1997; EAMCET 1988; MNR 1991]**

(a) CCl_4 (b) CH_3Cl

(c) CH_3F (d) $CHCl_3$

19. Which of the following molecules does not possess a permanent dipole moment **[CBSE PMT 1994]**

(a) H_2S (b) SO_2

(c) CS_2 (d) SO_3

20. Which of the following has zero dipole moment **[CPMT 1997; AFMC 1998; CBSE PMT 2001]**

(a) CH_2Cl_2 (b) CH_4

(c) NH_3 (d) PH_3

21. Fluorine is more electronegative than either boron or phosphorus. What conclusion can be drawn from the fact that BF_3 has no dipole moment but PF_3 does

[Pb. PMT 1998]

(a) BF_3 is not spherically symmetrical but PF_3 is

(b) BF_3 molecule must be linear

(c) The atomic radius of P is larger than the atomic radius of B

(d) The BF_3 molecule must be planar triangular

22. Which molecule does not show zero dipole moment

[RPET 1997, 99]

(a) BF_3
(b) NH_3
(c) CCl_4
(d) CH_4

23. The dipole moment of HBr is $1.6\times10^{-30}\,cm$ and interatomic spacing is $1\mathring{A}$. The % ionic character of HBr is

[MP PMT 2000]

(a) 7
(b) 10
(c) 15
(d) 27

24. Non-polar solvent is **[RPET 2000]**

(a) Dimethyl sulphoxide
(b) Carbon tetrachloride
(c) Ammonia
(d) Ethyl alcohol

25. Which shows the least dipole moment

[UPSEAT 2001; DPMT 1982]

(a) CCl_4
(b) $CHCl_3$
(c) CH_3CH_2OH
(d) CH_3COCH_3

26. Which molecule has zero dipole moment **[UPSEAT 2001]**

(a) H_2O
(b) AgI
(c) $PbSO_4$
(d) HBr

27. The dipole moment is zero for the molecule

[IIT 1989; MP PMT 2002]

(a) Ammonia
(b) Boron trifluoride
(c) Sulphur dioxide
(d) Water

28. N_2 is less reactive than CN^- due to **[UPSEAT 2003]**

(a) Presence of more electrons in orbitals

(b) Absence of dipole moment

(c) Difference in spin quantum no

(d) None of these

29. In a polar molecule, the ionic charge is 4.8×10^{-10} e.s.u. If the inter ionic distance is one Å unit, then the dipole moment is **[MH CET 2003]**

(a) 41.8 debye
(b) 4.18 debye
(c) 4.8 debye
(d) 0.48 debye

30. Which of the following is a polar compound

[Pb. CET 2000]

(a) HCl
(b) H_2Se
(c) CH_4
(d) HI

31. Which of the following has no dipole moment

[DCE 2002]

(a) CO_2
(b) SO_3
(c) O_3
(d) H_2O

32. Which of the following is non-polar **[DCE 2002]**

(a) PCl_5
(b) PCl_3
(c) SF_6
(d) IF_7

33. Identify the non-polar molecule in the set of compounds given : HCl, HF, H_2, HBr **[UPSEAT 2004]**

(a) H_2
(b) HCl
(c) HF, HBr
(d) HBr

34. Dipole moment is shown by **[IIT 1986]**

(a) 1, 4-dichlorobenzene

(b) *cis* 1, 2-dichloroethene

(c) *trans* 1, 2-dichloroethene

(d) *trans* 1, 2-dichloro-2-pentene

35. If HCl molecule is completely polarized, so expected value of dipole moment is 6.12D (deby), but experimental value of dipole moment is 1.03D. Calculate the percentage ionic character **[Kerala CET 2005]**

(a) 17
(b) 83
(c) 50
(d) Zero
(e) 90

Polarisation and Fajan's rule

1. BF_3 and NF_3 both molecules are covalent, but BF_3 is non-polar and NF_3 is polar. Its reason is

[CPMT 1989; NCERT 1980]

(a) In uncombined state boron is metal and nitrogen is gas

(b) $B-F$ bond has no dipole moment whereas $N-F$ bond has dipole moment

(c) The size of boron atom is smaller than nitrogen

(d) BF_3 is planar whereas NF_3 is pyramidal

2. Which one is polar molecule among the following

(a) CO_2
(b) CCl_4
(c) H_2O
(d) CH_4

3. If the electron pair forming a bond between two atoms A and B is not in the centre, then the bond is **[AIIMS 1984]**

(a) Single bond
(b) Polar bond
(c) Non-polar bond
(d) π bond

4. Which of the following liquids is not deflected by a non-uniform electrostatic field

(a) Water (b) Chloroform

(c) Nitrobenzene (d) Hexane

5. Which of the following is non-polar **[EAMCET 1983]**

(a) H_2S (b) $NaCl$

(c) Cl_2 (d) H_2SO_4

6. Polarization is the distortion of the shape of an anion by an adjacently placed cation. Which of the following statements is correct

(a) Maximum polarization is brought about by a cation of high charge

(b) Minimum polarization is brought about by a cation of

low radius

(c) A large cation is likely to bring about a large degree of polarization

(d) A small anion is likely to undergo a large degree of polarization

7. The bonds between P atoms and Cl atoms in PCl_5 are likely to be **[MP PMT 1987]**

(a) Ionic with no covalent character

(b) Covalent with some ionic character

(c) Covalent with no ionic character

(d) Ionic with some metallic character

8. Two electrons of one atom A and two electrons of another atom B are utilized to form a compound AB. This is an example of **[MNR 1981]**

(a) Polar covalent bond (b) Non-polar covalent bond

(c) Polar bond (d) Dative bond

9. In which of the following molecule is the covalent bond most polar **[AMU 1985; MP PET 2001]**

(a) HI (b) HBr

(c) HCl (d) H_2

10. Amongst ClF_3, BF_3 and NH_3 molecules the one with non-planar geometry is **[MP PMT 1999]**

(a) ClF_3 (b) NH_3

(c) BF_3 (d) None of these

11. Which of the following possesses highest melting point

[CPMT 1999]

(a) Chlorobenzene (b) *o*-dichlorobenzene

(c) *m*-dichlorobenzene (d) *p*-dichlorobenzene

12. The polar molecule among the following is

[Orissa JEE 1997]

(a) CCl_4 (b) CO_2

(c) CH_2Cl_2 (d) $CH_2 = CH_2$

[NCERT 1978]

13. Which of the following have both polar and non-polar bonds **[AIIMS 1997]**

(a) C_2H_6 (b) NH_4Cl

(c) HCl (d) $AlCl_3$

14. Which of the following has a high polarising power

[CET Pune 1998]

(a) Mg^{2+} (b) Al^{3+}

(c) Na^+ **[NCERT 1982]** (d) Ca^{2+}

15. Maximum covalent character is associated with the compound **[RPMT 1999]**

(a) NaI (b) MgI_2

(c) $AlCl_3$ (d) AlI_3

16. Polarisibility of halide ions increases in the order

[DCE 1999]

(a) F^-, I^-, Br^-, Cl^- (b) Cl^-, Br^-, I^-, F^-

(c) I^-, Br^-, Cl^-, F^- (d) F^-, Cl^-, Br^-, I^-

17. According to Fajan's rule, covalent bond is favoured by

[AIIMS 1999]

(a) Large cation and small anion

(b) Large cation and large anion

(c) Small cation and large anion

(d) Small cation and small anion

18. Which of the following statements is correct **[AMU 1999]**

(a) SF_4 is polar and non-reactive

(b) SF_6 is non-polar and very reactive

(c) SF_6 is a strong fluorinating agent

(d) SF_4 is prepared by fluorinating SCl_2 with NaF

19. Choose the correct statement **[RPMT 2000]**

(a) Amino polarisation is more pronounced by highly charged cation

(b) Small cation has minimum capacity to polarise an anion.

(c) Small anion has maximum polarizability

(d) None of these

20. The ICl molecule is **[DPMT 2001]**

(a) Purely electrovalent

(b) Purely covalent

(c) Polar with negative end on iodine

(d) Polar with negative end on chlorine

21. Which of the following is a polar compound **[AIIMS 2001]**

(a) HF (b) HCl

(c) HNO_3 (d) H_2SO_4

22. Which of the following has zero dipole moment

[MP PMT 2002]

(a) ClF (b) PCl_3

(c) SiF_4 (d) $CFCl_3$

23. Which of the following compounds has least dipole moment **[RPET 2003]**

(a) PH_3 (b) $CHCl_3$

(c) NH_3 (d) BF_3

24. Pauling's electronegativity values for elements are useful in predicting **[UPSEAT 2004]**

(a) Polarity of bonds in molecules

(b) Position of elements in electrochemical series

(c) Co-ordination number

(d) Dipole moment of various molecules

25. Amongst $LiCl$, $RbCl$, $BeCl_2$ and $MgCl_2$ the compounds with the greatest and the least ionic character, respectively, are **[UPSEAT 2002]**

(a) $LiCl$ and $RbCl$ (b) $RbCl$ and $BeCl_2$

(c) $RbCl$ and $MgCl_2$ (d) $MgCl_2$ and $BeCl_2$

26. Bond polarity of diatomic molecule is because of **[UPSEAT 2002]**

(a) Difference in electron affinities of the two atoms

(b) Difference in electronegativities of the two atoms

(c) Difference in ionisation potential

(d) All of these

Overlaping- σ and π- bonds

1. Triple bond in ethyne is formed from **[MP PMT 1990; NCERT 1979; EAMCET 1978; AMU 1985; CPMT 1988; MADT Bihar 1982; MH CET 2000]**

(a) Three sigma bonds

(b) Three pi bonds

(c) One sigma and two pi bonds

(d) Two sigma and one pi bond

2. The bond in the formation of fluorine molecule will be **[MP PMT 1987]**

(a) Due to $s-s$ overlapping

(b) Due to $s-p$ overlapping

(c) Due to $p-p$ overlapping

(d) Due to hybridization

3. Which type of overlapping results the formation of a π bond **[DPMT 1981]**

(a) Axial overlapping of $s-s$ orbitals

(b) Lateral overlapping of $p-p$ orbitals

(c) Axial overlapping of $p-p$ orbitals

(d) Axial overlapping of $s-p$ orbitals

4. The number and type of bonds between two carbon atoms in calcium carbide are **[AIEEE 2005]**

(a) One sigma, one pi (b) One sigma, two pi

(c) Two sigma, one pi (d) Two singma, two pi

5. In a double bond connecting two atoms, there is a sharing of **[CPMT 1977, 80, 81; NCERT 1975; Bihar MEE 1980; MP PET 1999]**

(a) 2 electrons (b) 1 electron

(c) 4 electrons (d) All electrons

6. Strongest bond is **[DPMT 1990]**

(a) $C-C$ (b) $C=C$

(c) $C\equiv C$ (d) All are equally strong

7. π bond is formed **[JIPMER 2002]**

(a) By overlapping of atomic orbitals on the axis of nuclei

(b) By mutual sharing of pi electron

(c) By sidewise overlapping of half filled *p*-orbitals

(d) By overlapping of *s*-orbitals with *p*-orbitals

8. The double bond between the two carbon atoms in ethylene consists of **[NCERT 1981; EAMCET 1979]**

(a) Two sigma bonds at right angles to each other

(b) One sigma bond and one pi bond

(c) Two pi bonds at right angles to each other

(d) Two pi bonds at an angle of 60^o to each other

9. In the series ethane, ethylene and acetylene, the $C-H$ bond energy is **[NCERT 1977]**

(a) The same in all the three compounds

(b) Greatest in ethane

(c) Greatest in ethylene

(d) Greatest in acetylene

10. In a sigma bond

(a) Sidewise as well as end to end overlap of orbitals take place

(b) Sidewise overlap of orbitals takes place

(c) End to end overlap of orbitals takes place

(d) None of the above

11. The number of sigma and pi bonds in 1-butene-3-yne are **[IIT 1989]**

(a) 5 sigma and 5 pi (b) 7 sigma and 3 pi

(c) 8 sigma and 2 pi (d) 6 sigma and 4 pi

12. The most acidic compound among the following is **[MP PET 1993]**

(a) CH_3CH_2OH (b) C_6H_5OH

(c) CH_3COOH (d) $CH_3CH_2CH_2OH$

13. Which of the following is not correct **[CBSE PMT 1990]**

(a) A sigma bond is weaker than π bond

(b) A sigma bond is stronger than π bond

(c) A double bond is stronger than a single bond
(d) A double bond is shorter than a single bond

14. Strongest bond formed, when atomic orbitals
(a) Maximum overlap (b) Minimum overlap
(c) Overlapping not done (d) None of them

15. The $p-p$ orbital overlapping is present in the following molecule **[MP PET 1994]**
(a) Hydrogen (b) Hydrogen bromide
(c) Hydrogen chloride (d) Chlorine

16. In N_2 molecule, the atoms are bonded by **[MP PET 1996; UPSEAT 2001]**
(a) One σ, Two π (b) One σ, One π
(c) Two σ, One π (d) Three σ bonds

17. In which of following there exists a $p\pi - d\pi$ bonding **[AFMC 2001]**
(a) Diamond (b) Graphite
(c) Dimethyl amine (d) Trisilylamine

18. Number of bonds in SO_2 **[DCE 2001]**
(a) Two σ and two π
(b) Two σ and one π
(c) Two σ, two π and one lone pair
(d) None of these

19. Which of the following has $p\pi - d\pi$ bonding **[CBSE 2002]**
(a) NO_3^- (b) CO_3^{-2}
(c) BO_3^{-3} (d) SO_3^{-2}

20. Number of sigma bonds in P_4O_{10} is **[AIEEE 2002]**
(a) 6 (b) 7
(c) 17 (d) 16

Hybridisation

1. Which molecule is not linear **[CPMT 1994]**
(a) BeF_2 (b) BeH_2
(c) CO_2 (d) H_2O

2. The bond angle in water molecule is nearly **or** Directed bonds in water forms an angle of **[NCERT 1980; EAMCET 1981; MNR 1983, 85; AIIMS 1982; CPMT 1989; MP PET 1994, 96; MP PET/PMT 1998]**
(a) 120^o (b) 180^o
(c) $109^o28'$ (d) $104^o30'$

3. The central atom in a molecule is in sp^2 hybrid state. The shape of molecule will be **[MP PMT 1987; CBSE PMT 1989]**
(a) Pyramidal (b) Tetrahedral
(c) Octahedral (d) Trigonal planar

4. Which molecule is linear **[MP PMT 1984; IIT 1982, 88; EAMCET 1993; CBSE PMT 1992; MP PET 1995; RPMT 1997]**
(a) NO_2 (b) ClO_2
(c) CO_2 (d) H_2S

5. Which of the following molecules has trigonal planer geometry **[CBSE PMT 2005]**
(a) IF_3 (b) PCl_3
(c) NH_3 (d) BF_3

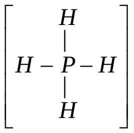
6. A sp^3 hybridized orbital contains **[DPMT 1984; BHU 1985; CPMT 1976]**
(a) $\frac{1}{4}s-$ character (b) $\frac{1}{2}s-$ character
(c) $\frac{2}{3}s-$ character (d) $\frac{3}{4}s-$ character

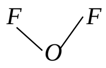
7. Structure of ammonia is **[MP PMT 1987, 89, 91; CPMT 1975, 82; RPMT 1999; JIPMER 2002]**
(a) Trigonal (b) Tetrahedral
(c) Pyramidal (d) Trigonal pyramidal

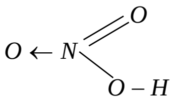
8. The bond angle in ethylene is **[CPMT 1987]**
(a) 180^o (b) 120^o
(c) 109^o (d) 90^o

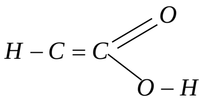
9. Compound formed by sp^3d hybridization will have structure **[BHU 1982; RPMT 1999]**
(a) Planar (b) Pyramidal
(c) Angular (d) Trigonal bipyramidal

10. Which of the following formula does not correctly represent the bonding capacity of the atom involved **[CBSE PMT 1990]**

(a) 
$\left[\begin{array}{c} H \\ | \\ H-P-H \\ | \\ H \end{array}\right]$

(b) 

(c) 

(d) 

11. Which of the following statement is not correct **[AIIMS 1983]**
(a) Hybridization is the mixing of atomic orbitals prior to their combining into molecular orbitals
(b) sp^2 hybrid orbitals are formed from two p atomic orbitals and one s atomic orbital
(c) d^2sp^3 hybrid orbitals are directed towards the corners of a regular octahedron

(d) dsp^3 hybrid orbitals are all at 90^o to one another

12. The mode of hybridisation of carbon in CO_2 is **[CPMT 1991]**

(a) sp (b) sp^2

(c) sp^3 (d) None of these

13. In which of the following the central atom does not use sp^3 hybrid orbitals in its bonding **[MNR 1992]**

(a) BeF_3^- (b) OH_3^+

(c) NH_2^- (d) NF_3

14. XeF_2 involves hybridisation **[DPMT 1990]**

(a) sp^3 (b) sp^3d

(c) sp^3d^2 (d) None of these

15. Which of the following hybridisation results in non-planar orbitals **[CBSE PMT 1991]**

(a) sp^3 (b) dsp^2

(c) sp^2 (d) sp

16. Octahedral molecular shape exists in .... hybridisation **[DPMT 1990]**

(a) sp^3d (b) sp^3d^2

(c) sp^3d^3 (d) None of these

17. The electronic structure of molecule OF_2 is a hybrid of

(a) sp (b) sp^2

(c) sp^3 (d) sd^3

18. Percentage of s-character in sp^3 hybrid orbital is

(a) 25 (b) 50

(c) 66 (d) 75

19. Shape of XeF_4 molecule is **[BHU 1987; AFMC 1992; CET Pune 1998; Roorkee Qualifying 1998; DCE 2002]**

(a) Linear (b) Pyramidal

(c) Tetrahedral (d) Square planar

20. For which of the following hybridisation the bond angle is maximum **[CBSE PMT 1991]**

(a) sp^2 (b) sp

(c) sp^3 (d) dsp^2

21. The $C-H$ bond distance is the longest in **[MNR 1990]**

(a) C_2H_2 (b) C_2H_4

(c) $C_2H_4Br_2$ (d) C_6H_6

22. The nature of hybridization in CH_2Cl-CH_2Cl for carbon is

(a) sp (b) sp^2

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

23. Shape of methane molecule is **[MNR 1983]**

(a) Tetrahedral (b) Pyramidal

(c) Octahedral (d) Square planer

24. Which one amongst the following possesses an sp hybridized carbon in its structure **[CBSE PMT 1989]**

(a) $CH_2=C.Cl-CH=CH_2$

(b) $C.Cl_2=C.Cl_2$

(c) $CH_2=C=CH_2$

(d) $CH_2=CH-CH=CH_2$

25. Which of the following is the correct electronic formula of chlorine molecule

(a) ${:}\underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}}{:}\underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}}{:}$ (b) ${:}\underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}}{}^{-}{:}{:}\underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}}{}^{+}{:}$

(c) ${:}\overset{\cdot\cdot}{Cl}{:}\overset{\cdot\cdot}{Cl}{:}$ (d) ${:}\overset{\cdot\cdot}{Cl}{:}{:}\overset{\cdot\cdot}{Cl}{:}$

26. In XeF_4 hybridization is

(a) sp^3d^2 (b) sp^3

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

27. In $HCHO$, 'C' has hybridization **[AIIMS 1987]**

(a) sp (b) sp^2

(c) sp^3 (d) All the above

28. Which has the shortest $C-C$ bond length **[NCERT 1982; CPMT 1989]**

(a) C_2H_5OH (b) C_2H_6

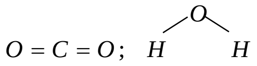
(c) C_2H_2 (d) C_2H_4

29. The hybridization of Ag in the linear complex $[Ag(NH_3)_2]^+$ is **[CPMT 1985; BHU 1981]**

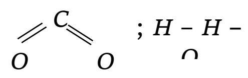
(a) dsp^2 (b) sp

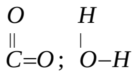
(c) sp^2 (d) sp^3

30. Experiment shows that H_2O has a dipole moment while CO_2 has not. Point out the structures which best illustrate these facts **[DPMT 1984; NCERT 1983; CPM**

(a) 

(b) $O=C=O;\ H-O-H$

(c) 

(d) 
$\overset{O}{\overset{\|}{C}}=O;\ \overset{H}{\overset{|}{O}}-H$

31. Which species do not have sp^3 hybridization **[DPMT 1985]**

(a) Ammonia (b) Methane

(c) Water (d) Carbon dioxide

32. As compared to pure atomic orbitals, hybrid orbitals have

(a) Low energy (b) Same energy

(c) High energy (d) None of these

33. The compound 1, 2-butadiene has **[IIT 1983; MP PMT 1996]**

(a) Only sp hybridized carbon atoms

(b) Only sp^2 hybridized carbon atoms

(c) Both sp and sp^2 hybridized carbon atoms

(d) sp, sp^2 and sp^3 hybridized carbon atoms

34. The number of unpaired electrons in O_2 molecule is **[MNR 1983; Kerala PET 2002]**

(a) 0 (b) 1

(c) 2 (d) 3

35. In the following molecule, the two carbon atoms marked by asterisk (*) possess the following type of hybridized orbitals $H_3C-C^* \equiv C^* - CH_3$ **[NCERT 1984]**

(a) sp^3 orbital (b) sp^2 orbital

(c) sp orbital (d) s orbital

36. The bond angle in carbon tetrachloride is approximately **[MNR 1981; MP PMT 1987]**

(a) 90^o (b) 109^o

(c) 120^o (d) 180^o

37. When two pairs of electrons are shared, bond is **[MNR 1979]**

(a) Single covalent bond (b) Double covalent bond

(c) Dative bond (d) Triple bond

38. The nature of hybridization in the NH_3 molecule is **[EAMCET 1982]**

(a) sp (b) sp^2

(c) sp^3 (d) sp^3d

39. Which one of the following compounds has bond angle as nearly 90^o **[MP PMT 1985]**

(a) NH_3 (b) H_2S

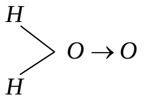
(c) H_2O (d) CH_4

40. In ethene, the bond angle(s) is/are **[CPMT 1976; AMU 1984; MP PMT 1985]**

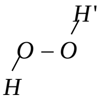
(a) $109^o 28'$ (b) 120^o

(c) 180^o (d) Different

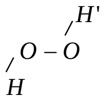
41. Structure formula of H_2O_2 is **[CPMT 1993]**

(a) 

(b) $H-O-O-H$ (straight line)

(c) 

Where $\angle H-O-O = \angle O-O-H' = 101.5^o$ and all the four atoms are in the same plane

(d) 

Where $\angle H-O-O = \angle O-O-H' = 97^o$ and the angle between $H-O-O$ plane and $O-O-H'$ plane is 101^o

42. Number of shared electrons in between carbon-carbon atoms in ethylene molecule is

(a) 2 (b) 4

(c) 6 (d) 3

43. The structural formula of a compound is $CH_3-CH=C=CH_2$. The type of hybridization at the four carbons from left to right are

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

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

44. Acetate ion contains **[AMU 1983]**

(a) One C, O single bond and one C, O double bond

(b) Two C, O single bonds

(c) Two C, O double bonds

(d) None of the above

45. The two carbon atoms in acetylene are **[AMU 1984; MADT Bihar 1982]**

(a) sp^3 hybridized (b) sp^2 hybridized

(c) sp hybridized (d) Unhybridized

46. Among the following compounds which is planar in shape **[AMU 1992]**

(a) Methane (b) Acetylene

(c) Benzene (d) Isobutene

47. In methane the bond angle is **[AMU 1983]**

(a) 180^o (b)

(c) 120^o (d) 109^o

48. The angle between sp^2 orbitals in ethylene is **[BHU 1987, 95; AMU 1985]**

(a) 90^o (b) 120^o

(c) 180^o (d) 109.5^o

49. The species in which the central atom uses sp^2 hybrid orbitals in its bonding is **[IIT 1988]**

(a) PH_3 (b) NH_3

(c) H_3C^+ (d) SbH_3

50. Carbon atoms in diamond are bonded to each other in a configuration **[CPMT 1981]**

(a) Tetrahedral (b) Planar

(c) Linear (d) Octahedral

51. Which of the following molecules can central atom said to adopt sp^2 hybridization **[CBSE PMT 1989; MP PET 1994]**

(a) BeF_2 (b) BCl_3

(c) C_2H_2 (d) NH_3

52. In $[Cu(NH_3)_4]SO_4$, ;Cu has following hybridization **[AIIMS 1988; UPSEAT 2001]**

(a) dsp^2 (b) sp^3

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

53. The hybridization of carbon atoms in $C-C$ single bond of $HC \equiv C-CH = CH_2$ is

(a) sp^3-sp^3 (b) sp^2-sp^3

(c) $sp-sp^2$ (d) sp^3-sp

54. The compound in which C^* uses sp^3 hybrids for bond formation is **[IIT 1989]**

(a) $H\overset{+}{C}OOH$ (b) $(NH_2)_2\overset{+}{C}O$

(c) $(NH_3)_3\overset{+}{C}OH\ HgCl_2$ (d) $CH_3\overset{+}{C}HO$

55. In diborane, the $H-B-H$ bond angle is 120^o. The hybridization of boron is likely to be **[BHU 1981; CBSE PMT 1999]**

(a) sp (b) sp^2

(c) sp^3 (d) dsp^2

56. The number of shared pairs of electrons in propane is **[BHU 1981]**

(a) 2 (b) 4

(c) 6 (d) 10

57. s-character in sp hybridised orbitals are

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

(c) $\frac{1}{4}$ (d) $\frac{2}{3}$

58. The two types of bonds present in B_2H_6 are covalent and **[IIT 1994]**

(a) Three centre bond (b) Hydrogen bond

(c) Two centre bond (d) None of the above

59. In the compound CH_3©OCl, which type of orbitals have been used by the circled carbon in bond formation **[MP PET 1994]**

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

(c) sp (d) p

60. The correct order of the $O-O$ bond length in O_2, H_2O_2 and O_3 is **[CBSE PMT 1995]**

(a) $O_2 > O_3 > H_2O_2$ (b) $O_3 > H_2O_2 > O_2$

(c) $H_2O_2 > O_3 > O_2$ (d) $O_2 > H_2O_2 > O_3$

61. The structure of PF_5 molecule is **[AFMC 1995; JIPMER 2001]**

(a) Tetrahedral (b) Trigonal bipyramidal

(c) Square planar (d) Pentagonal bipyramidal

62. Which of the following hybridisation has maximum s-characters **[MP PET 1995]**

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

(c) sp **[IIT 1991; MP PET 1995]** (d) None of these

63. The PCl_5 molecule is a result of the hybridisation of **[MP PET 1995; DCE 2000; MP PMT 2002]**

(a) sp^2d^2 (b) sp^3d

(c) spd^3 (d) sp^2d^3

64. Hybridisation involves **[MP PMT 1996]**

(a) Addition of an electron pair

(b) Mixing up of atomic orbitals

(c) Removal of an electron pair

(d) Separation of orbitals

65. The geometry of sulphur trioxide molecule is

(a) Tetrahedral (b) Trigonal planar

(c) Pyramidal (d) Square planar

66. The shapes of BCl_3, PCl_3 and ICl_3 molecules are all

(a) Triangular (b) Pyramidal

(c) $T-$shaped (d) All above are incorrect

67. In benzene molecule all $C-C$ bond lengths are equal because

(a) All carbon atoms are equivalent

(b) All carbon atoms are sp^2 hybridised

(c) All $C-C$ bonds in benzene, have same order

(d) All $C-C$ bonds are single covalent bond

68. Which one is false in the following statements **[MP PET 1997]**

(a) Each carbon in ethylene is in sp^2 hybridisation

(b) Each carbon in acetylene is in sp^3 hybridisation

(c) Each carbon in benzene is in sp^2 hybridisation

(d) Each carbon in ethane is in sp^3 hybridisation

69. Out of the following hybrid orbitals, the one which forms the bond at angle 120^o, is

(a) d^2sp^3 (b) sp^3

(c) sp^2 (d) sp

70. As the $p-$character increases, the bond angle in hybrid orbitals formed by s and atomic orbitals **[MP PMT 1997]**

(a) Decreases (b) Increases

(c) Doubles (d) Remains unchanged

71. sp^3 hybridization leads to which shape of the molecule

[MP PET/PMT 1998]

(a) Tetrahedron (b) Octahedron

(c) Linear (d) Plane triangle

72. Which of the following will be octahedral **[MP PET 1999]**

(a) SF_6 (b) BF_4^-

(c) PCl_5 (d) BO_3^{3-}

73. The hybrid orbitals used by central atoms in $BeCl_2, BCl_3$ and CCl_4 molecules are respectively **[MP PMT 1999]**

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

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

74. The structure of H_2O_2 is **[CBSE PMT 1999; AFMC 2003]**

(a) Planar (b) Non-planar

(c) Spherical (d) Linear

75. Which of the following is isoelectronic as well as has same structure as that of N_2O **[CPMT 1999]**

(a) N_3H (b) H_2O

(c) NO_2 (d) CO_2

76. CCl_4 has the hybridisation **[DPMT 1996]**

(a) sp^3d (b) dsp^2

(c) sp (d) sp^3

77. Compound having planar symmetry is **[DPMT 1996]**

(a) H_2SO_4 (b) H_2O

(c) HNO_3 (d) CCl_4

78. Which of the following compounds is not linear

[CPMT 1996]

(a) $SnCl_2$ (b) HCl

(c) CO_2 (d) $HgCl_2$

79. Which one of the following statements is true for ammonium ion

(a) All bonds are ionic

(b) All bonds are coordinate covalent

(c) H atoms are situated at the corners of a square

(d) H atoms are situated at the corners of a tetrahedron **[MP PMT 1997]**

80. The bond angle in sp^2 hybridisation is **[RPMT 1997]**

(a) 180^o (b) 120^o

(c) 90^o (d) $109^o2'$

81. The correct order towards bond angle is **[RPMT 1997]**

(a) $sp < sp^2 < sp^3$

(b) $sp^2 < sp < sp^3$

(c) $sp^3 < sp^2 < sp$

(d) Bond angle does not depend on hybridisation

82. The geometry and the type of hybrid orbital present about the central atom in BF_3 is **[IIT 1998; BHU 200**

(a) Linear, sp (b) Trigonal planar, sp^2

(c) Tetrahedral, sp^3 (d) Pyramidal, sp^3

83. In graphite, electrons are **[CBSE PMT 1997]**

(a) Localised on every third C atom

(b) Present in antibonding orbital

(c) Localised on each C atom

(d) Spread out between the structure

84. The ammonium ion is **[CET Pune 1998]**

(a) Tetrahedral (b) Trigonal pyramidal

(c) Square planar (d) Square pyramidal

85. In sp hybridisation, shape is **[Bihar MEE 1997]**

(a) Angular (b) Tetrahedral

(c) Bipyramidal (d) Linear

(e) None of these

86. When the hybridisation state of carbon atom changes from sp^3 to sp^2 to sp, the angle between the hybridised orbitals

[AIIMS 1998]

(a) Decreases gradually (b) Increases gradually

(c) Decreases considerably (d) All of these

87. The structure and hybridisation of $Si(CH_3)_4$ is

[CBSE PMT 1996]

(a) Bent, sp (b) Trigonal, sp^2

(c) Octahedral, sp^3d (d) Tetrahedral, sp^3

88. The type of hybridisation of boron in diborane is

[BHU 1999]

(a) *sp* - hybridisation (b) sp^2 - hybridisation

(c) sp^3 - hybridisation (d) sp^3d^2 - hybridisation

89. Which compound does not possess linear geometry **[RPET 1999]**

(a) $CH_2 = CH_2$ (b) $HC \equiv CH$

(c) $BeCl_2$ (d) CO_2

90. Which of the following molecule does not show tetrahedral shape **[RPET 1999]**

(a) CCl_4 (b) $SiCl_4$

(c) SF_4 (d) CF_4

91. Pyramidal shape would be of **[RPET 1999]**

(a) NO_3^- (b) H_2O

(c) H_3O^+ (d) NH_4^+

92. What is the correct mode of hybridization of the central atom in the following compounds : NO_2^+, SF_4, PF_6^- **[AMU 1999]**

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

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

93. The hybridization in PF_3 is **[DCE 2000]**

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

(c) dsp^3 (d) d^2sp^3

94. Which of the following molecule is linear**[MP PMT 2000]**

(a) SO_2 (b) NO_2^+

(c) NO_2^- (d) SCl_2

95. The geometry of the molecule with sp^3d^2 hybridised central atom is **[NCERT 1981; AFMC 1982; RPMT 2000]**

(a) Square planar (b) Trigonal bipyramidal

(c) Octahedral (d) Square pyramidal

96. The bond angle in PH_3 is **[RPMT 2000]**

(a) Much less than NH_3

(b) Equal to that of NH_3

(c) Much greater than NH_3

(d) Slightly greater than NH_3

97. Which of the following has tetrahedral structure **[CPMT 2000]**

(a) CO_3^- (b) NH_4^+

(c) $K_4[Fe(CN)_6]$ (d) None of these

98. The single, double and triple bond lengths of carbon in carbon dioxide are respectively**[AIIMS 2000]**

(a) 1.15, 1.22 and 1.10 Å (b) 1.22, 1.15 and 1.10 Å

(c) 1.10, 1.15 and 1.22 Å (d) 1.15, 1.10 and 1.22 Å

99. Shape of BF_3 molecule is **[CPMT 2000; Pb. CET 2002]**

(a) Linear (b) Planar

(c) Tetrahedral (d) Square pyramidal

100. In the complex $[SbF_5]^{2-}$, sp^3d hybridization is present. Geometry of the complex is**[Pb. PMT 2000]**

(a) Square (b) Square pyramidal

(c) Square bipyramidal (d) Tetrahedral

101. The bond angle is minimum in **[Pb. PMT 2001; MP PET 2003; UPSEAT 2004]**

(a) H_2Te (b) H_2Se

(c) H_2O (d) H_2S

102. The correct order of hybridization of the central atom in the following species NH_3 $[PtCl_4]^{2-}, PCl_5$ and BCl_3 is **[IIT Screening 2001; BHU 2005]**

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

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

103. Which of the following pairs has same structure**[BHU 2001**

(a) PH_3 and BCl_3 (b) SO_2 and NH_3

(c) PCl_5 and SF_6 (d) NH_4^+ and SO_4^{2-}

104. The smallest bond angle is found in **[AIIMS 2001]**

(a) IF_7 (b) CH_4

(c) BeF_2 (d) BF_3

105. Which of the following is not linear **[DCE 2001]**

(a) CO_2 (b) ClO_2

(c) I_3^- (d) None of these

106. Which of the following is not tetrahedral**[MP PMT 2001]**

(a) SCl_4 (b) SO_4^{2-}

(c) $Ni(CO)_4$ (d) $NiCl_4^{2-}$

107. As the *s*-character of hybridisation orbital increases, the bond angle **[BHU 2002; RPMT 2002]**

(a) Increases (b) Decreases

(c) Becomes zero (d) Does not change

108. The shape of IF_7 molecule is **[AFMC 2002; MHCET 2003]**

(a) Octahedral (b) Pentagonal bipyramidal

(c) Trigonal bipyramidal (d) Tetrahedral

109. A completely filled *d* orbital (d^{10}) **[UPSEAT 2002]**

(a) Spherically symmetrical

(b) Has octahedral symmetry

(c) Has tetrahedral symmetry

(d) Depends on the atom

110. Which has sp^3 hybridization of central atom **[UPSEAT 2002]**

(a) PCl_3 (b) SO_3

(c) BF_3 (d) NO_3^-

111. In which of the following species is the interatomic bond angle is $109^\circ 28'$ **[AIEEE 2002]**

(a) $NH_3, (BF_4)^{-1}$ (b) $(NH_4)^+, BF_3$

(c) NH_3, BF_4 (d) $(NH_2)^{-1}, BF_3$

112. A square planar complex is formed by hybridisation of which atomic orbitals **[AIEEE 2002]**

(a) s, p_x, p_y, d_{yz} (b) $s, p_x, p_y, d_{x^2-y^2}$

(c) s, p_x, p_y, d_{z^2} (d) s, p_y, p_z, d_{xy}

113. In benzene, all the six $C-C$ bonds have the same length because of **[MP PET 2002]**

(a) Tautomerism (b) sp^2 hybridisation

(c) Isomerism (d) Inductive effect

114. The bond energies of $H-H$ and $Cl-Cl$ are 430 kJ mol^{-1} and 242 kJ mol^{-1} respectively, ΔH_t for HCl is 91 $kJ\ mol^{-1}$. The bond energy of HCl will be **[MP PET 2003]**

(a) 427 kJ (b) 766 kJ

(c) 285 kJ (d) 245 kJ

115. Which of the following has dsp^2 hybridization **[MP PET 2003]**

(a) $NiCl_4^{2-}$ (b) SCl_4

(c) NH_4^+ (d) $PtCl_4^{2-}$

116. Which one of the following is a planar molecule **[EAMCET 2003]**

(a) NH_3 (b) H_3O^+

(c) BCl_3 (d) PCl_3

117. Which one of the following is a correct set with respect to molecule, hybridisation and shape **[EAMCET 2003]**

(a) $BeCl_2$, sp^2, linear

(b) $BeCl_2$, sp^2, triangular planar

(c) BCl_3, sp^2, triangular planar

(d) BCl_3, sp^3, tetrahedral

118. Which of the following compounds doesn't have linear structure **[RPET 1997, 2003]**

(a) CO_2 (b) SO_2

(c) $BeCl_2$ (d) C_2H_2

119. Which of the following bonds require the largest amount of bond energy to dissociate the atom concerned **[UPSEAT 2003]**

(a) $H-H$ bond in H_2 (b) $C-C$ bond in CH_4

(c) $N\equiv N$ bond in N_2 (d) $O=O$ bond in O_2

(e) $C-C$ bond in ethane

120. The percentage s-character of the hybrid orbitals in methane, ethene and ethyne are respectively **[KCET 200**

(a) 25, 33, 50 (b) 25, 50, 75

(c) 50, 75, 100 (d) 10, 20, 40

121. Arrange the hydra-acids of halogens in increasing order of acidity **[Orissa JEE 2003]**

(a) $HF < HCl < HBr < HI$ (b) $HI < HBr < HCl < HF$

(c) $HF < HBr < HI < HCl$ (d) $HF < HI < HBr < HCl$

122. Which one has sp^2 – hybridisation **[MP PMT 2004]**

(a) CO_2 (b) N_2O

(c) SO_2 (d) CO

123. Among the following compounds the one that is polar and has central atom with sp^2 – hybridization is **[MP PMT 2004; IIT 1997]**

(a) H_2CO_3 (b) BF_3

(c) SiF_4 (d) $HClO_2$

124. The molecule which is pyramid shape is **[MP PMT 2004; EAMCET 1985; IIT 1989]**

(a) PCl_3 (b) CO_3^{2-}

(c) SO_3 (d) NO_3^-

125. Which of the following has a linear structure **[MP PMT 200**

(a) CCl_4 (b) C_2H_2

(c) SO_2 (d) C_2H_4

126. In a regular octahedral molecule, MX_6, the number $X-M-X$ bonds at 180° is **[CBSE PMT 2004]**

(a) Six (b) Four

(c) Three (d) Two

127. sp^3d^2 hybrid orbitals are **[MP PET 2004]**

(a) Linear bipyramidal (b) Pentagonal

(c) Trigonal bipyramidal (d) Octahedral

128. In an octahedral structure, the pair of d orbitals involved in d^2sp^3 hybridization is

(a) d_{x^2}, d_{xz} (b) d_{xy}, d_{yz}

(c) $d_{x^2-y^2}, d_{z^2}$ (d) $d_{xz}, d_{x^2-y^2}$

129. The correct order of bond angles (smallest first) in H_2S, NH_3, BF_3 and SiH_4 is **[AIEEE 2004]**

(a) $H_2S < NH_3 < SiH_4 < BF_3$

(b) $NH_3 < H_2S < SiH_4 < BF_3$

(c) $H_2S < SiH_4 < NH_3 < BF_3$

(d) $H_2S < NH_3 < BF_3 < SiH_4$

130. Which one of the following has the regular tetrahedral structure **[AIEEE 2004]**

(a) BF_4^- (b) SF_4

(c) XeF_4 (d) $[Ni(CN)_4]^{2-}$

(Atomic no. : $B = 5, S = 16, Ni = 28, Xe = 54$)

131. The states of hybridazation of boron and oxygen atoms in boric acid (H_3BO_3) are respectively **[AIEEE 2004]**

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

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

132. The hybridisation in BF_3 molecule is **[Pb. PMT 2004]**

(a) sp (b) sp^2

(c) sp^3 (d) sp^3d

133. Among the compounds, BF_3, NCl_3, H_2S, SF_4 and $BeCl_2$, identify the ones in which the central atom has the same type of hybridisation

(a) BF_3 and NCl_3 (b) H_2S and $BeCl_2$

(c) BF_3, NCl_3 and H_2S (d) SF_4 and $BeCl_2$

(e) NCl_3 and H_2S

134. The molecule of CO_2 has 180° bond angle. It can be explanid on the basis of

(a) sp^3 hybridisation (b) sp^2 hybridisation

(c) sp hybridisation (d) d^2sp^3 hybridisation

135. sp^3 hybridisation is found in

[Pb. CET 2003; Orissa JEE 2005]

(a) CO_3^{2-} (b) BF_3

(c) NO_3^- (d) NH_3

136. Which set hydridisation is correct for the following compounds **[Pb. CET 2003]**

NO_2, SF_4 PF_6^-

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

(b) sp , sp^3d , sp^3d^2

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

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

137. The state of hybridisation of B in BCl_3 is

[Pb. CET 2000; BHU 2004]

(a) sp (b) sp^2

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

138. The hybrid state of sulphur in SO_3 molecule is **[DCE 2004]**

(a) sp^3d (b) sp^3

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

139. Which of the following molecules has pyramidal shape

[DCE 2004; J&K CET 2005]

(a) PCl_3 (b) SO_3

(c) CO_3^{2-} (d) NO_3^-

140. The hybrdization of IF_7 is **[Pb. CET 2001]**

(a) sp^3d^3 (b) sp^2d

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

141. In which compound, the hydrogen bonding is the strongest in its liquid phase **[Pb. CET 2001]**

(a) HF (b) HI

(c) CH_4 (d) PH_3

142. Geometry of ammonia **[Kerala PMT 2004]** molecule and the hybridization of nitrogen involved in it are **[MH CET 2004]**

(a) sp^3 -hybridization and tetrahedral geometry

(b) sp^3 -hybridization and distorted tetrahedral geometry

(c) sp^2 -hybridization and triangular geometry

(d) None of these **[AFMC 2004]**

143. Be in $BeCl_2$ undergoes **[MH CET 2004]**

(a) Diagonal hybridization

(b) Trigonal hybridization

(c) Tetrahedral hybridization

(d) No hybridization

144. Which of the following is non-linear molecule **[DCE 2003]**

(a) CO_3 (b) CO_2

(c) CS_2 (d) $BeCl_2$

145. The trigonal bipyramidal geometry results from the hybridisation **[UPSEAT 2004]**

(a) dsp^3 or sp^3d (b) dsp^2 or sp^2d

(c) d^2sp^3 or sp^3d^2 (d) d^3sp^2 or d^2sp^3

146. The valency of carbon is four. On what principle it can be explained in a better way

(a) Resonance (b) Hybridization

(c) Electron transfer (d) None of the above

147. Hybridization is due to the overlapping of

[MADT Bihar 1983]

(a) Orbitals of different energy levels

(b) Orbitals of different energy content

(c) Orbitals of same energy content

(d) None of the above

148. If a molecule MX_3 has zero dipole moment, the sigma bonding orbital used by M are

[IIT 1981; MP PMT 1994; Kerala PMT 2004]

(a) sp^3d – hybrid (b) sp – hybrid

(c) sp^3d^2 – hybrid (d) sp^2 – hybrid

149. The linear structure is assumed by **[IIT 1991]**

(a) $SnCl_2$ (b) NCO^-

(c) CS_2 (d) NO_2^+

150. Hybridisation of central atom in NF_3 is **[Orissa JEE 2005]**

(a) sp^3 (b) sp

(c) sp^2 (d) dsp^2

151. The pair having similar geometry is **[J&K CET 2005]**

(a) PCl_3, NH_3 (b) $BeCl_2, H_2O$

(c) CH_4, CCl_4 (d) IF_5, PF_5

152. The *d*-orbital involved in sp^3d hybridisation is

[J&K CET 2005]

(a) $d_{x^2-y^2}$ (b) d_{xy}

(c) d_{z^2} (d) d_{zx}

Resonance

1. Which one in the following is not the resonance structure of CO_2

(a) $O=C=O$ (b) $^-O-C\equiv O^+$

(c) $^+O\equiv C-O^-$ (d) $O\equiv C=O$

2. Which of the following molecule contains one pair of non-bonding electrons

(a) CH_4 (b) NH_3

(c) H_2O (d) HF

3. Resonance is due to **[NCERT 1981; Kurukshetra CEE 1998]**

(a) Delocalization of *sigma* electrons

(b) Delocalization of *pi* electrons

(c) Migration of *H* atoms

(d) Migration of protons

4. Resonating structures have different **[AMU 1983]**

(a) Atomic arrangements (b) Electronic arrangements

(c) Functional groups (d) Alkyl groups

5. In the cyanide ion, the formal negative charge is on

[AMU 1984]

(a) *C*

(b) *N*

(c) Both *C* and *N*

(d) Resonate between *C* and *N*

6. Which does not show resonance **[CPMT 1990]**

(a) Benzene (b) Aniline

(c) Ethyl amine (d) Toluene

7. The enolic form of acetone contains

[IIT 1990; Bihar MEE 1997]

(a) 9 sigma bonds, 1 pi bond and 2 lone pairs

(b) 8 sigma bonds, 2 pi bonds and 2 lone pairs

(c) 10 sigma bonds, 1 pi bond and 1 lone pair

(d) 9 sigma bonds, 2 pi bonds and 1 lone pair

8. Point out incorrect statement about resonance

[MP PET 1997]

(a) Resonance structures should have equal energy

(b) In resonance structures, the constituent atoms should be in the same position

(c) In resonance structures, there should not be the same number of electron pairs

(d) Resonance structures should differ only in the location of electrons around the constituent atoms

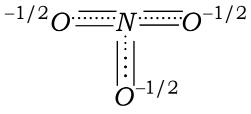
9. The number of possible resonance structures for CO_3^{2-} is

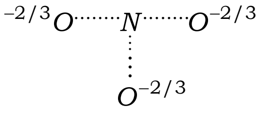
[MP PMT 2000]

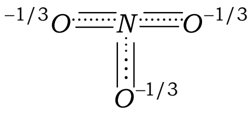
(a) 2 (b) 3

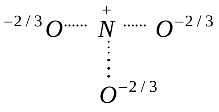
(c) 6 (d) 9

10. Resonance hybrid of nitrate ion is **[RPET 2000]**

(a)


(b)


(c)


(d)


11. CO_3^{2-} anion has which of the following characteristics

[Roorkee 1999]

(a) Bonds of unequal length

(b) sp^2 hybridization of *C* atom

(c) Resonance stabilization

(d) Same bond angles

VSEPR Theory

1. The structure of $\left[Cu\left(H_2O\right)_4\right]^{++}$ ion is

[NCERT 1983; MP PMT 1983]

(a) Square planar (b) Tetrahedral

(c) Distorted rectangle (d) Octahedral

2. The bond angle in PH_3 would be expected to be close to

(a) 90^o (b) 105^o

(c) 109^o (d) 120^o

3. In which molecule are all atoms coplanar **[MP PMT 1994]**

(a) CH_4 (b) BF_3

(c) PF_3 (d) NH_3

4. Which has the least bond angle **DPMT 1990; CBSE PMT 1990; UPSEAT 2003]**

(a) NH_3 (b) BeF_2

(c) H_2O (d) CH_4

5. In compound X, all the bond angles are exactly $109^o28'$, X is **[CBSE PMT 1991]**

(a) Chloromethane (b) Iodoform

(c) Carbon tetrachloride (d) Chloroform

6. The shape of SO_4^{2-} ion is **[CPMT 1982; DPMT 1983, 84, 96; Bihar MEE 1997]**

(a) Square planar (b) Tetrahedral

(c) Trigonal bipyramidal (d) Hexagonal

7. Which of the following molecules has one lone pair of electrons on the central atom **[EAMCET 1980; AMU 1982; MNR 1989]**

(a) H_2O (b) NH_3

(c) CH_4 (d) PCl_5

8. Of the following compounds, the one having a linear structure is **[NCERT 1981; CPMT 1991; DPMT 1982; MP PMT 1985; AIIMS 1996]**

(a) NH_2 (b) CH_4

(c) C_2H_2 (d) H_2O

9. XeF_6 is

(a) Octahedral (b) Distorted octahedral

(c) Planar (d) Tetrahedral

10. Which has maximum bond angle

(a) CHF_3

(b) $CHCl_3$

(c) $CHBr_3$

(d) All have maximum bond angle

11. Of the following species the one having a square planar structure is **[NCERT 1981; MP PMT 1994]**

(a) NH_4^+ (b) BF_4^-

(c) XeF_4 (d) SCl_4

12. In which of the following is the angle between the two covalent bonds greatest **[NCERT 1975; AMU 1982; MNR 1987; IIT 1981; CPMT 1988; MP PMT 1994]**

(a) CO_2 (b) CH_4

(c) NH_3 (d) H_2O

13. As the *s*-character of hybridized orbital decreases, the bond angle **[DPMT 1986]**

(a) Decreases (b) Increases

(c) Does not change (d) Becomes zero

14. XeF_2 molecule is **[BHU 1982]**

(a) Linear (b) Triangular planar

(c) Pyramidal (d) Square planar

15. **[NCERT 1978;** Of the following sets which one does NOT contain isoelectronic species **[AIEEE 2005]**

(a) $PO_4^{3-}, SO_4^{2-}, ClO_4^-$ (b) CN^-, N_2, C_2^{2-}

(c) $SO_3^{2-}, CO_3^{2-}, NO_3^-$ (d) $BO_3^{3-}, CO_3^{2-}, NO_3^-$

16. A molecule which contains unpaired electrons is **[NCERT 1982]**

(a) Carbon monoxide (b) Molecular nitrogen

(c) Molecular oxygen (d) Hydrogen peroxide

17. H_2O is **[MADT Bihar 1983]**

(a) A linear triatomic molecule

(b) A bent (angular) triatomic molecule

(c) Both of these

(d) None of these

18. Bond angle between two hybrid orbitals is 105^o.% s-orbital character of hybrid orbital is **[MP PMT 1986]**

(a) Between $20-21\%$ (b) Between $19-20\%$

(c) Between $21-22\%$ (d) Between $22-23\%$

19. The bond angle between $H-O-H$ in ice is closest to **[CPMT 1989; UPSEAT 2002]**

(a) $120^o28'$ (b) 60^o

(c) 90^o (d) 105^o

20. Which of the following molecules does not have a linear arrangement of atoms **[CPMT 1993]**

(a) H_2S (b) C_2H_2

(c) BeH_2 (d) CO_2

21. BCl_3 is a planar molecule while NCl_3 is pyramidal, because **[CBSE PMT 1995]**

(a) BCl_3 has no lone pair of electrons but NCl_3 has a lone pair of electrons

(b) $B-Cl$ bond is more polar than $N-Cl$ bond

(c) Nitrogen atom is smaller than boron atom

(d) $N-Cl$ bond is more covalent than $B-Cl$ bond

22. The isoelectronic pair is **[AIIMS 2005]**

(a) Cl_2O, ICl_2^- (b) ICl_2^-, ClO_2

(c) IF_2^+, I_3^- (d) ClO_2^-, CIF_2^+

23. According to VSEPR theory, the most probable shape of the molecule having 4 electron pairs in the outer shell of the central atom is

(a) Linear (b) Tetrahedral

(c) Hexahedral (d) Octahedral

24. The molecular shapes of SF_4, CF_4 and XeF_4 are **[AIEEE 2005]**

(a) The same with 2, 0 and 1 lone pairs of electrons on the central atom, respectively

(b) The same with 1, 1 and 1 lone pair of electrons on the central atoms, respectively

(c) Different with 0, 1 and 2 lone pairs of electrons on the central atom, respectively

(d) Different with 1, 0 and 2 lone pairs of electrons on the central atom, respectively

25. Which of the following species is planar **[JIPMER 1997]**

(a) CO_3^{2-} (b) NH_2

(c) PCl_3 (d) None of these

26. The shape of CH_3^+ species is **[RPET 1999]**

(a) Tetrahedral (b) Square planar

(c) Trigonal planar (d) Linear

27. Which of the following is the correct reducing order of bond-angle **[BHU 2000]**

(a) $NH_3 < CH_4 < C_2H_2 < H_2O$

(b) $C_2H_2 > NH_3 > H_2O < CH_4$

(c) $NH_3 > H_2O > CH_4 < C_2H_2$

(d) $H_2O < NH_3 > CH_4 < C_2H_2$

28. Which compound has bond angle nearly to $90°$ **[Pb. PMT 2001]**

(a) H_2O (b) H_2S

(c) NH_3 (d) CH_4

29. A lone pair of electrons in an atom implies **[KCET 2002]**

(a) A pair of valence electrons not involved in bonding

(b) A pair of electrons involved in bonding

(c) A pair of electrons

(d) A pair of valence electrons

30. The bond angle of water is 104.5^o due to **[CPMT 2002]**

(a) Repulsion between lone pair and bond pair

(b) sp^3 hybridization of O

(c) Bonding of H_2O

(d) Higher electronegativity of O

31. The correct sequence of decrease in the bond angle of the following hybrides is **[MP PET 2002]**

(a) $NH_3 > PH_3 > AsH_3 > SbH_3$

(b) $NH_3 > AsH_3 > PH_3 > SbH_3$

(c) $SbH_3 > AsH_3 > PH_3 > NH_3$

(d) $PH_3 > NH_3 > AsH_3 > SbH_3$

32. Central atom of the following compound has one lone pair of electrons and three bond pairs of electrons **[JIPMER 2002]**

(a) H_2S (b) $AlCl_3$

(c) NH_3 (d) BF_3

33. Among KO_2, AlO_2^-, BaO_2 and NO_2^+ unpaired electron is present in **[MP PET 2003]**

(a) NO_2^+ and BaO_2 (b) KO_2 and AlO_2^-

(c) KO_2 only (d) BaO_2 only

34. True order of bond angle is **[RPET 2003]**

(a) $H_2O > H_2S > H_2Se > H_2Te$

(b) $H_2Te > H_2Se > H_2S > H_2O$

(c) $H_2S > H_2O > H_2Se > H_2Te$

(d) $H_2O > H_2S > H_2Te > H_2Se$

35. Which of the following has not a lone pair over the central atom **[Orissa JEE 2003]**

(a) NH_3 (b) PH_3

(c) BF_3 (d) PCl_3

36. In BrF_3 molecule,the lone pairs occupy equatorial positions to minimize **[CBSE PMT 2004]**

(a) Lone pair- lone pair repuilsion and lone pair-bond pair repulsion

(b) Lone pair- lone pair repulsion only

(c) Lone pair- bond pair repulsion only

(d) Bond pair- bond pair repulsion only

37. H_2O is dipolar, whereas BeF_2 is not. It is because **[CBSE PMT 1989; 2004]**

(a) H_2O is linear and BeF_2 is angular

(b) H_2O is angular and BeF_2 is linear

(c) The electornegativity of F is greater than that of O

(d) H_2O involves hydrogen bonding whereas BeF_2 is a discrete molecule

38. Maximum bond angle is present in **[BVP 2004]**

(a) BCl_3 (b) BBr_3

(c) BF_3 (d) Same for all

39. The shape of a molecule of NH_3, in which central atoms contains lone pair of electron, is **[MHCET 2003]**

(a) Tetrahedral (b) Planar trigonal

(c) Square planar (d) Pyramidal

40. The largest bond angle is in **[DCE 2002; MNR 1984]**

(a) AsH_3 (b) NH_3

(c) H_2O (d) PH_3

41. The bond angle in ammonia molecule is **[EAMCET 1980]**

(a) $91^o8'$ (b) $93^o3'$

(c) $106^o45'$ (d) $109^o28'$

42. Which of the following gives correct arrangement of compounds involved based on their bond strength **[BHU 2005]**

(a) HF > HCl > HBr > HI

(b) HI > HBr > HCl > HF

(c) HF > HBr > HCl > HI

(d) $HCl > HF > HBr > HI$

43. Which one has a pyramidal structure **[CBSE PMT 1990]**

(a) CH_4 (b) NH_3

(c) H_2O (d) CO_2

44. Among the following the pair in which the two species are not isostructural is **[CBSE PMT 2004]**

(a) BH_4^- and NH_4^+ (b) PF_6^- and SF_6

(c) SiF_4 and SF_4 (d) IO_3^- and XeO_3

45. The maximum number of 90° angles between bond pair-bond pair of electrons is observed in **[AIEEE 2004]**

(a) dsp^2 hybridization (b) sp^3d hybridization

(c) dsp^3 hybridization (d) sp^3d^2 hybridization

Molecular orbital theory

1. Bond order is a concept in the molecular orbital theory. It depends on the number of electrons in the bonding and antibonding orbitals. Which of the following statements is true about it ? The bond order **[AIIMS 1980]**

(a) Can have a negative quantity

(b) Has always an integral value

(c) Can assume any positive or integral or fractional value including zero

(d) Is a non zero quantity

2. The bond order of NO molecule is **[MP PET 1996]**

(a) 1 (b) 2

(c) 2.5 (d) 3

3. When two atomic orbitals combine they form

(a) One molecular orbital (b)Two molecular orbital

(c) Three molecular orbital (d)Four molecular orbital

4. Which of the following species is the least stable

(a) O_2 (b) O_2^{-2}

(c) O_2^{+1} (d) O_2^{-1}

5. The bond order is maximum in

[AIIMS 1983, 85; CBSE PMT 1994; MP PET 2002]

(a) O_2 (b) O_2^{-1}

(c) O_2^{+1} (d) O_2^{-2}

6. Which of the following compounds of boron does not exist in the free form

(a) BCl_3 (b) BF_3

(c) BBr_3 (d) BH_3

7. Molecular orbital theory was developed mainly by

[BHU 1987; Pb. CET 2003]

(a) Pauling (b) Pauling and Slater

(c) Mulliken (d) Thomson

8. The bond order of a molecule is given by **[NCERT 1984]**

(a) The difference between the number of electrons in bonding and antibonding orbitals

(b) Total number of electrons in bonding and antibonding orbitals

(c) Twice the difference between the number of electrons in bonding and antibonding electrons

(d) Half the difference between the number of electrons in bonding and antibonding electrons

9. Oxygen molecule is paramagnetic because

[NCERT 1984; IIT 1984]

(a) Bonding electrons are more than antibonding electrons

(b) Contains unpaired electrons

(c) Bonding electrons are less than antibonding electrons

(d) Bonding electrons are equal to antibonding electrons

10. Which one is paramagnetic from the following

[IIT 1989; CBSE PMT 1995]

(a) O_2^- (b) NO

(c) Both (a) and (b) (d) CN^-

11. The bond order in N_2^+ ion is **[Pb. CET 2004]**

(a) 1 (b) 2

(c) 2.5 (d) 3

12. Out of the following which has smallest bond length

[RPMT 1997]

(a) O_2 (b) O_2^+

(c) O_2^- (d) O_2^{2-}

13. Which of the following molecule is paramagnetic

[CPMT 1980; RPET 1999;MP PMT 1999; RPMT 2000]

(a) Chlorine (b) Nitrogen

(c) Oxygen (d) Hydrogen

14. Which molecule has the highest bond order

(a) N_2 (b) Li_2

(c) He_2 (d) O_2

15. The molecular electronic configuration of H_2^- ion is

(a) $(\sigma 1s)^2$ (b) $(\sigma 1s)^2(\sigma^x 1s)^2$

(c) $(\sigma 1s)^2(\sigma^x 1s)^1$ (d) $(\sigma 1s)^3$

16. The paramagnetic nature of oxygen molecule is best explained on the basis of

(a) Valence bond theory (b) Resonance

(c) Molecular orbital theory (d) Hybridization

17. In which case the bond length is minimum between carbon and nitrogen

(a) CH_3NH_2 (b) $C_6H_5CH = NOH$

(c) CH_3CONH_2 (d) CH_3CN

18. Which one of the following species is diamagnetic in nature

[AIEEE 2005]

(a) He_2^+ (b) H_2

(c) H_2^+ (d) H_2^-

19. Which one of the following oxides is expected exhibit paramagnetic behaviour **[CBSE PMT 2005]**

(a) CO_2 (b) SO_2

(c) ClO_2 (d) SiO_2

20. The bond order in N_2 molecule is

[CBSE 1995; Pb. PMT 1999; MP PET 1997]

(a) 1 (b) 2

(c) 3 (d) 4

21. Which one is paramagnetic and has the bond order 1/2

[NCERT 1983]

(a) O_2 (b) N_2

(c) F_2 (d) H_2^+

22. When two atoms of chlorine combine to form one molecule of chlorine gas, the energy of the molecule **[AMU 1982]**

(a) Greater than that of separate atoms

(b) Equal to that of separate atoms

(c) Lower than that of separate atoms

(d) None of the above statement is correct

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

[CPMT 1974, 84; RPMT 1999]

(a) A_3B_4 (b) A_2B_3

(c) A_3B_2 (d) A_2B

24. The bond order of individual carbon-carbon bonds in benzene is **[IIT 1980]**

(a) One (b) Two

(c) Between 1 and 2 (d) One and two alternately

25. PCl_5 exists but NCl_5 does not because

[EAMCET 1977; MP PET/PMT 1988]

(a) Nitrogen has no vacant d-orbitals

(b) NCl_5 is unstable

(c) Nitrogen atom is much smaller

(d) Nitrogen is highly inert

26. Paramagnetism is exhibited by molecules

[NCERT 1979; MP PET 2002]

(a) Not attracted into a magnetic field

(b) Containing only paired electrons

(c) Carrying a positive charge

(d) Containing unpaired electrons

27. Which one of the following is paramagnetic **[DPMT 1985]**

(a) H_2O (b) NO_2

(c) SO_2 (d) CO_2

28. The energy of a $2p$ orbital except hydrogen atom is

[AMU 1983]

(a) Less than that of $2s$ orbital

(b) More than that of $2s$ orbital

(c) Equal to that of $2s$ orbital

(d) Double that of $2s$ orbital

29. In the electronic structure of acetic acid, there are

[AMU 1983]

(a) 16 shared and 8 unshared electrons

(b) 8 shared and 16 unshared electrons

(c) 12 shared and 12 unshared electrons

(d) 18 shared and 6 unshared electrons

30. Which of the following does not exist on the basis of molecular orbital theory **[AFMC 1990; MP PMT 1996]**

(a) H_2^+ (b) He_2^+

(c) He_2 (d) Li_2

31. In P_4O_{10}, the number of oxygen atoms attached to each phosphorus atom is **[IIT 1995]**

(a) 2 (b) 3

(c) 4 (d) 2.5

32. Of the following statements which one is correct

(a) Oxygen and nitric oxide molecules are both paramagnetic because both contain unpaired electrons

(b) Oxygen and nitric oxide molecules are both diamagnetic because both contain no unpaired electrons

(c) Oxygen is paramagnetic because it contains unpaired electrons, while nitric oxide is diamagnetic because it contains no unpaired electrons

(d) Oxygen is diamagnetic because it contains no unpaired electrons, while nitric oxide is paramagnetic because it contains an unpaired electron

33. According to the molecular orbital theory, the bond order in C_2 molecule is

(a) 0 (b) 1

(c) 2 (d) 3

34. The molecular orbital configuration of a diatomic molecule is

$$\sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \sigma 2p_x^2 \left\{\begin{matrix}\pi 2p_y^2\\ \pi 2p_z^2\end{matrix}\right.$$

Its bond order is

(a) 3 (b) 2.5

(c) 2 (d) 1

35. The difference in energy between the molecular orbital formed and the combining atomic orbitals is called

(a) Bond energy (b) Activation energy

(c) Stabilization energy (d) Destabilization energy

36. According to molecular orbital theory, the paramagnetism of O_2 molecule is due to presence of **[MP PMT 1997]**

(a) Unpaired electrons in the bonding σ molecular orbital

(b) Unpaired electrons in the antibonding σ molecular orbital

(c) Unpaired electron in the bonding π molecular orbital

(d) Unpaired electrons in the antibonding π molecular orbital

37. The bond order in O_2^+ is **[MP PET 1999; BHU 2001]**

(a) 2 (b) 2.5

(c) 1.5 (d) 3

38. Which of the following is paramagnetic **[MP PET 1999]**

(a) O_2 (b) CN^-

(c) CO (d) NO^+

39. If N_x is the number of bonding orbitals of an atom and N_y is the number of antibonding orbitals, then the molecule/atom will be stable if **[DPMT 1996]**

(a) $N_x > N_y$ (b) $N_x = N_y$

(c) $N_x < N_y$ (d) $N_x \le N_y$

40. Which of the following molecular orbitals has two nodal planes **[KCET 1996]**

(a) $\sigma 2s$ (b) $\pi 2p_y$

(c) $\pi^* 2p_y$ (d) $\sigma^* 2p_x$

41. The number of nodal planes 'd' orbital has **[KCET 1996]**

(a) Zero (b) One

(c) Two (d) Three

42. Atomic number of an element is 26. The element shows

[CPMT 1996]

(a) Ferromagnetism (b) Diamagnetism

(c) Paramagnetism (d) None of these

43. What is correct sequence of bond order **[BHU 1997]**

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

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

44. Which bond is strongest **[RPMT 1997]**

(a) $F-F$ (b) $Br-F$

(c) $Cl-F$ (d) $I-F$

45. Which of the following is not paramagnetic **[AIIMS 1997]**

(a) S^{-2} (b) N_2^-

(c) O_2^- (d) NO

46. Which one of the following molecules is paramagnetic

[Pb. PMT 1998]

(a) CO_2 (b) SO_2

(c) NO (d) H_2O

47. N_2 and O_2 are converted into monoanions N_2^- and O_2^- respectively, which of the following statements is wrong

[CBSE PMT 1997]

(a) In N_2, the $N-N$ bond weakens

(b) In O_2, the $O-O$ bond order increases

(c) In O_2, bond length increases

(d) N_2^- becomes diamagnetic

48. With increasing bond order, stability of a bond

[CET Pune 1998]

(a) Remains unaltered (b) Decreases

(c) Increases (d) None of these

49. Which is not paramagnetic **[DCE 1999, 2000]**

(a) O_2 (b) O_2^+

(c) O_2^{2-} (d) O_2^-

50. The number of antibonding electron pairs in O_2^{2-} molecular ion on the basis of molecular orbital theory is

[Pb. PMT 2000]

(a) 4 (b) 3

(c) 2 (d) 5

51. The bond order of He_2^+ molecule ion is

[Pb. PMT 2000; Pb CET 2001]

(a) 1 (b) 2

(c) $\frac{1}{2}$ (d) $\frac{1}{4}$

52. Which one does not exhibit paramagnetism **[DPMT 2000]**

(a) ClO_2 (b) ClO_2^-

(c) NO_2 (d) NO

53. In which of the following pairs the two molecules have identical bond order

(a) N_2, O_2^{2+} (b) N_2, O_2^-

(c) N_2^-, O_2 (d) O_2^+, N_2

54. The bond order is not three for **[MP PMT 2001]**

(a) N_2^+ (b) O_2^{2+}

(c) N_2 (d) NO^+

55. In H_2O_2 molecule, the angle between the two O – H planes is

(a) 90^o (b) 101^o

(c) 103^o (d) 105^o

56. Which of the following molecule has highest bond energy

[AIIMS 2002]

(a) $F-F$ (b) $C-C$

(c) $N-N$ (d) $O-O$

57. Which of the following species would be expected paramagnetic **[UPSEAT 2002]**

(a) Copper crystals (b) Cu^+

(c) Cu^{++} (d) H_2

58. Which of the following is correct for N_2 triple bond

[CPMT 2002]

(a) 3*s* (b) 1*p*, 2s

(c) 2*p*, 1s (d) 3*p*

59. In which of the following pairs molecules have bond order three and are isoelectronics **[MP PET 2003]**

(a) CN^-, CO (b) NO^+, CO^+

(c) CN^-, O_2^+ (d) CO, O_2^+

60. Which of the following is paramagnetic **[MP PET 2003]**

(a) O_2^+ (b) CN^-

(c) CO (d) N_2

61. How many bonding electron pairs are there in white phosphorous **[MP PET 2003]**

(a) 6 (b) 12

(c) 4 (d) 8

62. The atomicity of phosphorus is X and the $P\hat{P}P$ bond angle in the molecule is Y. What are X and Y **[EAMCET 2003]**

(a) X = 4, Y = 90^o (b) X = 4, Y = 60^o

(c) X = 3, Y = 120^o (d) X = 2, Y = 180^o

63. From elementary molecular orbital theory we can give the electronic configuration of the singly positive nitrogen molecular ion N_2^+ as

(a) $\sigma(1s)^2\sigma^*(1s)^2\sigma(2s)^2\sigma^*(2s)^2\pi(2p)^4\sigma(2p)^1$

(b) $\sigma(1s)^2\sigma^*(1s)^2\sigma(2s)^2\sigma^*(2s)^2\sigma(2p)^1\pi(2p)^3$

(c) $\sigma(1s)^2\sigma^*(1s)^2\sigma(2s)^2\sigma^*(2p)^2\pi(2p)^4$

(d) $\sigma(1s)^2\sigma^*(1s)^2\sigma(2s)^2\sigma^*(2s)^2\sigma(2p)^2\pi(2p)^2$

[MP PMT 2000]

64. The paramagnetic property of the oxygen molecule due to the presence of unpaired electorns present in

[Kerala PMT 2004]

(a) $(\sigma 2p_x)^1$ and $(\sigma^* 2p_x)^1$

(b) $(\sigma 2p_x)^1$ and $(\pi 2p_y)^1$

(c) $(\pi * 2p_y)^1$ and $(\pi * 2p_z)^1$

(d) $(\pi * 2p_x)^1$ and $(\pi 2p_y)^1$

[CBSE PMT 2002]

(e) $(\pi * 2p_z)^1$ and $(\pi 2p_z)^1$

65. In PO_4^{3-} ion, the formal charge on each oxygen atom and $P-O$ bond order respectively are **[DPMT 2004]**

(a) –0.75, 1.25 (b) –0.75, 1.0

(c) –0.75, 0.6 (d) –3, 1.25

66. The bond order in CO_3^{2-} ion between $C-O$ is

[Pb. PMT 2004]

(a) Zero (b) 0.88

(c) 1.33 (d) 2

67. The bond order of O_2^+ is the same as in **[CPMT 2004]**

(a) N_2^+ (b) CN^-

(c) CO (d) NO^+

68. Bond order of O_2 is **[DPMT 2004]**

(a) 2 (b) 1.5

(c) 3 (d) 3.5

69. The total number of electron that takes part in forming bonds in N_2 is **[MP PET 2004]**

(a) 2 (b) 4

(c) 6 (d) 10

70. The bond length the species O_2, O_2^+ and O_2^- are in the order of **[MP PET 2004]**

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

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

71. According to molecular orbital theory which of the following statement about the magnetic character and bond order is correct regarding O_2^+ **[IIT JEE**

(a) Paramagnetic and bond order $< O_2$

(b) Paramagnetic and bond order $> O_2$

(c) Dimagnetic and bond order $< O_2$

(d) Dimagnetic and bond order $> O_2$

[UPSEAT 2003]

72. The bond order in NO is 2.5 while that in NO^+ is 3. Which of the following statements is true for these two species

[AIEEE 2004]

(a) Bond length in NO^+ is equal to that in NO

(b) Bond length in NO is greater than in NO^+

(c) Bond length in NO^+ is greater than in NO

(d) Bond length is unpredictable

73. Which of the following is diamagnetic **[BVP 2004]**

(a) Oxygen molecule (b) Boron molecule

(c) N_2^+ (d) None

74. Bond energies in NO, NO^+ and NO^- are such as **[Pb. CET 2004]**

(a) $NO^- > NO > NO^+$ (b) $NO > NO^- > NO^+$

(c) $NO^+ > NO > NO^-$ (d) $NO^+ > NO^- > NO$

75. Which of the following is paramagnetic **[UPSEAT 2004]**

(a) B_2 (b) C_2

(c) N_2 (d) F_2

76. The paramagnetic molecule at ground state among the following is **[UPSEAT 2004]**

(a) H_2 (b) O_2

(c) N_2 (d) CO

77. Which has the highest bond energy **[DCE 2002]**

(a) F_2 (b) Cl_2

(c) Br_2 (d) I_2

78. In O_2^-, O_2 and O_2^{-2} molecular species, the total number of antibonding electrons respectively are **[DCE 2003]**

(a) 7, 6, 8 (b) 1, 0, 2

(c) 6, 6, 6 (d) 8, 6, 8

79. Which of the following is not paramagnetic **[DCE 2002]**

(a) O_2 (b) O_2^{2+}

(c) O_2^{2-} (d) O_2^-

80. Which of the following species have maximum number of unpaired electrons

(a) O_2 (b) O_2^+

(c) O_2^- (d) O_2^{2-}

81. The correct order in which the $O - O$ bond length increases in the following is **[BHU 2000; CBSE PMT 2005]**

(a) $H_2O_2 < O_2 < O_3$ (b) $O_2 < H_2O_2 < O_3$

(c) $O_2 < O_3 < H_2O_2$ (d) $O_3 < H_2O_2 < O_2$

82. Correct order of bond length is **[Orissa JEE 2005]**

(a) $CO_3^{2-} > CO_2 > CO$ (b) $CO_2 > CO > CO_3^{2-}$

(c) $CO > CO_2 > CO_3^{2-}$ (d) None of these

83. Which of the following is paramagnetic **[DPMT 2005]**

(a) N_2 (b) C_2

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

84. Among the following molecules which one have smallest bond angle **[Orissa JEE 2005]**

(a) NH_3 (b) PH_3

(c) H_2O (d) H_2Sc

(e) H_2S

Hydrogen bonding

1. In the following which bond will be responsible for maximun value of hydrogen bond

(a) $O-H$ (b) $N-H$

(c) $S-H$ (d) $F-H$

2. In which of the following hydrogen bond is present

(a) H_2 (b) Ice

(c) Sulphur (d) Hydrocarbon

3. In the following which has highest boiling point **[MP PMT 1989; RPMT 1997]**

(a) HI (b) HF

(c) HBr (d) HCl

4. Which contains hydrogen bond

(a) HF (b) HCl

(c) HBr (d) HI

5. Contrary to other hydrogen halides, hydrogen fluoride is a liquid because **[MP PMT 1990; AMU 1983; EAMC**

(a) Size of F atom is small

(b) HF is a weak acid

(c) HF molecule are hydrogen bonded

(d) Fluorine is highly reactive

6. In the following which species does not contain sp^3 hybridization **[DPMT 1985]**

(a) NH_3 (b) CH_4

(c) H_2O (d) CO_2

7. As a result of sp hybridization, we get **[IIT 1984]** **[AIIMS 1983]**

(a) Two mutual perpendicular orbitals

(b) Two orbitals at 180^o

(c) Four orbitals in tetrahedral directions

(d) Three orbitals in the same plane

8. The reason for exceptionally high boiling point of water is

[DPMT 1986; NCERT 1976; AMU 1984; EAMCET 1979; MP PMT 1993; AIIMS 1996; KCET 2001; CPMT 2003]

(a) Its high specific heat

(b) Its high dielectric constant

(c) Low ionization of water molecules

(d) Hydrogen bonding in the molecules of water

9. Which concept best explains that *o*-nitrophenol is more volatile than *p*-nitrophenol

[AIIMS 1980, 82; Kurukshetra CEE 1998; MP PET 2002]

(a) Resonance (b) Hyperconjugation

(c) Hydrogen bonding (d) Steric hindrence

10. Which contains strongest $H-$bond

[IIT 1986; MP PET 1997, 2003; UPSEAT 2001, 03]

(a) $O-H.....S$ (b) $S-H.....O$

(c) $F-H.....F$ (d) $F-H.....O$

11. Which of the following compound can form hydrogen bonds

[NCERT 1978; MP PMT 1997]

(a) CH_4 (b) $NaCl$

(c) $CHCl_3$ (d) H_2O

12. Of the following hydrides which has the lowest boiling point

[CBSE PMT 1987]

(a) NH_3 (b) PH_3

(c) SbH_3 (d) AsH_3

13. The pairs of bases in DNA are held together by

[NCERT 1978; DPMT 1985; CBSE PMT 1992]

(a) Hydrogen bonds (b) Ionic bonds

(c) Phosphate groups (d) Deoxyribose groups

14. Water has high heat of vaporisation due to **[AFMC 1982]**

(a) Covalent bonding (b) $H-$bonding

(c) Ionic bonding (d) None of the above

15. In which of the following compounds does hydrogen bonding occur **[CBSE PMT 1989]**

(a) SiH_4 (b) LiH

(c) HI (d) NH_3

16. Which among the following compounds does not show hydrogen bonding **[MP PMT 1989]**

(a) Chloroform (b) Ethyl alcohol

(c) Acetic acid (d) Ethyl ether

17. Acetic acid exists as dimer in benzene due to **[CPMT 1982]**

(a) Condensation reaction

(b) Hydrogen bonding

(c) Presence of carboxyl group

(d) Presence of hydrogen atom at $\alpha-$carbon

18. Which one among the following does not have the hydrogen bond **[IIT 1983; MP PMT 1994; UPSEAT 2001]**

(a) Phenol (b) Liquid NH_3

(c) Water (d) Liquid HCl

19. The bond that determines the secondary structure of a protein is **[NCERT 1984; MP PET 1996]**

(a) Coordinate bond (b) Covalent bond

(c) Hydrogen bond (d) Ionic bond

20. HCl is a gas but HF is a low boiling liquid. This is because

[NCERT 1984; MP PMT 2001]

(a) $H-F$ bond is strong

(b) $H-F$ bond is weak

(c) Molecules aggregate because of hydrogen bonding

(d) HF is a weak acid

21. The relatively high boiling point of HF is due to

[NCERT 1984]

(a) Hydrogen bonding

(b) Covalent bonding

(c) Unshared electron pair on F

(d) Being a halogen acid

22. Water is liquid due to **[MADT Bihar 1983]**

(a) Hydrogen bonding (b) Covalent bond

(c) Ionic bond (d) Vander Waals forces

23. The maximum possible number of hydrogen bonds in which an H_2O molecule can participate is

[MP PMT 1986; MNR 1991; IIT 1992;MP PET 1999]

(a) 1 (b) 2

(c) 3 (d) 4

24. Hydrogen bonding is maximum in

[IIT 1987; MP PMT 1991; MP PET 1993, 2001; MNR 1995; CPMT 1999; KCET (Med.) 2002]

(a) Ethanol (b) Diethyl ether

(c) Ethyl chloride (d) Triethyl amine

25. The hydrogen bond is strongest in

[BHU 1987; CBSE PMT 1990, 92]

(a) Water (b) Ammonia

(c) Hydrogen fluoride (d) Acetic acid

26. The high boiling point of ethanol $(78.2^{o}C)$ compared to dimethyl ether $(-23.6^{o}C)$, though both having the same molecular formulae C_6H_6O, is due to **[MP PMT 1993]**

(a) Hydrogen bonding

(b) Ionic bonding

(c) Coordinate covalent bonding

(d) Resonance

27. Methanol and ethanol are miscible in water due to

[CPMT 1989]

(a) Covalent character

(b) Hydrogen bonding character

(c) Oxygen bonding character

(d) None of these

28. B.P. of $H_2O(100^{o}C)$ and $H_2S(-42^{o}C)$ explained by

(a) Vander Waal's forces (b) Covalent bond

(c) Hydrogen bond (d) Ionic bond

29. Strength of hydrogen bond is intermediate between **[DPMT 1991]**

(a) Vander Waal and covalent

(b) Ionic and covalent

(c) Ionic and metallic

(d) Metallic and covalent

30. In which of the following compounds intramolecular hydrogen bond is present **[MP PET 1994]**

(a) Ethyl alcohol (b) Water

(c) Salicylaldehyde (d) Hydrogen sulphide

31. Hydrogen bonding is formed in compounds containing hydrogen and **[MP PET 1995]**

(a) Highly electronegative atoms

(b) Highly electropositive atoms

(c) Metal atoms with *d*-orbitals occupied

(d) Metalloids

32. Which of the following compounds in liquid state does not have hydrogen bonding **[MP PMT 1996]**

(a) H_2O (b) HF

(c) NH_3 (d) C_6H_6

33. Compounds showing hydrogen bonding among HF, NH_3, H_2S and PH_3 are

(a) Only HF, NH_3 and PH_3

(b) Only HF and NH_3

(c) Only NH_3, H_2S and PH_3

(d) All the four

34. The high density of water compared to ice is due to **[CBSE PMT 1997; BHU 1999; AFMC 2001]**

(a) Hydrogen bonding interactions

(b) Dipole-dipole interactions

(c) Dipole-induced dipole interactions

(d) Induced dipole-induced dipole interactions

35. Ethanol and dimethyl ether form a pair of functional isomers. The boiling point of ethanol is higher than that of dimethyl ether due to the presence of **[AIIMS 1998]**

(a) Hydrogen bonding in ethanol

(b) Hydrogen bonding in dimethyl ether

(c) CH_3 group in ethanol

(d) CH_3 group in dimethyl ether

36. Which of the following hydrogen bonds are strongest in vapour phase **[AMU 1999]**

(a) $HF --- HF$ (b) $HF --- HCl$

(c) $HCl --- HCl$ (d) $HF --- HI$

37. Which of the following shows hydrogen bonding **[CPMT 2000]**

(a) NH_3 (b) P

(c) As (d) Sb

38. The boiling point of a compound is raised by **[DPMT 2001]**

(a) Intramolecular hydrogen bonding

(b) Intermolecular hydrogen bonding

(c) Covalent bonding

(d) Ionic covalent

39. The boiling point of water is exceptionally high because **[KCET 2001]**

(a) Water molecule is linear

(b) Water molecule is not linear

(c) There is covalent bond between H and O

(d) Water molecules associate due to hydrogen bonding

40. NH_3 has a much higher boiling point than PH_3 because **[UPSEAT 2002; MNR 1994]**

(a) NH_3 has a larger molecular weight

(b) NH_3 undergoes umbrella inversion

(c) NH_3 forms hydrogen bond

(d) NH_3 contains ionic bonds whereas PH_3 contains covalent bonds

41. Which one has the highest boiling point **[MP PET 2002]**

(a) Acetone (b) Ethyl alcohol

(c) Diethyl ether (d) Chloroform

42. Which of the following compounds has the highest boiling point **[JIPMER 2002]**

(a) HCl (b) HBr

(c) H_2SO_4 (d) HNO_3

43. Which of the following has minimum melting point **[UPSEAT 2003]**

(a) CsF (b) HCl

(c) HF (d) LiF

44. Hydrogen bond energy is equal to

(a) 3 – 7 *cals* (b) 30 – 70 *cals*

(c) 3 – 10 *kcals* (d) 30 – 70 *kcals*

45. H_2O is a liquid while H_2S is gas due to **[BHU 2003]**

(a) Covalent bonding

(b) Molecular attraction

(c) H – bonding

(d) H – bonding and molecular attraction

46. H – bonding is maximum in **[BHU 2003]**

(a) C_6H_5OH (b) C_6H_5COOH

(c) CH_3CH_2OH (d) CH_3COCH_3

47. Select the compound from the following which dissolves in water **[IIT 1980]**

(a) CCl_4 (b) CS_2

(c) $CHCl_3$ (d) C_2H_5OH

48. When two ice cubes are pressed over each other, they unit to form one cube. Which of the following force is responsible for holding them together **[NCERT 1978]**

(a) Vander Waal's forces

(b) Hydrogen bond formation

(c) Covalent attraction

(d) Dipole–dipole attraction

49. Which is the weakest among the following types of bond

[NCERT 1979; MADT Bihar 1984]

(a) Ionic bond (b) Metallic bond

(c) Covalent bond (d) Hydrogen bond

50. H-bond is not present in **[BCECE 2005]**

(a) Water (b) Glycerol

(c) Hydrogen fluoride (d) Hydrogen Sulphide

Types of bonding and Forces in solid

1. In a crystal cations and anions are held together by

[EAMCET 1982]

(a) Electrons (b) Electrostatic forces

(c) Nuclear forces (d) Covalent bonds

2. In the following metals which one has lowest probable interatomic forces

(a) Copper (b) Silver

(c) Zinc (d) Mercury

3. In solid argon, the atoms are held together by

[NCERT 1981; MP PET 1995]

(a) Ionic bonds (b) Hydrogen bonds

(c) Vander Waals forces (d) Hydrophobic forces

4. Which one is the highest melting halide **[AIIMS 1980]**

(a) $NaCl$ (b) $NaBr$

(c) NaF (d) NaI

5. The enhanced force of cohesion in metals is due to

[NCERT 1972]

(a) The covalent linkages between atoms

(b) The electrovalent linkages between atoms

(c) The lack of exchange of valency electrons

(d) The exchange energy of mobile electrons

6. Which one of the following substances consists of small discrete molecules **[CPMT 1987]**

(a) $NaCl$ (b) Graphite

(c) Copper (d) Dry ice

7. Which of the following does not apply to metallic bond

[CBSE PMT 1989]

(a) Overlapping valency orbitals

(b) Mobile valency electrons

(c) Delocalized electrons

(d) Highly directed bonds

8. In melting lattice, structure of solid **[CPMT 1982]**

(a) Remains unchanged (b) Changes

(c) Becomes compact (d) None of the above

9. Which of the following has the highest melting point

[CPMT 1994]

(a) Pb (b) Diamond

(c) Fe (d) Na

10. In the formation of a molecule by an atom **[AFMC 1995]**

(a) Attractive forces operate

(b) Repulsive forces operate

(c) Both attractive and repulsive forces operate

(d) None of these

11. Which has weakest bond **[RPMT 1997]**

(a) Diamond (b) Neon (Solid)

(c) KCl (d) Ice

12. Which of the following exhibits the weakest intermolecular forces **[AIIMS 1999; BHU 2000]**

(a) He (b) HCl

(c) NH_3 (d) H_2O

[MP PMT 1990]

13. Glycerol has strong intermolecular bonding therefore it is

[RPET 2000]

(a) Sweet (b) Reactive

(c) Explosive (d) Viscous

14. Among the following the weakest one is

[Pb. PMT 2004; CPMT 2002]

(a) Metallic bond (b) Ionic bond

(c) Van der Waal's force (d) Covalent bond

15. Lattice energy of alkali metal chlorides follows the order

[DPMT 2004]

(a) $LiCl > NaCl > KCl > RbCl > CsCl$

(b) $CsCl > NaCl > KCl > RbCl > LiCl$

(c) $LiCl > CsCl > NaCl > KCl > RbCl$

(d) $NaCl > LiCl > KCl > RbCl > CsCl$

16. In the following which molecule or ion possesses electrovalent, covalent and co-ordinate bond at the same time

(a) HCl (b) NH_4^+

(c) Cl^- (d) H_2O_2

17. Both ionic and covalent bond is present in the following **[MNR 1986; MP PMT 2004]**

(a) CH_4 (b) KCl

(c) SO_2 (d) $NaOH$

18. The formation of a chemical bond is accompanied by **[MP PET 1995]**

(a) Decrease in energy

(b) Increase in energy

(c) Neither increase nor decrease in energy

(d) None of these

19. Chemical bond implies **[KCET 2002]**

(a) Attraction

(b) Repulsion

(c) Neither attraction nor repulsion

(d) Both (a) and (b)

20. Which of the following statements is true **[AIEEE 2002]**

(a) HF is less polar than HBr

(b) Absolutely pure water does not contain any ions

(c) Chemical bond formation take place when forces of attraction overcome the forces of repulsion

(d) In covalency transference of electron takes place

21. Which of the following statements is true about $[Cu(NH_3)_4]SO_4$ **[CPMT 1988]**

(a) It has coordinate and covalent bonds

(b) It has only coordinate bonds

(c) It has only electrovalent bonds

(d) It has electrovalent, covalent and coordinate bonds

22. Blue vitriol has

(a) Ionic bond (b) Coordinate bond

(c) Hydrogen bond (d) All the above

23. The number of ionic, covalent and coordinate bonds in NH_4Cl are respectively **[MP PMT 1999]**

(a) 1, 3 and 1 (b) 1, 3 and 2

(c) 1, 2 and 3 (d) 1, 1 and 3

24. Covalent molecules are usually held in a crystal structure by

[CPMT 1987] **[MP PET 1995]**

(a) Dipole-dipole attraction

(b) Electrostatic attraction

(c) Hydrogen bonds

(d) Vander Waal's attraction

Critical Thinking

Objective Questions

1. The values of electronegativity of atoms A and B are 1.20 and 4.0 respectively. The percentage of ionic character of $A-B$ bond is

(a) 50 % (b) 43 %

(c) 55.3 % (d) 72.24%

2. O_2^{2-} is the symbol of ..... ion **[EAMCET 2003]**

(a) Oxide (b) Superoxide

(c) Peroxide (d) Monoxide

3. The number of electrons that are paired in oxygen molecule is

(a) 7 (b) 8

(c) 14 (d) 16

4. When N_2 goes to N_2^+, the $N-N$ bond distance ..... and when O_2 goes to O_2^+, the $O-O$ bond distance .... **[IIT 1996]**

(a) Decrease, increase (b) Increase, decrease

(c) Increase, increase (d) None of these

5. Which of the following contains a coordinate covalent bond **[UPSEAT 2001]**

(a) $N_2H_5^+$ (b) $BaCl_2$

(c) HCl (d) H_2O

6. Which combination is best explained by the co-ordinate covalent bond **[JIPMER 2001; CBSE PMT 1990]**

(a) $H^+ + H_2O$ (b) $Cl + Cl$

(c) $Mg + \frac{1}{2}O_2$ (d) $H_2 + I_2$

7. Arrange the following compounds in order of increasing dipole moment.

(I) Toluene (II) $m-$dichlorobenzene

(III) $o-$dichlorobenzene (IV) $p-$dichlorobenzene

[IIT 1996]

(a) $I < IV < II < III$ (b) $IV < I < II < III$

(c) $IV < I < III < II$ (d) $IV < II < I < III$

8. The correct order of dipole moment is **[Roorkee 1999]**

(a) $CH_4 < NF_3 < NH_3 < H_2O$

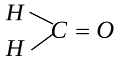
(b) $NF_3 < CH_4 < NH_3 < H_2O$

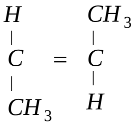
(c) $NH_3 < NF_3 < CH_4 < H_2O$

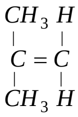
(d) $H_2O < NH_3 < NF_3 < CH_4$

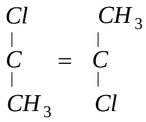
9. Which of the following has the highest dipole moment

[AIIMS 2002]

(a)


(b)


(c)


(d)


10. Which of the following arrangement of molecules is correct on the basis of their dipole moments **[AIIMS 2002]**

(a) $BF_3 > NF_3 > NH_3$ (b) $NF_3 > BF_3 > NH_3$

(c) $NH_3 > BF_3 > NF_3$ (d) $NH_3 > NF_3 > BF_3$

11. The type of hybrid orbitals used by the chlorine atom in ClO_2^- is **[IIT 1992]**

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

(c) sp (d) None of these

12. Among the following species, identify the isostructural pairs, NF_3, NO_3^-, BF_3, H_3O^+, HN_3 **[IIT 1996]**

(a) $[NF_3, NO_3^-]$ and $[BF_3, H_3O^+]$

(b) $[NF_3, HN_3]$ and $[NO_3^-, BF_3]$

(c) $[NF_3, H_3O^+]$ and $[NO_3^-, BF_3]$

(d) $[NF_3, H_3O^+]$ and $[HN_3, BF_3]$

13. In the compound $CH_2 = CH - CH_2 - CH_2 - C \equiv CH$, the $C_2 - C_3$ bond is of the type **[IIT 1999]**

(a) $sp - sp^2$ (b) $sp^3 - sp^3$

(c) $sp - sp^3$ (d) $sp^2 - sp^3$

14. The correct order of increasing $C - O$ bond length of CO, CO_3^{2-}, CO_2 is **[IIT 1999]**

(a) $CO_3^{2-} < CO_2 < CO$ (b) $CO_2 < CO_3^{2-} < CO$

(c) $CO < CO_3^{2-} < CO_2$ (d) $CO < CO_2 < CO_3^{2-}$

15. In the dichromate dianion **[IIT 1999]**

(a) $4\, Cr - O$ bonds are equivalent

(b) $6\, Cr - O$ bonds are equivalent

(c) All $Cr - O$ bonds are equivalent

(d) All $Cr - O$ bonds are non-equivalent

16. Bond length of ethane (I), ethene (II), acetylene (III) and benzene (IV) follows the order **[CPMT 1999]**

(a) $I > II > III > IV$ (b) $I > II > IV > III$

(c) $I > IV > II > III$ (d) $III > IV > II > I$

17. Hybridisation state of chlorine in ClF_3 is **[RPET 1999]**

(a) sp^3 (b) sp^3d

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

18. Molecular shapes of SF_4, CF_4 and XeF_4 are

[IIT Screening 2000]

(a) The same with 2, 0 and 1 lone pairs of electrons respectively

(b) The same, with 1, 1 and 1 lone pairs of electrons respectively

(c) Different, with 0, 1 and 2 lone pairs of electrons respectively

(d) Different, with 1, 0 and 2 lone pairs of electrons respectively

19. Structure of IF_4^+ and hybridization of iodine in this structure are **[UPSEAT 2001]**

(a) sp^3d, Linear

(b) sp^3d^2, T-shaped

(c) sp^3d, Irregular tetrahedral

(d) sp^3d^2, Octahedral

20. In which of the following the central atom does not use sp^3 hybrid orbitals in its bonding **[UPSEAT 2001, 02**

(a) BeF_3^- (b) OH_3^+

(c) NH_2^- (d) NF_3

21. The magnetic moment of $K_3[Fe(CN)_6]$ is found to be 1.7 $B.M.$ How many unpaired electron (s) is/are present per molecule **[Orissa JEE 2003]**

(a) 1 (b) 2

(c) 3 (d) 4

22. N_2 and O_2 are converted into monocations N_2^+ and O_2^+ respectively. Which is wrong **[CBSE PMT 1997]**

(a) In N_2, the $N - N$ bond weakens

(b) In O_2, the $O - O$ bond order increases

(c) In O_2, paramagnetism decreases

(d) N_2^+ becomes diamagnetic

23. The common features among the species CN^-, CO and NO^+ are **[IIT Screening 2001]**

(a) Bond order three and isoelectronic

(b) Bond order three and weak field ligands

(c) Bond order two and π-acceptors

(d) Isoelectronic and weak field ligands

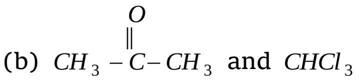
24. The number of $S-S$ bonds in sulphur trioxide trimer S_3O_9 is **[IIT Screening 2001]**

(a) Three (b) Two

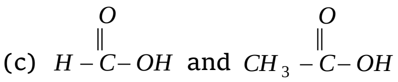
(c) One (d) Zero

25. Strongest intermolecular hydrogen bond is present in the following molecules pairs

(a) SiH_4 and SiF



(b) $CH_3-\overset{\overset{O}{\|}}{C}-CH_3$ and $CHCl_3$



(c) $H-\overset{\overset{O}{\|}}{C}-OH$ and $CH_3-\overset{\overset{O}{\|}}{C}-OH$

(d) H_2O and H_2O_2

26. A compound contains atoms $X, Y, Z.$ The oxidation number of X is $+2$, Y is + 5 and Z is -2. Therefore, a possible formula of the compound is **[CPMT 1988]**

(a) XYZ_2 (b) $X_2(YZ_3)_2$

(c) $X_3(YZ_4)_2$ (d) $X_3(Y_4Z)_2$

27. Bonds present in $CuSO_4.5H_2O$ is

(a) Electrovalent and covalent

(b) Electrovalent and coordinate

(c) Electrovalent, covalent and coordinate

(d) Covalent and coordinate

28. The ionization of hydrogen atom would give rise to

[UPSEAT 2001]

(a) Hybrid ion (b) Hydronium ion

(c) Proton (d) Hydroxyl ion

29. Which can be described as a molecule with residual bonding capacity

(a) $BeCl_2$ (b) $NaCl$

(c) CH_4 (d) N_2

AR Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.

(c) If assertion is true but reason is false.

(d) If the assertion and reason both are false.

(e) If assertion is false but reason is true.

1. Assertion : Water is a good solvent for ionic compounds but poor one for covalent compounds.

Reason : Hydration energy of ions releases sufficient energy to overcome lattice energy and break hydrogen bonds in water, while covalent bonded compounds interact so weakly that even Vander Wall's forces between molecules of covalent compounds cannot be broken. **[AIIMS 1996]**

[IIT 1981; DCE 2000]

2. Assertion : The atoms in a covalent molecule are said to share electrons, yet some covalent molecules are polar.

Reason : In a polar covalent molecule, the shared electrons spend more time on the average near one of the atoms. **[AIIMS 1996]**

3. Assertion : Diborane is electron deficient

[IIT 1983; DCE 2001]

Reason : There are no enough valence electrons to form the expected number of covalent bonds **[AIIMS 2001]**

4. Assertion : A resonance hybrid is always more stable than any of its canonical structures

Reason : This stability is due to delocalization of electrons **[AIIMS 1999]**

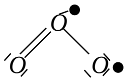
5. Assertion : All $F-S-F$ angle in SF_4 greater than 90° but less than 180°

Reason : The lone pair-bond pair repulsion is weaker than bond pair-bond pair repulsion

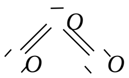
[JIPMER 2000]

[AIIMS 2004]

6. Assertion : The electronic structure of O_3 is



Reason :



structure is not allowed because octet around cannot be expanded.

[IIT 1998]

7. Assertion : Bond order can assume any value number including zero

Reason : Higher the bond order, shorter is bond length and greater is bond energy

[AIIMS 1999]

8. Assertion : Ortho nitrophenol molecules are associated due to the presence of intermolecular hydrogen bonding while paranitrophenol involves intramolecular, hydrogen bonding

Reason : Ortho nitrophenol is more volatile than the para nitrophenol**[AIIMS 1999]**

9. Assertion : Nitrogen molecule diamagnetic.

Reason : N_2 molecule have unpaired electrons.

10. Assertion : Ice is less dense than liquid water.

Reason : There are vacant spaces between hydrogen bonded water molecules in ice.

11. Assertion : Water is liquid but H_2S is a gas.

Reason : Oxygen is paramagnetic.

12. Assertion : Iodine is more soluble in water then in carbon tetrachloride.

Reason : Iodine is a polar compound.

13. Assertion : o and p-nitrophenols can be separated by steam distillation.

Reason : o-nitrophenol have intramolecular hydrogen bonding while p-nitrophenol exists as associated molecules.

14. Assertion : The fluorine has lower reactivity.

Reason : $F-F$ bond has low bond dissociation energy.

15. Assertion : σ is strong while π is a weak bond.

Reason : Atoms rotate freely about π bond.

16. Assertion : The crystal structure gets stabilized even though the sum of electron gain enthalpy and ionization enthalpy is positive.

Reason : Energy is absorbed during the formation of crystal lattice.

17. Assertion : Order of lattice energy for same halides are as $LiX > NaX > KX$.

Reason : Size of alkaline – earth metal increases from Li to K.

18. Assertion : Born-Haber cycle is based on Hess's law.

Reason : Lattice enthalpy can be calculated by Born- Haber cycle.

19. Assertion : Bond energy has order like $C-C < C=C < C\equiv C$.

Reason : Bond energy increases with increase in bond order.

20. Assertion : Electron affinity refers to an isolated atom's attraction for an additional electron while electronegativity is the ability of an element to attract electrons towards itself in a shared pair of electrons.

Reason : Electron affinity is a relative number and electronegativity is experimentally measurable.

21. Assertion : Geometry of SF_4 molecule can be termed as distorted tetrahedron, a folded square or see saw.

Reason : Four fluorine atoms surround or form bond with sulphur molecule.

22. Assertion : BF_3 has greater dipole moment than H_2S.

Reason : Fluorine is more electronegative than sulphur.

23. Assertion : The bond between two identical nonmetal atoms has a pair of electrons with identical spin.

Reason : Electrons are transferred fully from one atom to another.

24. Assertion : B_2 molecule is diamagnetic.

Reason : The highest occupied molecular orbital is of σ type. **[AIIMS 2005]**

25. Assertion : The nearly tetrahedral arrangement of the orbitals about the oxygen atom allows each water molecule to form hydrogen bonds with as many as four neighbouring water molecules.

Reason : In ice each molecule forms four hydrogen bonds as each molecule is fixed in the space.

26. Assertion : The bond order of helium is always zero.

Reason : The number of electrons in bonding molecular orbital and antibonding molecular orbital is equal.

Answers

Electrovalent bonding

1	b	2	a	3	a	4	c	5	c
6	d	7	d	8	b	9	c	10	d
11	b	12	a	13	d	14	a	15	a
16	c	17	b	18	a	19	d	20	c
21	b	22	d	23	a	24	a	25	b

26	d	27	d	28	c	29	a	30	d
31	b	32	b	33	b	34	d	35	b
36	a	37	b	38	a	39	a	40	c
41	c	42	b	43	d	44	b	45	c
46	c	47	a	48	b	49	c	50	b
51	b	52	b	53	a	54	a	55	a
56	c	57	a	58	c	59	a	60	c
61	a	62	b	63	d	64	d	65	b
66	a	67	abc	68	bd				

Covalent bonding

1	c	2	c	3	B	4	b	5	d
6	a	7	c	8	a	9	d	10	a
11	b	12	b	13	c	14	b	15	c
16	a	17	a	18	c	19	a	20	b
21	a	22	a	23	c	24	c	25	c
26	c	27	a	28	a	29	a	30	d
31	b	32	a	33	d	34	a	35	d
36	b	37	d	38	c	39	d	40	c
41	b	42	b	43	b	44	b	45	b
46	d	47	d	48	b	49	a	50	a
51	b	52	d	53	c	54	d	55	d
56	d	57	a	58	a	59	d	60	a
61	c	62	a	63	b	64	b	65	b
66	b	67	b	68	d	69	b	70	c
71	c	72	c	73	cd	74	ad	75	ab
76	a								

Co-ordinate or Dative bonding

1	d	2	b	3	c	4	d	5	c
6	b	7	a	8	d	9	a	10	d
11	c	12	a	13	a	14	b	15	c

Dipole moment

1	b	2	d	3	d	4	a	5	c
6	c	7	a	8	a	9	c	10	b
11	b	12	d	13	b	14	c	15	d
16	c	17	c	18	a	19	c	20	b
21	d	22	b	23	b	24	b	25	a
26	b	27	b	28	b	29	c	30	a
31	a	32	c	33	a	34	bd	35	a

Polarisation and Fajan’s rule

1	d	2	c	3	b	4	d	5	c
6	a	7	b	8	a	9	c	10	b
11	d	12	c	13	b	14	b	15	d
16	d	17	c	18	b	19	a	20	d
21	a	22	c	23	d	24	a	25	b
26	b								

Overlaping - σ and π- bonds

1	c	2	c	3	b	4	b	5	c
6	c	7	c	8	b	9	d	10	c
11	b	12	c	13	a	14	a	15	d
16	a	17	d	18	c	19	d	20	d

Hybridisation

1	d	2	d	3	d	4	c	5	d
6	a	7	c	8	b	9	d	10	d
11	d	12	a	13	a	14	b	15	a
16	b	17	c	18	a	19	d	20	b
21	c	22	c	23	a	24	c	25	a
26	a	27	b	28	c	29	b	30	a
31	d	32	a	33	d	34	c	35	c
36	b	37	b	38	c	39	b	40	b
41	d	42	b	43	c	44	a	45	c
46	c	47	d	48	b	49	c	50	a
51	b	52	a	53	c	54	c	55	c
56	d	57	b	58	a	59	b	60	c
61	b	62	c	63	b	64	b	65	b
66	a	67	c	68	b	69	c	70	a
71	a	72	a	73	b	74	b	75	d
76	d	77	c	78	a	79	d	80	b
81	c	82	b	83	d	84	a	85	d
86	b	87	d	88	c	89	a	90	c
91	c	92	c	93	a	94	b	95	c
96	a	97	b	98	b	99	b	100	b
101	a	102	b	103	d	104	a	105	b
106	a	107	a	108	b	109	b	110	a
111	a	112	b	113	b	114	d	115	d
116	c	117	c	118	b	119	c	120	a
121	a	122	c	123	a	124	a	125	b
126	c	127	d	128	c	129	c	130	a
131	b	132	b	133	e	134	c	135	d
136	b	137	b	138	d	139	a	140	a

141	a	142	b	143	a	144	a	145	a
146	b	147	c	148	d	149	bcd	150	a
151	ac	152	a						

Resonance

1	d	2	b	3	b	4	b	5	b
6	c	7	a	8	c	9	b	10	c
11	abcd								

VSEPR Theory

1	a	2	a	3	b	4	c	5	c
6	b	7	b	8	c	9	b	10	a
11	c	12	a	13	a	14	a	15	c
16	c	17	b	18	d	19	d	20	a
21	a	22	d	23	b	24	d	25	a
26	c	27	b	28	b	29	a	30	a
31	a	32	c	33	c	34	a	35	c
36	b	37	b	38	d	39	d	40	b
41	c	42	a	43	b	44	c	45	d

Molecular orbital theory

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

Hydrogen bonding

1	d	2	b	3	b	4	a	5	c
6	d	7	b	8	d	9	c	10	c
11	d	12	b	13	a	14	b	15	d
16	d	17	b	18	d	19	c	20	c
21	a	22	a	23	d	24	a	25	c
26	a	27	b	28	c	29	a	30	c
31	a	32	b	33	d	34	a	35	a
36	a	37	a	38	b	39	d	40	c
41	a	42	c	43	b	44	c	45	c
46	b	47	d	48	b	49	d	50	d

Types of bonding and Forces in solid

1	b	2	d	3	c	4	c	5	d
6	d	7	d	8	b	9	b	10	c
11	d	12	a	13	d	14	c	15	a
16	b	17	d	18	a	19	d	20	c
21	d	22	d	23	a	24	d		

Critical Thinking Question

1	d	2	c	3	c	4	b	5	a
6	a	7	b	8	a	9	a	10	d
11	a	12	c	13	d	14	d	15	b
16	c	17	b	18	d	19	c	20	a
21	a	22	d	23	a	24	d	25	c
26	c	27	c	28	c	29	a		

Assertion & Reason

1	a	2	a	3	a	4	a	5	c
6	b	7	b	8	e	9	c	10	a
11	b	12	d	13	a	14	e	15	c
16	c	17	c	18	b	19	a	20	c
21	b	22	e	23	d	24	d	25	a
26	a								

Answers and Solutions

Electrovalent bonding

1. (b) $NaCl$ is ionic crystal so it is formed by Na^+ and Cl^- ions.

2. (a) Bond formation is always exothermic. Compounds of sodium are ionic.

3. (a) According to Fajan's rule ionic character is less.

4. (c) Valencies of *L, Q, P* and *R* is – 2, – 1, + 1 and + 2 respectively so they will form P_2L, RL, PQ and RQ_2.

5. (c) Electrovalent compounds are good conductor of heat and electricity in molten state or in aqueous solution.

7. (d) Electrovalent bond formation depends on ionization energy of cation, electron affinity of anion and on lattice energy.

8. (b) Because CsF is electrovalent compound.

9. (c) $NaCl$ is formed by electrovalent bonding.

10. (d) Valency of metal is + 2 by formula *MO* so its phosphate would be $M_3(PO_4)_2$ because valency of $[PO_4]$ is – 3.

11. (b) *Li, Na* and *K* are alkali metals with low ionization energy and one electron in their outermost shell so they will form cation easily.

12. (a) Melting point and boiling point of electrovalent compounds are high due to strong electrostatic force of attraction between the ions.

13. (d) The value of lattice energy depends on the charges present on the two ions and distance between them. It shell be high if charges are high and ionic radii are small.

14. (a) *Cs* is more electropositive.

15. (a) *X* loses electron, *Y* gains it.

16. (c) Formation of $NaCl$ occurs by Na^+_{ion} and Cl^-_{ion}.

17. (b) $MgCl_2$ has electrovalent linkage because magnesium is electropositive metal while chlorine is electronegative.

18. (a) Electrovalent compounds generally have high m.pt and high b.pt due to stronger coulombic forces of attractions.

19. (d) Water is a polar solvent so it decreases the interionic attraction in the crystal lattice due to solvation.

20. (c) Element *C* has electronic structure $1s^2, 2s^2 2p^5$, it requires only one electron to complete its octet and it will form anion so it will form electrovalent bond.

21. (b) Since the chloride of a metal is MCl_2 therefore metal '*M*' must be divalent *i.e.* M^{2+}. As a result the formula of its phosphate is $M_3(PO_4)_2$.

22. (d) In MPO_4 the oxidation state of *M* is +3. Hence, the formula of nitrate is $M(NO_3)_3$.

23. (a) Ion is formed by gaining or losing electrons. To form cation electron are lost from the valency shell, so *Zn* atoms to Zn^{++} ions there is a decrease in the no. of valency electron.

24. (a) $M_3(PO_4)_2$ means *M* is divalent so formula of its sulphate is MSO_4.

25. (b) As the molecular formula of chloride of a metal *M* is MCl_3, it is trivalent so formula of its carbonate will be $M_2(CO_3)_3$.

26. (d) Sodium chloride is electrovalent compound so it dissolves in water which is a polar solvent.

27. (d) When sodium chloride is dissolved in water, the sodium ion is hydrated.

30. (d) Yet the formula of sulphate of a metal (*M*) is $M_2(SO_4)_3$, it is M^{3+} ion so formula of its phosphate would be MPO_4.

32. (b) Molten sodium chloride conducts electricity due to the presence of free ions.

33. (b) The phosphate of a metal has the formula $MHPO_4$ it means metal is divalent so its chloride would be MCl_2.

34. (d)

35. (b) *Cs* is highly electropositive while *F* is highly electronegative so they will form ionic bond.

37. (b) *Na* is highly electropositive while *Cl* is highly electronegative so they will form ionic bond.

38. (a) Ionic compounds are good conductors of heat and electricity so they are good electrolyte.

39. (a) Metal tends to lose electrons due to low ionization energy.

40. (c) As the formula of calcium pyrophosphate is $Ca_2P_2O_7$ means valency of pyrophosphate radical is – 4 so formula of ferric pyrophosphate is $Fe_4(P_2O_7)_3$.

41. (c) $M-X$ bond is a strongest bond so between $Na-Cl$ is a strongest bond.

42. (b) The solubility order is :
$BeF_2 > MgF_2 > CaF_2 > SrF_2$ so SrF_2 is least soluble.

43. (d) *NaF* has maximum melting point, melting point decreases of sodium halide with increase in size of halide their bond energy get lower.

44. (b) Sulphanilic acids have bipolar structure so their melting point is high and insoluble in organic solvents.

45. (c) $CaCl_2$ will have electrovalent bonding because calcium is electropositive metal while chlorine is electronegative so they will combined with electrovalent bond.

47. (a) Electrovalent bond is formed by losing electrons from one atom and gaining electron by other atom *i.e.* redox reaction.

48. (b) Electrovalent compound are polar in nature because they are formed by ions.

50. (b) $CsCl$ has ionic bonding.

51. (b) As soon as the electronegativity increases, ionic bond strength increases.

52. (b) This *X* element is a second group element so its chloride will be XCl_2.

53. (a) When electronegativity difference is from 1.7 to 3.0. This bond is called as ionic bond.

54. (a) Ethyl chloride is an organic compound so it will be covalent.

55. (a) Lithium oxide and calcium fluoride show ionic characters.

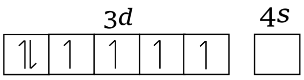
57. (a) Generally cation and anion form ionic bond.

58. (c) Those atoms which contain *+ve* and *–ve* sign are known as ion.

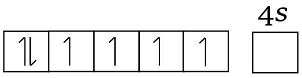
59. (a) Generally *Br-F* contain maximum electronegativity difference compare to other compound.

61. (a) Due to greater electronegativity difference.

62. (b) $Co^{3+} = 3d^6 4s^0$,



$Ni^{4+} = 3d^6 4s^0$,



64. (d) $BaCl_2$ contain higher ionic character.

66. (a) Electrolytes are compound which get dissociated into their ion in water so it contains electrovalent bond.

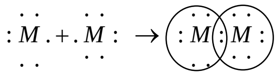
67. (abc) CaH_2, BaH_2, SrH_2 are ionic hydride.

68. (bcd) Generally $MgCl_2, SrCl_2, BaCl_2$ are ionic compounds so they conduct electricity in fused state.

Covalent bonding

2. (c) In N_2 molecule each Nitrogen atom contribute $3e^-$ so total no. of electron's are 6.

3. (b) Non-metals readily form diatomic molecules by sharing of electrons. Element $M(1s^2 2s^2 2p^5)$ has seven electrons in its valence shell and thus needs one more electron to complete its octet. Therefore, two atoms share one electron each to form a diatomic molecule (M_2)



5. (d) Covalent character depend on the size of cation and anion.

6. (a) In graphite all carbon atoms are sp^2-hybridised and have covalent bond.

7. (c) Silica has tendency to form long chain covalent structure such as carbon so it has giant covalent structure.

8. (a) All have linear structure.
$O = C = O,\ Cl - Hg - Cl,\ HC\equiv CH$

9. (d) Similar atoms form covalent bond.

10. (a) Covalent bond forms when electronegativity difference of two atom is equal to 1.7 or less than 1.7

11. (b) Similar atoms form covalent bond.

12. (b) Water is a polar solvent while covalent compounds are non-polar so they usually insoluble in water.

13. (c) BCl_3 is electron deficient compound because it has only '6' electrons after forming bond.

14. (b) Due to its small size and 2 electrons in *s*-orbital *Be* forms covalent compound.

18. (c) H_2O will formed by covalent bonding.

21. (a) Two identical atoms are joined with covalent bond so H_2 will be covalent.

23. (c) Element '*X*' has atomic no. 7 so its electronic configuration will be 2, 5. So its electron dot symbol would be $:\overset{\cdot}{\underset{\cdot}{X}}\cdot$

24. (c) *C-S* will be most covalent. Covalent character depend on the size of cation and anion.

25. (c) *HCl* has ionic character yet it has covalent compound because electronegativity of chlorine is greater than that of hydrogen.

26. (c) *Order of polarising power* $Be^{++} > Li^+ > Na^+$

Hence order of covalent character $BeCl_2 > LiCl > NaCl$.

31. (b) Valency of phosphorus in H_3PO_4 is supposed '*x*' then $3 + x - 8 = 0$, $x - 5 = 0$, $x = 5$.

33. (d) $(+1) + x + 3(-2) = 0 \Rightarrow 1 + x - 6 = 0 \Rightarrow x = 6 - 1 = 5$.

34. (a) *HCl* molecule has covalent bond.

35. (d) Electrovalent compounds have high melting point and high boiling point.

36. (b) Middle length of $H_2 = 74\,pm$

Length of $H = \frac{74}{2} = 37\,pm$

Middle length of $Cl_2 = 198\,pm$

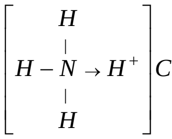
Length of $Cl = \frac{198}{2} = 99\,pm$

Bond length of *HCl* = Length of *H* + Length of *Cl*

= 37 + 99 = 136 *pm*

37. (d) Compound has 254 *gm* of I_2 means $\frac{254}{127} = 2$ mole, while 80 *gm* O_2 means $\frac{80}{16} = 5$ mole so they will form compound I_2O_5.

38. (c) NH_4Cl has covalent as well as ionic bond.

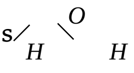


$$\left[\begin{array}{c} H \\ | \\ H - N \rightarrow H^+ \\ | \\ H \end{array}\right] Cl^-$$

39. (d) Covalent character increases when we come down a group so CaI_2 will have highest covalent character.

41. (b) In water molecule three atom are linked by covalent bond.

Structure is



42. (b) $:N \equiv N^+ - \underset{\cdot\cdot}{\ddot{O}}:^-$ or $N \equiv N \rightarrow O$.

44. (b) The electronic configuration of $Na(Z = 11)$ is $1s^2, 2s^2 2p^6, 3s^1$. The oxide of *Na* is Na_2O.

45. (b) Covalent bond is directional.

47. (d) Bond dissociation energy decreases with increase in size. So *D* is smallest.

48. (b) Molecule *X* is nitrogen because nitrogen molecule has triple bond. It's configuration will be $1s^2, 2s^2 2p^3$.

49. (a) PCl_5 does not follow octet rule, it has 10 electrons in its valence shell.

50. (a) The compound will be A_2B_3 (By criss cross rule).

51. (b) Each nitrogen share 3 electrons to form triple bond.

52. (d) Urea solution does not conduct electricity because it is a covalent compound.

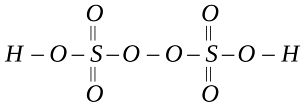
54. (d) Due to the small size and higher ionization energy, boron forms covalent compound.

58. (a) BF_3 contain 6 electron so it is lewis acid.

59. (d) Among the given species. The bond dissociation energy of $C - O$ bond is minimum in case of CO_3^{2-} by which $C - O$ bond become more weaker in CO_3^{2-} or the bond order of CO_3^{2-} (1.33) is minimum so the bond become weaker.

60. (a) Valency of $Na_2S_2O_3$ is supposed to be *x*, then $2 + 2x + (-6) = 0$, $2x - 4 = 0$, $x = 2$.

61. (c)



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

(Marshall acid)

62. (a) Among the given choice *Al* is least electropositive therefore, the bond between *Al* and *Cl* will be least ionic or most covalent or the difference in electronegativeity of two atom is less than 1.8.

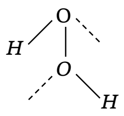
63. (b) Electronic configuration of ${}_{16}S^{32} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^4$. In the last orbit it has only 6 electron. So it require 2 electron to complete its octet, therefore it share 2 electron with two hydrogen atom and forms 2 covalent bond with it.

64. (b) The acidity of hydrides of *VI* group elements increase from top to bottom as the bond strength $X - H$ decrease from top to bottom $H_2O < H_2S < H_2Se < H_2Te$

65. (b) We know that Al^{+3} cation is smaller than Na^+ (because of greater nuclear change) According to Fajan's rule, small cation polarise anion upto greater extent. Hence Al^{3+} polarise Cl^- ion upto greater extent, therefore $AlCl_3$ has covalent bond between *Al* and *Cl* atoms.

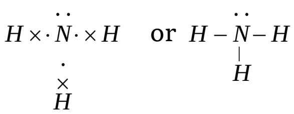
66. (b) Sulphur has the second highest catenation property after carbon. Its molecule has eight atom bonded together (*i.e.* S_8)

67. (b) H_2O_2 has open book structure.



69. (b) The electronic configuration of nitrogen is $_7N = 1s^2, 2s^2, 2p^3$

It has 5 electrons in valency shell, hence in ammonia molecule it complete its octet by sharing of three electron with three H atom, therefore it has 8 electrons in its valence shell in ammonia molecule



$H \times \cdot \ddot{N} \cdot \times H$ or $H-\ddot{N}-H$ with H below

71. (c) Multiple bonds have more bond energy so $C \equiv N$ will be the strongest.

72. (c) Diamond, silicon and quartz molecule bounded by covalent bond.

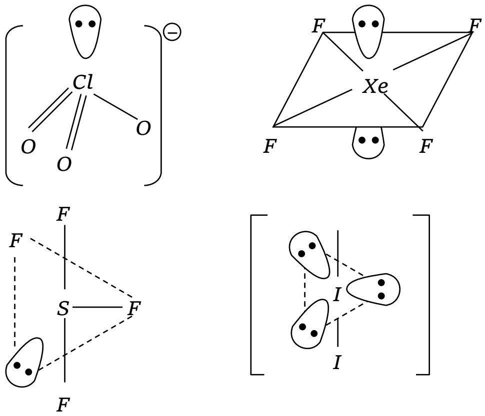
73. (cd) C_2H_4 and N_2 has multiple bonds.

74. (ad) CO has only 6 electrons while PCl_5 has 10 electrons after sharing so both don't follow octet rule.

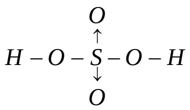
76. (a) Among these, NaH and CaH_2 are ionic hydrides and B_2H_6 and NH_3 are covalent hydrides.

Co-ordinate or Dative bonding

1. (d)



2. (b) H_2SO_4 has co-ordinate covalent bond.

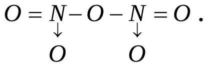


$$H-O-\overset{\overset{O}{\uparrow}}{\underset{\underset{O}{\downarrow}}{S}}-O-H$$

3. (c) NH_3 has lone pair of electron while BF_3 is electron deficient compound so they form a co-ordinate bond. $NF_3 \to BF_3$

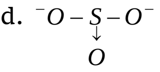
4. (d) HNO_2 does not have co-ordinate bond. Structure is $H-O-N=O$.

7. (a) Structure of N_2O_5 is



$$O=\underset{\underset{O}{\downarrow}}{N}-O-\underset{\underset{O}{\downarrow}}{N}=O.$$

9. (a) SO_3^{2-} has one coordinate bond.

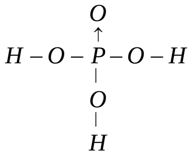


$$^{-}O-\underset{\underset{O}{\downarrow}}{S}-O^{-}$$

10. (d) Co-ordinate bond is a special type of covalent bond which is formed by sharing of electrons between two atoms, where both the electrons of the shared pair are contributed by one atom. Since this type of sharing of electrons exits in O_3, SO_3 and H_2SO_4. Therefore all these contains coordinate bond.

12. (a) $CH_3N \overset{\rightarrow}{\equiv} C$ contain dative bond.

13. (a) H_3PO_4 is orthophosphoric acid.



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

15. (c) Sulphuric acid contain, covalent and co-ordinate bond.

Dipole moment

1. (b) CO_2 is a symmetrical molecule so its dipole moment is zero.

2. (d) These all have zero dipole moment.

3. (d) HF has largest dipole moment because electronegativity difference of both is high so it is highly polar.

5. (c) Due to its symmetrical structure.

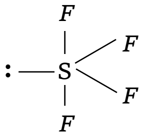
6. (c) Chloroform has 3 chlorine atom and one hydrogen atom attached to the carbon so it is polarised and it will show dipole moment.

8. (a) The dipole moment of two dipoles inclined at an angle θ is given by the equation

$\mu = \sqrt{X^2 + Y^2 + 2XY\cos\theta}$

$\cos 90° = 0$. Since the angle increases from $90-180$, the value of $\cos\theta$ becomes more and more – *ve* and hence resultant decreases. Thus, dipole moment is maximum when $\theta = 90°$.

9. **(c)** *Due to distorted tetrahedral geometry* SF_4 *has permanent dipole moment*



10. (b) CCl_4 has no net dipole moment because of its regular tetrahedral structure.

12. (d) *H-F* is polar due to difference of electronegativity of hydrogen and fluorine so it shows positive dipole moment.

14. (c) BCl_3 has zero dipole moment because of its trigonal planar geometry.

16. (c) Dipole moment of CH_3OH is maximum in it.

20. (b) CH_4 have regular tetrahedron so its dipole moment is zero.

22. (b) Ammonia have some dipole moment.

23. (b) Charge of $e^- = 1.6 \times 10^{-19}$

Dipole moment of $HBr = 1.6 \times 10^{-30}$

Inter atomic spacing $= 1Å = 1 \times 10^{-10} m$

% of ionic character in

$$HBr = \frac{\text{dipole moment of } HBr \times 100}{\text{inter spacing distance} \times q}$$

$$= \frac{1.6 \times 10^{-30}}{1.6 \times 10^{-19} \times 10^{-10}} \times 100$$

$$= 10^{-30} \times 10^{29} \times 100 = 10^{-1} \times 100 = 0.1 \times 100 = 10\%$$

25. (a) Carbon tetrachloride has a zero dipole moment because of its regular tetrahedral structure.

27. (b) BF_3 has zero dipole moment.

29. (c) Given ionic charge $= 4.8 \times 10^{-10}$ e.s.u. and ionic distance $= 1A° = 10^{-8} cm$ we know that dipole moment = ionic charge × ionic distance $= 4.8 \times 10^{-10} \times 10^{-8}$

$= 4.8 \times 10^{-8}$ e.s.u. *per cm* $= 4.8$ debye.

30. (a) Higher is the difference in electronegativity of two covalently bonded atoms, higher is the polarity. In *HCl* there is high difference in the electronegativity of *H* and *Cl* atom so it is a polar compound.

31. (a) Linear molecular has zero dipole moment CO_2 has linear structure so it does not have the dipole moment $O = C = O$.

32. (c) SF_6 is symmetrical and hence non polar because its net dipole moment is zero.

33. (a) Polarity create due to the difference in electronegativity of both atom in a molecule except H_2 all other molecule have the different atom so they will have the polarity while H_2 will be non polar.

34. (bd) *cis* isomer shows dipole moment while that of trans is zero or very low value. Trans 1, 2 di-chloro-2-pentene will also show dipole moment due to unsymmetry.

35. (a) % of ionic character

$$= \frac{\text{Experiment al value of dipole moment}}{\text{Expected value of dipole moment}}$$

$$= \frac{1.03}{6.12} \times 100 = 16.83\% \approx 17\%$$

Polarisation and Fajan's rule

1. (d) BF_3 is planar while NF_3 is pyramidal due to the presence of lone pair of electron on nitrogen in NF_3.

2. (c) H_2O is a polar molecule due to electronegativity difference of hydrogen and oxygen.

3. (b) When electronegativity difference is more between two joined atoms then covalent bond becomes polar and electron pair forming a bond don't remain in the centre.

4. (d) Hexane has symmetrical structure so does not have polarity.

5. (c) When two identical atoms form a bond, bond is non-polar.

6. (a) According to Fajan's rule, polarisation of anion is influenced by charge and size of cation more is the charge on cation, more is polarisation of anion.

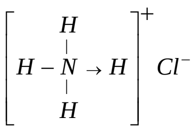
8. (a) When two atoms shares two electrons it is an example of covalent bond. This covalent bond may be polar or may be non-polar depends on the electronegativity difference. In given example formula is *AB*. So it is polar.

9. (c) *HCl* is most polar due to high electronegativity of *Cl*.

10. (b) NH_3 has sp^3 hybridised central atom so it is non planar.

11. (d) *p*-dichloro benzene have highest melting point.

13. (b) NH_4Cl has both types of bonds polar and non polar



$$\left[H - \overset{\displaystyle H}{\underset{\displaystyle H}{\overset{|}{\underset{|}{N}}}} \rightarrow H \right]^+ Cl^-$$

14. (b) Greater the charge of cation more will be its polarising power (according to Fajan's rule).

15. (d) AlI_3 Aluminiumtriiodide shows covalent character. According to Fajan's rule.

16. (d) As the size of anion increases, polarity character increases.

20. (d) Due to the electronegativity difference.

21. (a) We know that greater the difference in electronegativity of two atoms forming a covalent bond. More is its polar nature. In *HF* there is a much difference in the electronegatives of hydrogen and flourine. Therefore (*HF*) is a polar compound.

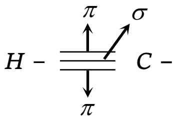
22. (c) Silicon tetrafloride has a centre of symmetry.

23. (d) BF_3 have zero dipole moment.

25. (b) According to Fajan's rule largest cation and smallest anion form ionic bond.

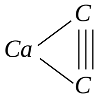
26. (b) Polarity character is due to the difference in electronegativity of two atoms or molecule.

Overlaping- σ and π- bonds

1. (c) 

2. (c) In fluorine molecule formation *p-p* orbitals take part in bond formation.

3. (b) π-bond is formed by lateral overlapping of unhybridised *p-p* orbitals.

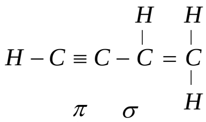
4. (b) 

1σ and 2π

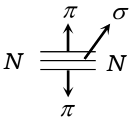
5. (c) In a double bond connecting two atom sharing of 4 electrons take place as in $H_2C=CH_2$.

6. (c) $C\equiv C$ is a multiple bond so it is strongest.

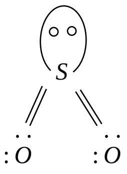
9. (d) As the bond order increases, $C-H$ bond energy also increases so it will be greatest in acetylene because its B.O. is 3.

11. (b) 

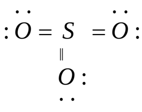
$H-C\equiv C-\overset{\overset{H}{|}}{C}=\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}$

16. (a) 

17. (d) We know that trisilylamine is sp^2–hybridized therefore $p\pi-d\pi$ bonding is possible due to the availability of vacant *d*-orbitals with silicon.

18. (c) 

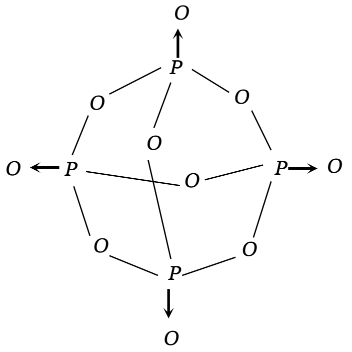
2σ, 2π bond and one lone pair.

19. (d) 

$:\ddot{O}=S=\ddot{O}:$ with $\overset{\|}{\underset{..}{O}}:$ below S

5 atoms has 12 electrons in its outermost shell. One $(S-O)\pi$ bond will be (*p-p*) π bond while two $(S-O)\pi$ bond will be (*p-d*) π bond.

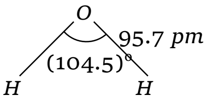
20. (d) Structure of P_4O_{10} is



Each phosphorus is attached to 4 oxygen atoms.

Hybridisation

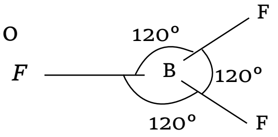
1. (d) H_2O is not linear because oxygen is sp^3 hybridised in H_2O.

2. (d) 

4. (c) CO_2 has *sp* – hybridization and is linear.

5. (d) *No. of* e^- *pair* $=3+\frac{1}{2}[3-3]=0$

No. of e^- *pair* $=3+0$



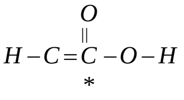
No. of atom bonded to the central atom $=3$

In case of 3, 3 geometry is Trigonal planar.

6. (a) In sp^3–hybridisation each sp^3 hybridised orbital has 1/4 *s*-character.

8. (b) In ethylene both Carbon atoms are sp^2-hybridised so 120^o.

9. (d) Structure of sp^3d hybridized compound is Trigonal bipyramidal.

10. (d) In 

$H-C=\underset{*}{\overset{\overset{O}{\|}}{C}}-O-H$ the asterisked carbon has a valency of 5 and hence this formula is not correct.

11. (d) dsp^3 hybrid orbitals have bond angles $120^o, 90^o$.

13. (a) In BeF_3^-, *Be* is not sp^3–hybridised it is sp^2 hybridised.

17. (c) In molecule OF_2 oxygen is sp^3 hybridised.

18. (a) In sp^3 hybrid orbitals s-character is 1/4th means 25%.

19. (d) XeF_4 molecule has 'Xe' sp^3d^2 hybridised and its shape is square planar.

20. (b) The bond angle is maximum for sp hybridisation because two sp hybridised orbitals lies at angle of 180^o.

21. (c) $C_2H_4Br_2$ has all single bonds so $C-H$ bond distance is the largest.

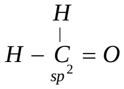
23. (a) In methane molecule C is sp^3 hybridised so its shape will be tetrahedral.

24. (c) In compound $\overset{3}{C}H_2 = \overset{2}{C} = \overset{1}{C}H_2$ the second carbon sp-hybridised.

25. (a) $:\ddot{\underset{..}{Cl}} \cdot\cdot \ddot{\underset{..}{Cl}}:$ is the correct electronic formula of Cl_2 molecule because each chlorine has 7 electrons in its valence shell.

26. (a) XeF_4 has sp^3d^2 hybridisation, its shape is square planar.

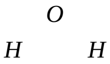
27. (b) In $HCHO$, carbon is sp^2 hybridized



$$H - \underset{sp^2}{\overset{\overset{H}{|}}{C}} = O$$

28. (c) Because of the triple bond, the carbon-carbon bond distance in ethyne is shortest.

29. (b) The hybridisation of Ag in complex $[Ag(NH_3)_2]^+$ will be sp because it is a Linear complex.

30. (a) Structure of CO_2 is linear $O=C=O$ while that of H_2O is  *i.e.* bent structure so in CO_2 resultant dipole moment is zero while that of H_2O has some value.

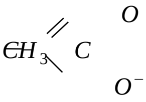
31. (d) CO_2 is not sp^3 hybridised, it is sp hybridised.

32. (a) As compare to pure atomic orbitals, hybrid orbitals have low energy.

33. (d) $\overset{sp^2}{C}H_2 = \overset{sp}{C} = \overset{sp^2}{C}H - \overset{sp^3}{C}H_3$ 1, 2-butadiene.

36. (b) CCl_4 is sp^3 hybridised so bond angle will be approximately 109^o.

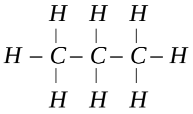
40. (b) Ethene has sp^2 hybridised carbon so bond angles are 120^o.

44. (a) Acetate ion is  *i.e.* one $C-O$ single bond and one $C=O$ double bond.

46. (c) Benzene has all carbons sp^2 hybridised and planar in shape.

47. (d) In methane C is sp^3 hybridized and bond angle is 109^o.

56. (d)



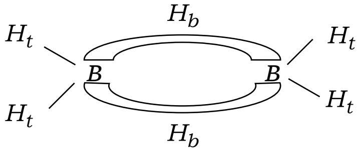
$$H - \underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}} - \underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}} - \underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}} - H$$

There are 10 shared pairs of electrons.

58. (a) The diborane molecule has two types of $B-H$ bond :

(i) $B-H_t$ – It is a normal covalent bond.

(ii) $B-H_b$ – It is a three centred bond.



61. (b) PF_5 involves sp^3d hybridization and hence has trigonal bipyramidal structure.

62. (c) s-character in $sp = \frac{1}{2} \times 100 = 50\%$

s-character in $sp^2 = \frac{1}{3} \times 100 = 33.3\%$

s-character in $sp^3 = \frac{1}{4} \times 100 = 25\%$

Hence, maximum s-character is found in sp-hybridisation.

63. (b) The molecule of PCl_5 has sp^3d hybridisation, structure is trigonal bipyramidal.

64. (b) Merging (mixing) of dissimilar orbitals of different energies to form new orbitals is known as hybridisation and the new orbital formed are known as hybrid oribitals. They have similar energy.

65. (b) In SO_3 sulphur is sp^2 hybridized so its shape will be trigonal planar.

66. (a) These all are triangular with sp^2 hybridization.

67. (c) Bond length depends upon bond order and in benzene all $C-C$ bonds have same bond order.

68. (b) In C_2H_2 each carbon has sp-hybridization $H - \underset{sp}{C} \equiv \underset{sp}{C} - H$

70. (a) As p-character increases the bond angle decreases.

In sp - p-character $\frac{1}{2}$, bond angle - 180^o

In sp^2 - p-character $\frac{2}{3}$, bond angle - 120^o

In sp^3 - p-character $\frac{3}{4}$, bond angle - 109^o

71. (a) sp^3-hybridization called tetrahedral because it provides tetrahedral shape to the molecule.

72. (a) S-atom in SF_6 has sp^3d^2 hybridisation. So, the structure of SF_6 will be octahedral.

74. (b) Structure of H_2O_2 is non-planar. It has open book structure.

75. (d) Structure of N_2O is similar to CO_2 both have linear structure.

78. (a) $SnCl_2$ is V–shaped.

79. (d) In NH_4^+ nitrogen is sp^3 hybridised so 4 hydrogen situated at the corners of a tetrahedron.

81. (c) Increasing order of bond angle is $\underset{109°}{sp^3} < \underset{120°}{sp^2} < \underset{180°}{sp}$.

84. (a) NH_4^+ has sp^3–hybridized nitrogen so its shape is tetrahedral.

86. (b) Bond angle increases with change in hybridisation in following order $sp^3 < sp^2 < sp$.

88. (c) In Diborane boron shows sp^3–hybridization.

89. (a) Alkene does not show linear structure but it has planar structure due to sp^2–hybridisation.

90. (c) Generally SF_4 consist of 10 electrons, 4 bonding electron pair and one lone pair of electron, hence it shows sp^3d hybridization.

92. (c)

Atom/Ion	Hybridisation
NO_2^+	sp
SF_4	sp^3d with one lone pair of electron
PF_6^-	sp^3d^2

93. (a) PF_3 consist of three bonding pair electrons and one lone pair of electron hence it shows sp^3 – hybridization.

94. (b) NO_2^+ shows sp–hybridization. So its shape is linear.

95. (c) Generally octahedral compound show sp^3d^2–hybridization.

96. (a) In fifth group hydride bond angle decreases from top to bottom

$NH_3 > PH_3 > AsH_3 > SbH_3 > BiH_3$.

97. (b) Generally NH_4^+ shows sp^3 hybridization.

98. (b) We know that single, double and triple bond lengths of carbon in carbon dioxide are 1.22 Å, 1.15 Å and 1.10Å respectively.

99. (b) It shows sp^2–hybridization so it is planar.

101. (a) Bond angle of hydrides decreases down the group.

102. (b) Hybridization of N in NH_3 is sp^3 that of Pt in $[PtCl_4]^{2-}$ is dsp^2 that P in PCl_5 is sp^3d and that of B in BCl_3 is sp^2.

103. (d) NH_4^+ and SO_4^{2-} both show sp^3–hybridization and tetrahedral structure.

104. (a) It is shows sp^3d^3–hybridization. Hence the bond angle is about 72^o.

107. (a) s-character increases with increase in bond angle.

Hybridization	s%	Angle
sp	50	180^o
sp^2	33.3	120^o
sp^3	25	109.28^o
sp^3d^1	20	90^o and 120^o

108. (b) IF_7 molecule show sp^3d^3–hybridization.

110. (a) PCl_3 contain three bonding and one lone pair electron. Hence shows sp^3–hybridization.

111. (a) Ammonia and $(BF_4)^{-1}$ shows sp^3–hybridization.

112. (b) For square planar geometry hybridization is dsp^2 involving s, p_x, p_y and $d_{x^2-y^2}$ orbital.

113. (b) All carbon atoms of benzene consist of alternate single and double bond and show sp^2 hybridization.

116. (c) BCl_3 molecule show sp^2–hybridization and planar structure.

117. (c) BCl_3 Boron trichloride molecule show sp^2–hybridization and trigonal planar structure.

118. (b) SO_2 molecule shows sp^2–hybridization and bent structure.

119. (c) Due to multiple bonding in N_2 molecule.

120. (a) % of s-character in

$$\underset{(sp^3)}{CH_4} = \frac{100}{4} = 25\ ,\quad \underset{(sp^2)}{C_2H_4} = \frac{100}{3} = 33\ ,$$

$\underset{(sp)}{C_2H_2} = \frac{100}{2} = 50$

121. (a) Acidic character increases when we come down a group, so HI is the strongest acid.

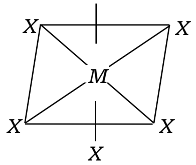
122. (c) SO_2 has sp^2 hybridization have the V shape structure $(< 120°)$ due to 2 lone pair of electron over S atom. CO_2 and N_2O have the sp hybridization.

123. (a) In H_2CO_3 and BF_3 central atom are in sp^2 hybridization but in H_2CO_3 due to the ionic character of $O-H$ bond it will be polar (High electronegativity of oxygen).

124. (a) Due to sp^3 hybridization and presence of lone pair of electron on p atom PCl_3 are of pyramidal shape like that of NH_3.

125. (b) There is *sp* hybridization in C_2H_2 so it has the linear structure.

126. (c) In octahedral molecule six hybrid orbitals directed towards the corner of a regular octahedron with a bond angle of 90°.



according to this geometry, the number of $X-M-X$ bond at 180° must be three.

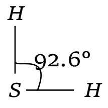
127. (d) sp^3d^2 hybrid orbital have octahedral shape

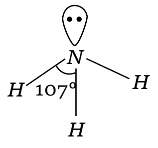
128. (c) In the formation of d^2sp^3 hybrid orbitals two $(n-1)d$ orbitals of *e.g.*, set [*i.e.*, $(n-1)dz^2$ and $(n-1)dx^2-y^2$ orbitals] one *ns* and three *np* $[np_x, np_y$ and $np_z]$ orbitals combine together and form six d^2sp^3 hybrid orbitals.

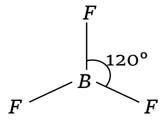
129. (c) The correct order of bond angle (Smallest first) is

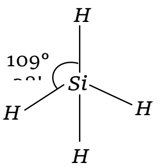
$H_2S < NH_3 < SiH_4 < BF_3$

$92.6° < 107° < 109°28' < 120°$

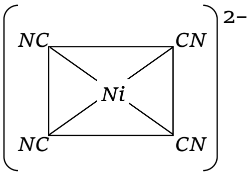




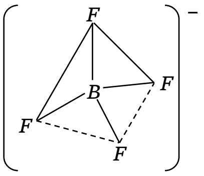




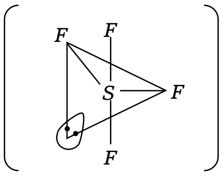
130. (a)



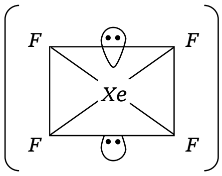
Square planar



Regular

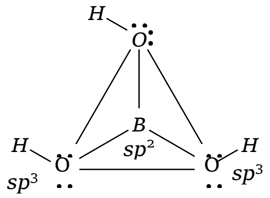


See saw shaped



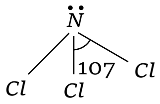
Square planar

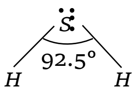
131. (b)



132. (b) In the formation of BF_3 molecule, one *s* and 2*p* orbital hybridise. Therefore it is sp^2 hybridization.

133. (e) In NCl_3 and H_2S the central atom of both (N and S) are in sp^3 hybridization state



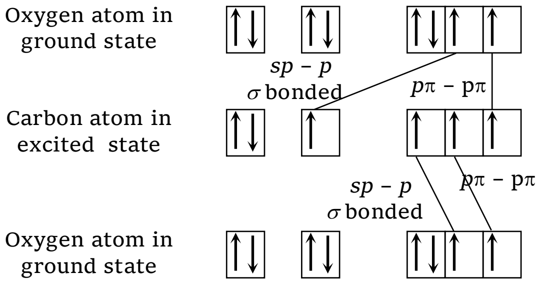


while in BF_3 and NCl_3 central atoms are in sp^2 and sp^3 hybridization respectively. In H_2S and $BeCl_2$ central atom are in sp^3 and sp^2 hybridization In BF_3, NCl_3 & H_2S central atom are in sp^2, sp^3 & sp^3 hybridization and in the central atom are in sp^3 and sp hybridization.

134. (c) $C_{\text{ground state}} = 2s^2, 2p_x^{\ 1} p_y^{\ 1}$; $C_{\text{excited state}} = 2s^1, 2p_x^{\ 1} p_y^{\ 1} p_z^{\ 1}$

$O_{\text{ground state}} = 2s^2, 2p_x^{\ 2} p_y^{\ 1} p_z^{\ 1}$

In the formation of CO_2 molecule, hybridization of orbitals of carbon occur only to a limited extent involving only one *s* and one *p* orbitals there is thus *sp* hybridisation of valence shell orbitals of the carbon atom resulting in the formation of two *sp* hybrid orbitals.

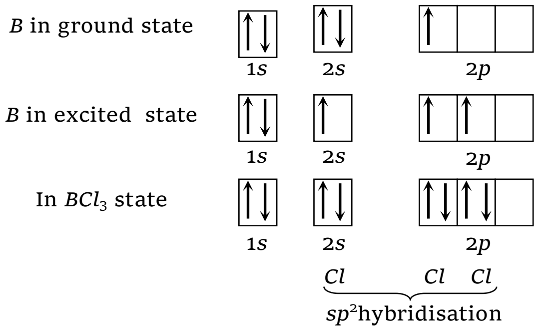


135. (d) In NH_3, N undergoes sp^3 hybridization. Due to the presence of one lone pair, it is pyramidal in shape.

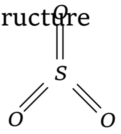
136. (b)

NO_2	SF_4	PF_6^-
sp	sp^3d	sp^3d^2

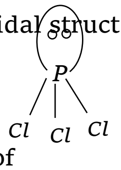
137. (b) The configuration of $_5B = 1s^2, 2s^2 2p^1$



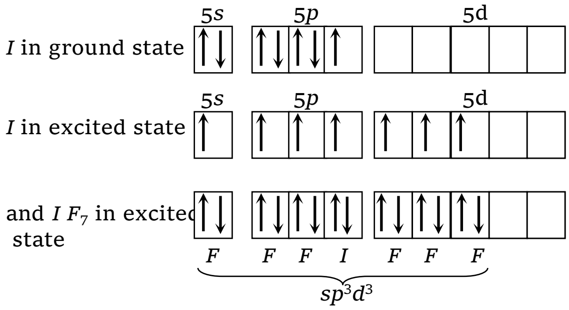
138. (d) In SO_3 molecule, S atom remains sp^2 hybrid, hence it has trigonal planar structure



139. (a) In PCl_3 molecule, phosphorous is sp^3 – hybridised but due to presence of lone pair of electron, it has pyramidal structure



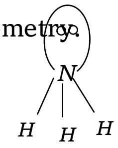
140. (a) The electronic configuration of $I = [Xe] 5s^2, 5p^5$ hence



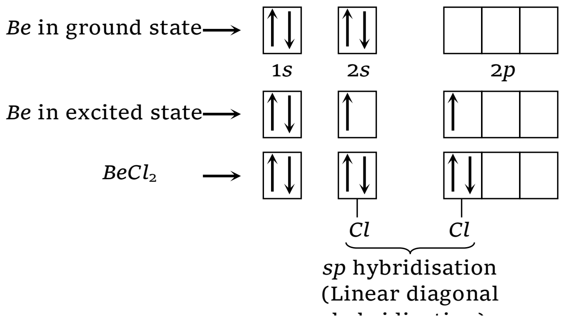
IF_7 shows sp^3d^2 hybridization. So, its structure is pentagonal bipyramidal.

141. (a) Compound containing highly electronegative element (F, O, N) attached to an electropositive element (H) show hydrogen bonding. Fluorine (F) is highly electronegative and has smaller size. So hydrogen fluoride shows the strongest hydrogen bonding in the liquid phase.

142. (b) In the ammonia molecule N atom is sp^3 – hybridized but due to the presence of one lone pair of e^- (*i.e.* due to greater $L_p - b_p$ repulsion) it has distorted tetrahedral (or pyramidal) geometry.

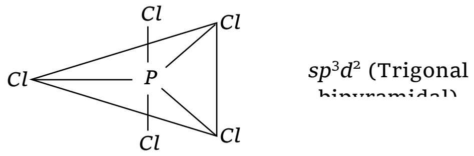


143. (a) $_4Be \rightarrow 1s^2, 2s^2, 2p^0$



144. (a) Except CO_3 other choice CO_2, CS_2 and $BeCl_2$ have sp – hybridization and shows the linear structure while CO_3 have sp^3 hybridization and show the non linear structure because sp^3 generate tetrahedral structure.

145. (a) dsp^3 or sp^3d hybridization exhibit trigonal bipyramidal geometry *e.g.,* PCl_5



146. (b) Carbon has only two unpaired electrons by its configuration but hybridization is a concept by which we can explain its valency 4.

147. (c) Hybridization is due to overlapping of orbitals of same energy content.

148. (d) MX_3 show the sp^2 hybridization in which $3sp^2$ hybridized orbital of M bonded by $3X$ from σ bond and having the zero dipole moment.

149. (bcd) $SnCl_2$ has V–shaped geometry.

150. (a) NF_3 is predominantly covalent in nature and has pyramidal structure (the central atom is

sp^3 hybridised) with a lone pair of electrons in the fourth orbital.

151. (ac) $PCl_3, NH_3 \rightarrow$ Pyramidal.

$CH_4, CCl_4 \rightarrow$ Tetrahedral.

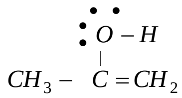
152. (a) dsp^3 or sp^3d : one s^+ three p^+ one $d(d_{z^2})$.

Resonance

1. (d) Choice (a), (b), (c) are the resonance structures of CO_2.

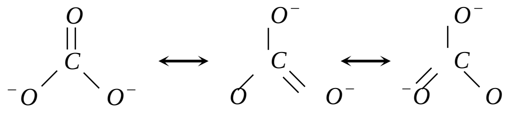
2. (b) In NH_3 nitrogen has one lone pair of electron.

5. (b) In CN^- ion formal negative charge is on nitrogen atom due to lone pair of electrons.

7. (a) 
$CH_3 - \overset{\overset{\ddot{O}-H}{|}}{C} = CH_2$ has 9σ, 1π and 2 lone pairs.

8. (c) In resonance structure there should be the same number of electron pairs.

9. (b) There are three resonance structure of CO_3^{2-} ion.



(I) (II) (III)

11. (abcd) It has all the characteristics.

VSEPR Theory

2. (a) The bond angle in PH_3 would be expected to be close to 90^o. (The bond angle $H-P-H$ in PH_3 is 93^o)

3. (b) In BF_3 molecule Boron is sp^2 hybridised so its all atoms are co-planar.

4. (c) Due to $lp-lp$ repulsions, bond angle in H_2O is lower $(104^o.5^o)$ than that in $NH_3\,(107^o)$ and $CH_4(109^o28')$. BeF_2 on the other hand, has *sp*-hybridization and hence has a bond angle of 180^o.

5. (c) Compound is carbontetrachloride because CCl_4 has sp^3 –hybridization 4 orbitals giving regular tetrahedron geometry. In others the geometry is little distorted inspite of sp^3 hybridization due to different atoms on the vertices of tetrahedron.

6. (b) SO_4^{2-} ion is tetrahedral since hybridization of S is sp^3.

7. (b) NH_3 molecule has one lone pair of electrons on the central atom *i.e.* Nitrogen.

8. (c) C_2H_2 has linear structure because carbons are *sp*-hybridised and lies at 180^o.

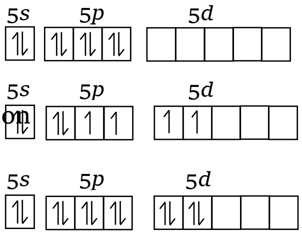
9. (b) XeF_6 is distorted Octahedral. It has sp^3d^3 hybridisation with lone pair of electron on *Xe*, so its shape is distorted.

10. (a)

11. (c) *Xe* ground state

Xe double excitation

XeF_4



sp^3d^2 - hybridization

12. (a) CO_2 has bond angle 180^o.

13. (a) As the *s*-character of hybridized orbitals decreases the bond angle also decreases

In sp^3 hybridisation: *s*-character 1/4, bond angle 109^o

In sp^2 hybridisation: *s*-character 1/3, bond angle 120^o

In *sp* hybridisation: *s*-character 1/2, bond angle 180^o

14. (a) XeF_2 molecule is Linear because *Xe* is *sp* hybridised.

15. (c) SO_4^{2-} has 42 electrons; CO_3^{2-} has 32 electrons; NO_3^- has 32 electrons.

16. (c) Molecular oxygen contains unpaired electron so it is paramagnetic (according to MOT).

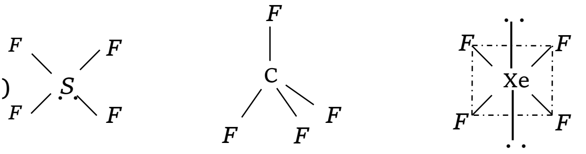
17. (b) Structure of H_2O is a bent structure due to repulsion of lone pair of oxygen.

18. (d) Bond angle between two hybrid orbitals is 105^o it means orbitals are sp^3 hybridised but to lone pair repulsion bond angle get changed from 109^o to 105^o. So its % of *s*-character is between 22-23%.

22. (d) Number of electrons in ClO_2^- = 7 + 6 + 6 + 1 = 20

Number of electrons in ClF_2^+ = 7+7+7 – 1=20.

23. (b) Central atom having four electron pairs will be of tetrahedral shape.

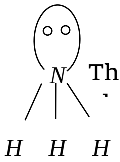
24. (d) 

26. (c) It shows sp^2 –hybridization and show trigonal planar structure.

28. (b) H_2S show bond angle nearly 90^o.

31. (a) Bond angle of hydrides is decreases top to bottom in the group. $NH_3 > PH_3 > AsH_3 > SbH_3$

32. (c)



Three bond pair and one lone pair of

33. (c) Unpaired electrons are present in KO_2 while others have paired electron

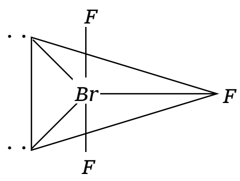
NO_2^+ = 22 electrons ; BaO_2 = 72 electrons

$AlO_2 = 30$ electrons ; $KO_2 = 35$ electrons

34. (a) Bond angle decreases from H_2O to H_2Te.

35. (c) BF_3 does not contain lone pair of electron.

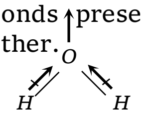
36. (b)

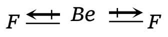


Bent *T*-shaped geometry in which both lone pairs occupy the equatorial position of the trigonal bipyramidal here $(l_p - l_p)$ repulsion = 0

$(l_p - b_p)$ repulsion = 4 and

37. (b) The overall value of the dipole moment of a polar molecule depends on its geometry and shape *i.e.*, vectorial addition of dipole moment of the constituent bonds water has angular structure with bond angle 105° as it has dipole moment. However BeF_2 is a linear molecule since dipole moment summation of all the bonds present in the molecule cancel each other.

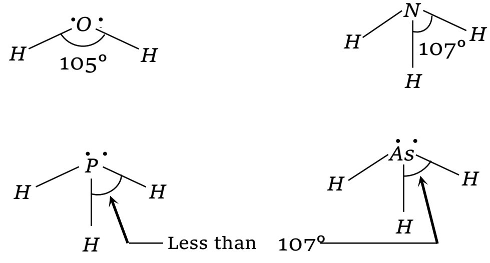




38. (d) BCl_3, BBr_3 and BF_3, all of these have same structure *i.e.* trigonal planar (sp^2 hybridization) Hence bond angle is same for all of them (*i.e.*, equal to 120°)

39. (d) We know that molecule of (NH_3) has maximum repulsion due to lone pair of electron. Its shape is pyramidal and is sp^3 hybridization.

40. (b)



As the electronegativity of central atom decreases bond angle is decreases

$\therefore$ NH_3 has largest bond angle.

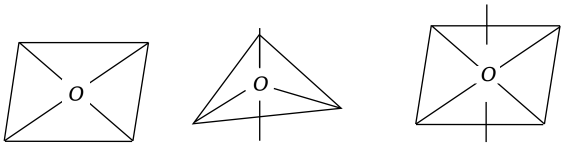
41. (c) In NH_3, sp^3-hybridization is present but bond angle is $106^o 45'$ because Nitrogen has lone pair of electron according to VSEPR theory due to *bp-lp* repulsion bond angle decreases from $109^o 45'$ to $106^o 45'$.

42. (a) Bond strength decreases as the size of the halogen increases from *F* to *I*.

43. (b) NH_3 has pyramidal structure, yet nitrogen is sp^3 hybridised. This is due to the presence of lone pair of electron.

44. (c) SiF_4 has symmetrical tetrahedral shape which is due to sp^3 hybridization of the central sulphur atom in its excited state configuration. SF_4 has distorted tetrahedral or Sea- Saw geometry which arise due to sp^3d hybridization of central sulphur atom and due to the presence of lone pair of electron in one of the equatorial hybrid orbital.

45. (d)



dsp^2 hybridization (Four 90° angles between

sp^3d hybridization (Six 90° angle between bond

sp^3d^2 hybridization (Twelve 90° angle between

Molecular orbital theory

2. (c) $\text{B.O.} = \dfrac{\text{No. of bonding } e^- - \text{No. of antibonding } e^-}{2}$

$= \dfrac{8-3}{2} = \dfrac{5}{2} = 2.5$.

3. (b) One bonding M.O. and one anti-bonding M.O.

4. (b) O_2^{2-} is least stable.

5. (c) B.O. of O_2 is 2, B.O. of O_2^{-1} is 1.5, B.O. of O_2^{+1} is 2.5 and of O_2^{2-} is 1.

6. (d) Hydride of boron does not exist in BH_3 form. It is stable as its dimer di borane (B_2H_6).

10. (c) $O_2^-(2 \times 8 + 1 = 17)$ has odd number of electrons and hence it is paramagnetic. All the remaining molecules/ions, *i.e.*,

$CN^-(6 + 7 + 1 = 14)$ diamagnetic

$NO(7 + 8 = 15)$ has odd number of electrons and hence it is paramagnetic.

11. (c) $\text{B.O.} = \dfrac{\text{No. of } N_b - \text{No. of } N_a}{2} = \dfrac{5}{2} = 2.5$.

12. (b) Bond order of O_2^+ is highest so its bond length is smallest.

13. (c) Oxygen is paramagnetic due to the presence of two unpaired electron :

$$O_2 = \sigma(1s)^2\sigma^*(1s)^2\sigma(2s)^2\sigma^*(2s)^2$$
$$\sigma(2p_x)^2\pi(2p_y)^2\pi(2p_x)^2\pi^*(2p_y)^1\pi^*(2p_z)^1$$

17. (d) In CH_3CN bond order between C and N is 3 so its bond length is minimum.

18. (b)

	He_2^+	H_2	H_2^+	H_2^-
$\sigma(1s)$	↑↓	↑↓	↑	↑↓
$\overset{*}{\sigma}(1s)$	↑	—	—	↑
$B.O.$	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$
Magnetic nature	P	D	P	P

(P = Paramagnetic, D = Diamagnetic)

19. (c) Due to unpaired e^- ClO_2 is paramagnetic.

20. (c) The Bond order in N_2 molecule is 3, $N\equiv N$ Here, $N_b = 2+4+2=8$ and $N_a = 2$

$\therefore$ B.O. $=(8-2)/2=3$.

21. (d) H_2^+ has the bond order $\frac{1}{2}$, it has only one electron so it will be paramagnetic.

22. (c) When bond forms between two atom then their energy get lower than that of separate atoms because bond formation is an exothermic process.

23. (b) Valency of A is 3 while that of B is 2 so according to Criss Cross rule the formula of the compound between these two will be A_2B_3.

24. (c) Due to resonance bond order of $C-C$ bonds in benzene is between 1 and 2.

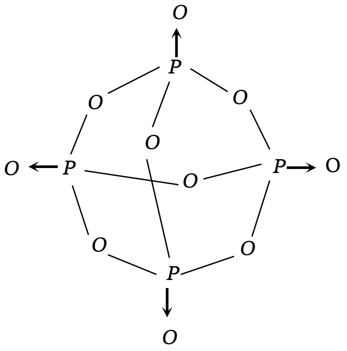
25. (a) Nitrogen does not have vacant 'd'-orbitals so it can't have +5 oxidation state i.e. the reason PCl_5 exists but NCl_5 does not.

26. (d) Molecules having unpaired electrons show paramagnetism.

27. (b) NO_2 has unpaired electrons so it would be paramagnetic.

30. (c) Helium molecule does not exist as bond order of $He_2 = 0$.

31. (c) Structure of P_4O_{10} is



Each phosphorus is attached to 4 oxygen atoms.

33. (c) B.O. of carbon $= \frac{N_b - N_a}{2} = \frac{8-4}{2} = 2$.

34. (a) B.O. $= \frac{N_b - N_a}{2} = \frac{10-4}{2} = 3$.

37. (b) B.O. $= \frac{N_b - N_a}{2} = \frac{8-3}{2} = \frac{5}{2} = 2.5$.

38. (a) Electronic configuration of O_2 is

$$O_2 = \sigma(1s)^2\sigma^*(1s)^2\sigma(2s)^2\sigma^*(2s)^2\sigma(2p_x)^2\pi(2p_y)^2$$
$$\pi(2p_z)^2\pi^*(2p_y)^1\pi^*(2p_z)^1$$

The molecule has two unpaired electrons So, it is paramagnetic

40. (c) $\overset{*}{\pi}2p_y$ has two nodal planes.

42. (a) Element with atomic number 26 is Fe. It is a ferromagnetic.

43. (b) Correct Sequence of bond order is

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

B.O – 2.5 2 1.5

44. (a) Due to small bond length.

45. (a) S^{-2} have all paired electrons so it is diamagnetic.

46. (c) NO has 15 electrons.

47. (b) In the conversion of O_2 into O_2^- bond order decreases.

49. (c) O_2^{2-} does not have any unpaired electron so it is diamagnetic.

50. (a) O_2^{2-} consist of four antibonding electron pair [1s and 2s have two antibonding and $2p_x 2p_y$ have two antibonding electron pair].

51. (c) The electron's distribution in molecular orbitals is $1s^2, 2s^1$

B.O. $= \frac{2-1}{2} = \frac{1}{2} = 0.5$.

52. (b) ClO_2^- has all paired electrons hence it does not show paramagnetism.

53. (a) B.O. $= \frac{1}{2}[N_b - N_a]$

$N_2 = \frac{1}{2}[10-4] = \frac{6}{2} = 3$; $O_2^{2+} = \frac{1}{2}[10-4] = \frac{6}{2} = 3.$

54. (a) B.O. for $N_2^+ = \frac{1}{2}[N_b - N_a] = \frac{1}{2}[9-4] = \frac{5}{2} = 2.5$.

55. (a) H_2O_2 contain bond angle between two $O-H$ planes about 90^o.

56. (c) Nitrogen molecule has highest bond energy due to presence of triple bond.

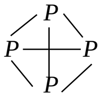
57. (c) $Cu^{2+} = [Ar_{18}]3d^9 4s^0$ it has one unpaired electron so it is paramagnetic.

59. (a) CN^- = 14 electrons ; CO =14 electrons

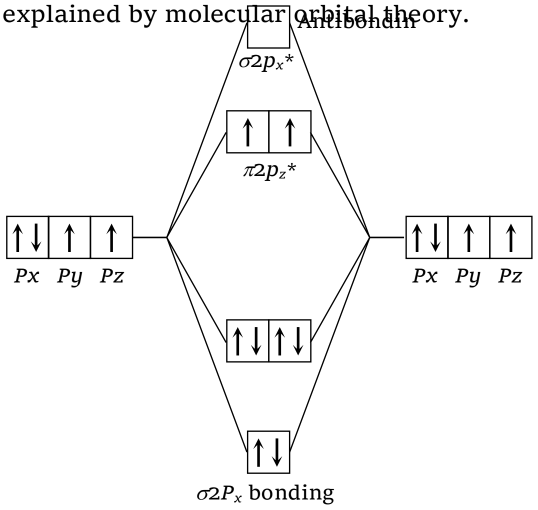
B.O. $= \frac{1}{2}[10-4] = \frac{6}{2} = 3$.

60. (a) B.O. $= \frac{1}{2}[10-5] = \frac{5}{2} = 2.5$, paramagnetic

61. (a)



64. (c) The paramagnetic property in oxygen came through unpaired electron which can be explained by molecular orbital theory.

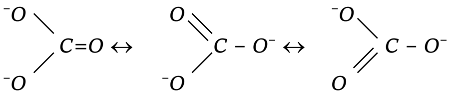


So 2 unpaired of electron present in $\pi\, 2p_y^*$ and $\pi\, 2p_z^*$.

65. (a) Bond order $= \frac{\text{Total number of bonds between atoms}}{\text{Total number of resonating structure}}$

$= \frac{5}{4} = 1.25$

66. (c) We know that carbonate ion has following resonating structures



Bond order $= \frac{\text{Total number of bonds between atoms}}{\text{Total number of resonating structure}}$

$= \frac{1+1+2}{3} = \frac{4}{3} = 1.33$.

67. (a) $O_2^+(15e^-) = K : K^*(\sigma 2s)^2(\sigma^* 2s)^2(\sigma 2p_x)^2$

$(\pi 2p_y)^2(\pi 2p_z)^2(\pi^* 2p_y)^1(\pi^* 2p_z)^0$

Hence, bond order $= \frac{1}{2}(10-5) = 2.5$

$N_2^+(13e^-) = KK^*(\sigma 2s)^2(\sigma^* 2s)^2(\sigma 2p_x)^2$

$(\pi\, 2p_y)^2(\pi\, 2p_z)^1$

Hence, bond order $= \frac{1}{2}(9-4) = 2.5$.

68. (a) Electronic configuration of O_2 is

$O_2 = (\sigma 1s)^2(\sigma^* 1s)^2(\sigma 2s)^2(\sigma^* 2s)^2(\sigma^* 2s)^2(\sigma 2p_z)^2$

$(\pi 2p_x^2 \equiv \pi 2p_y^2)\,(\pi^* 2p_x^1 \equiv \pi^* 2p_y^1)$

Hence bond order $= \frac{1}{2}\left[N_b - N_a\right] = \frac{1}{2}[10-6] = 2$.

69. (c) Nitrogen form triple bond $N \equiv N$
In which 6 electron take part.

70. (a) As bond order increase bond length decrease the bond order of species are

$= \frac{\text{number of bonding electron - Number of } a.b. \text{ electron}}{2}$

For $O_2 = \frac{10-6}{2} = 2$;

$O_2^+ = \frac{10-5}{2} = 2.5$

$O_2^- = \frac{10-7}{2} = 1.5$

So, bond order $O_2^+ > O_2 > O_2^-$ and bond length are $O_2^+ > O_2 > O_2^-$.

71. (b) O_2 **:**

$$\sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_x{}^2 \begin{cases} \pi 2p_y{}^2 & \pi^* 2p_y{}^1 \\ \pi 2p_z{}^2 & \pi^* 2p_z{}^1 \end{cases}$$

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

(Two unpaired electrons in antibonding molecular
orbital)

$O_2^+ : \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_x{}^2 \begin{cases} \pi 2py^2 \\ \pi 2pz^2 \end{cases} \begin{cases} \pi^* 2py^1 \\ \pi^* 2pz^0 \end{cases}$

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

(One unpaired electron in antibonding molecular orbital so it is paramagnetic)

72. (b) Higher the bond order, shorter will be the bond length, thus NO^+ having the higher bond order that is 3 as compared to NO having bond order 2 so NO^+ has shorter bond length.

73. (d) Oxygen molecule (O_2) boron molecule (B_2) and N_2^+ ion, all of them have unpaired electron, hence they all are paramagnetic.

74. (c) Bond order of NO^+, NO and NO^- are $3, 2.5$ and 2 respectively, bond energy $\propto$ bond order

75. (a) Paramagnetic property arise through unpaired electron. B_2 molecule have the unpaired electron so it show paramagnetism.

$$B_2 \rightarrow \underset{\text{(2 unpaired electron)}}{\sigma 1s^2 \sigma^* 1s^2, \sigma 2s^2 \sigma^* 2s^2, \pi 2p_x{}^1 = \pi 2p_y{}^1}$$

$$C_2 \rightarrow \underset{\text{(No unpaired electron)}}{\sigma 1s^2 \sigma^* 1s^2, \sigma 2s^2 \sigma^* 2s^2, \pi 2p_x{}^2 . \pi 2p_y{}^2}$$

$$N_2 \rightarrow \underset{\text{(No unpaired electron)}}{\sigma 1s^2 \sigma^* 1s^2, \sigma 2s^2 \sigma^* 2s^2, \sigma 2p_x{}^2, \pi 2p_y{}^2 \pi 2p_z{}^2}$$

$$F_2 \rightarrow \sigma s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_x{}^2, \pi 2p_y{}^2, \pi 2p_z{}^2, \pi^* 2p_y{}^2, \pi^* 2p_z{}^2$$

(No unpaired electron)

So only B_2 exist unpaired electron and show the paramagnetism.

76. (b)

$$O_2 \rightarrow \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x{}^2 \begin{array}{l} \pi 2p_y{}^2 \; \pi^* 2p_y{}^1 \\ \pi 2p_z{}^2 \; \pi^* 2p_z{}^2 \end{array}$$

So two unpaired electron found in O_2 at ground stage by which it shows paramagnetism.

77. (b) Due to greater electron affinity Cl_2 has the highest bond energy.

78. (a) Molecular orbital electronic configuration of these species are :

$$O_2^-(17e^-) = \sigma 1s^2 \sigma^* 1s^2, \sigma 2s^2 \sigma^* 2s^2, \sigma 2p_x{}^2, \pi 2p_y{}^2, \pi 2p_z{}^2, \pi^* 2p_y{}^2 \pi^* 2p_z{}^1$$

$$O_2(16e) = \sigma 1s^2 \sigma^* 1s^2, \sigma 2s^2 \sigma^* 2s^2, \sigma 2p_x{}^2, \pi 2p_y{}^2, \pi 2p_z{}^2 \pi^* 2p_y{}^1 \pi^* 2p_z{}^1$$

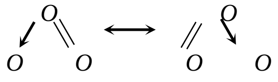
$$O_2^{2-}(18e) = \sigma 1s^2 \sigma^* 1s^2, \sigma 2s^2 \sigma^* 2s^2, \sigma 2p_x{}^2, \pi 2p_y{}^2, \pi 2p_z{}^2 \pi^* 2p_y{}^2 \pi^* 2p_z{}^2$$

Hence number of antibonding electrons are 7,6,and 8 respectively.

79. (c) Species with unpaired electrons is paramagnetic O_2 has 2 unpaired electrons, O_2^- has one unpaired, O_2^{2-} has zero unpaired electrons, O_2^{2+} has one unpaired.

80. (a) O_2 has 2 unpaired electron while O_2^+ and O_2^- has one each unpaired electrons while O_2^{2+} does not have any unpaired electron.

81. (c) $H-O-O-H, O \leftarrow O = O, O = O$



Due to resonance in O_3 $O-O$ *bond length will be in b/w* $O=O$ *and* $O-O$.

82. (a) From valency bond theory, bond order in CO, *i.e.* $:\overset{-}{C} \equiv \overset{+}{O}:$ is 3, that of $O=C=O$ is 2 while that of CO_3^{2-} ion is 1.33. Since the bond length increases as the bond order decreases, *i.e.* $CO < CO_2 < CO_3^{2-}$.

83. (c) $N_2 : KK\sigma(2s)^2 \sigma^*(2s)^2 \pi(2p_x)^2 \pi(2p_y)^2 \sigma(2p_z)^2$ (diamagnetic)

$C_2 : KK\sigma(2s)^2 \sigma^*(2s)^2 \pi(2p_x)^2 \pi(2p_y)^2$ (diamagnetic)

$N_2^+ : KK\sigma(2s)^2 \sigma^*(2s)^2 \pi(2p_x)^2 \pi(2p_y)^2 \sigma(2p_z)^2$ (paramagnetic)

$O_2^{2-} : KK\sigma(2s)^2 \sigma^*(2s)^2 \sigma(2p_z)^2 \pi(2p_x)^2 \pi(2p_y)^2 \pi^*(2p_x)^2 \pi^*(2p_y)^2$ (diamagnetic)

84. (d) $NH_3 = 107°, PH_3 = 93°, H_2O = 104.5°$

$H_2Se = 91°, H_2S = 92.5°$

Hydrogen bonding

1. (d) Hydrogen bonding will be maximum in *F-H* bond due to greater electronegativity difference.

2. (b) Ice has hydrogen bonding.

3. (b) *H* – *F* has highest boiling point because it has hydrogen bonding.

6. (d) CO_2 is *sp*-hybridised

7. (b) *sp*-hybridization gives two orbitals at 180^o with Linear structure.

8. (d) Hydrogen bonding increases the boiling point of compound.

9. (c) *o*-Nitrophenol has intramolecular hydrogen bonding but *p*-Nitrophenol has intermolecular hydrogen bonding so boiling point of *p*-Nitrophenol is more than *o*-Nitrophenol.

10. (c) The strongest hydrogen bond is in hydrogen fluoride because the power of hydrogen bond $\propto$ electronegativity of atom and

electronegativity $\propto \frac{1}{\text{atomic size}}$

So fluorine has maximum electronegativity and minimum atomic size.

11. (d) H_2O can form hydrogen bonds rest CH_4 and $CHCl_3$ are organic compound having no oxygen while *NaCl* has itself intraionic attraction in the molecule.

12. (b) PH_3 has the lowest boiling point because it does not form Hydrogen bond.

14. (b) Hydrogen bonding increases heat of vaporisation.

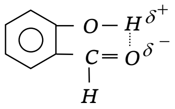
15. (d) Only NH_3 forms H-bonds.

22. (a) Water molecule has hydrogen bonding so molecules get dissociated so it is liquid.

23. (d) In case of water, five water molecules are attached together through four hydrogen bonding.

25. (c) Hydrogen bond is strongest in hydrogen fluoride.

28. (c) Boiling point of H_2O is more than that of H_2S because H_2O forms hydrogen bonding while H_2S does not.

30. (c)  Interamolecular H-bonding.

31. (a) Hydrogen bond is formed when hydrogen is attached with the atom which is highly electronegative and having small radius.

34. (a) Water is dense than ice because of hydrogen bonding interaction and structure of ice.

35. (a) Ethanol have hydrogen bonding so its boiling point is higher than its isomer dimethyl ether.

36. (a) A compound having maximum electronegative element will form strong Hydrogen bond.

37. (a) Due to electronegativity difference of N_2 and H_2, NH_3 form hydrogen bond.

38. (b) Intermolecular hydrogen bonding compound contain more b.p. compare to intramolecular hydrogen bonding compound.

39. (d) Water molecule contain hydrogen bonding.

40. (c) It contain intermolecular hydrogen bonding.

41. (b) Ethyl alcohol has a intermolecular hydrogen bond.

43. (b) HCl contain weak covalent bond.

45. (c) Due to intermolecular hydrogen bonding water molecules come close to each other and exist in liquid state.

46. (b) Due to greater resonance stabilization.

47. (d) C_2H_5OH will dissolve in water because it forms hydrogen bond with water molecule.

48. (b) In ice cube all molecules are held by inter molecular hydrogen bond.

49. (d) Hydrogen bonding is developed due to inter atomic attraction so it is the weakest.

Types of bonding and Forces in solid

1. (b) In electrovalent crystal has cation and anion are attached by electrostatic forces.

2. (d) Mercury has very weak interatomic forces so it remains in liquid state.

3. (c) The melting and boiling points of argon is low hence, in solid argon atoms are held together by weak Vander Waal's forces.

4. (c) NaF is the strongest ionic crystal so its melting point would be highest.

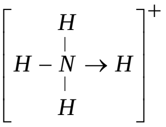
9. (b) Diamond is the hardest substance it's melting point would be highest.

10. (c) Bond is formed by attractive and repulsive forces of both the atoms.

12. (a) Generally zero group elements are linked by the Vander Waal's force. Hence these show weakest intermolecular forces.

13. (d) Glycerol has a three OH group hence it is viscous in nature.

14. (c) Vander waal's forces is the weakest force of attraction.

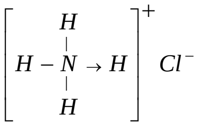
16. (b) NH_4^+ contain all three types of bond in its structure 

$$\left[\begin{array}{c} H \\ | \\ H-N\rightarrow H \\ | \\ H \end{array}\right]^+$$

17. (d) In $NaOH$ covalent bond is present in $O-H$ bond while ionic bond is formed between OH^- and Na^+.

18. (a) Bond formation is an exothermic reaction so there is decrease in energy of product.

22. (d) Blue vitriol is $CuSO_4.5H_2O$ and it has all types of bonds.

23. (a) 

$$\left[\begin{array}{c} H \\ | \\ H-N\rightarrow H \\ | \\ H \end{array}\right]^+ Cl^-$$

Ionic bond = 1, Covalent bond = 3

Co-ordinate bond = 1.

Critical Thinking Questions

1. (d) We know that ionic characters

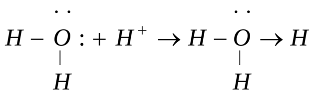
$$=16\,[E_A-E_B]+3.5\times[E_A-E_B]^2$$

or ionic characters = 72.24%

3. (c) Configuration of O_2 molecule is

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

No. of pair are 7 so total no. of paired electrons are 14.

6. (a) 

$$H-\underset{\underset{H}{|}}{\overset{..}{O}}:+H^+\rightarrow H-\underset{\underset{H}{|}}{\overset{..}{O}}\rightarrow H$$

7. (b) The correct order of increasing dipole moment is

p-dichlorobenzene < Toluene < m-dichlorobenzene < o-dichlorobenzene.

8. (a) The dipole moment of $CH_4=0D$, $NF_3=0.2D$, $NH_3=1.47D$ and $H_2O=1.85D$. Therefore the correct order of the dipole moment is $CH_4<NF_3<NH_3<H_2O$.

10. (d) Ammonia molecule is more basic than nitrogen trifluoride and Boron trifluoride because ammonia molecule easily gives lone pair of electron.

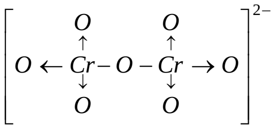
11. (a) Chlorine atom in ClO_2^- is sp^3 hybridised but its shape is angular.

12. (c) [NF_3 and H_3O^+] are pyramidal while [NO_3^- and BF_3] are planar. Hence answer (c) is correct.

13. (d) $\underset{sp^2}{CH_2=CH}-\underset{\substack{sp^3\\ \text{hybridised}}}{CH_2}-CH_2-C\equiv CH$

14. (d) B.O. in CO *i.e.*, $:\overset{-}{C}=\overset{+}{O}:$ is 3, that of $O=C=O$ is 2 while that of CO_3^{2-} ion is 1.33. Since the bond length increases as the bond order decreases *i.e.* $CO<CO_2<CO_3^{2-}$. Thus option (d) is correct.

15. (b) Dichromate dianion has following structure



$$\left[O\leftarrow\underset{\underset{O}{\downarrow}}{\overset{\overset{O}{\uparrow}}{Cr}}-O-\underset{\underset{O}{\downarrow}}{\overset{\overset{O}{\uparrow}}{Cr}}\rightarrow O\right]^{2-}$$

6, $Cr-O$ bonds are equivalent.

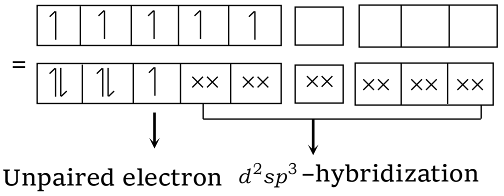
17. (b) ClF_3 is a $[AB_3]$ type of molecule because it consist of three bonding pair and two lone pair of electrons hence this compound shows sp^3d hybridization.

20. (a) BeF_3^- does not show sp^3–hybridization because this compound is not formed.

21. (a) $K_3[Fe(CN)_6]$

$Fe_{26}=4s^2 3d^6$

$Fe^{3+}=3d^5 4s^0$

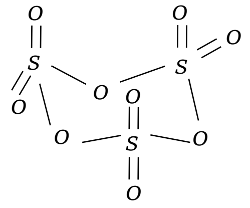


22. (d) N_2^+ has one unpaired electron so it would be paramagnetic.

23. (a) Each of the species has 14 electron so isoelectronic and shows bond order 3.

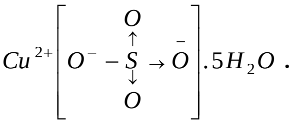
B.O. $=\frac{1}{2}[N_b-N_a]=\frac{1}{2}[10-4]=\frac{6}{2}=3$.

24. (d)



Trimer of SO_3.

27. (c) $CuSO_4.5H_2O$ has electrovalent, covalent and coordinate bonds.



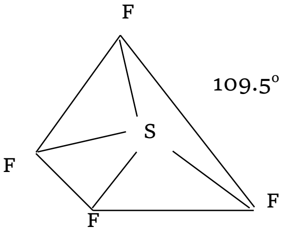
$$Cu^{2+}\left[O^- -\underset{\underset{O}{\downarrow}}{\overset{\overset{O}{\uparrow}}{S}}\rightarrow\overset{-}{O}\right].5H_2O\ .$$

Assertion & Reason

1. (a) Solubility in water depends on hydration energy and lattice energy.

2. (a) Polarity in covalent bond developed due to shifting of electrons towards one of the bonded atoms.

5. (c) SiF_4 have sp^3 hybridization & shape of regular tetrahedral where the bond angle of $F-S-F$ are found 109.5^o which is greater than 90^o but less than 180^o.



Repulsion sequence are $Lp-Lp>Lp-Bp>Bp-Bp$ so assertion are true but the reason are false.

9. (c) N_2 molecule is diamagnetic. The diamagnetic character is due to the presence of paired electron N_2 molecule does not contain any unpaired electron. Thus, assertion is coorect but the reason is false.

10. (a) It is correct that during formation of Ice from water there are vacant spaces between hydrogen bonded molecules of Ice. Ice has a cage like structure. Due to this reason Ice is less dense than liquid water. hence both assertion & reason are true & reason are the correct explanation of assertion.

11. (b) Water is liquid while H_2S is gas because oxygen is of small size & more electronegative in comparision to sulphur. Hence water molecules exist as associated molecules to form liquid state due to hydrogen bonding H_2S does not have hydrogen bonding & can't associated hence it is gas.

12. (d) Iodine is more soluble in CCl_4 than in H_2O because iodine is non polar & thus it dissolve in CCl_4 because like dissolves like.

13. (a) o & p-nitrophenols can be separated by steam distillation because o-nitrophenol is steam volatile. Here, both assertion & reason are correct & reason is correct explanation of assertion.

14. (e) Fluorine is highly reactive $F-F$ bond has low bond dissociation energy. Here assertion is false but reason is true.

15. (c) It is true that sigma (σ) bond is stronger than pi (π) bond but the reason that there is free rotation of atoms is false.

16. (c) Energy is released in the formation of the crystal lattice. It is qualitative measure of the stability of an ionic compound so assertion is true & reason are false.

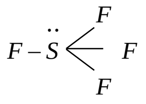
17. (c) Li, Na & K are alkali metals & not alkaline earth metal so, size of alkali metal increases So. Assertion is true & reason are false.

18. (b) Hess's law states that the enthalpy of a reaction is the same, whether it takes place in a single step or in more than one step. In born haber cycle the formation of an cycle ionic compound may occur either by direct combination of the element or by a stepwise process involving vaporization of elements, conversion of the gaseous atoms into ions & the combination of the gaseous ions to form the ionic solid.

19. (a) With increase in bond order, bond length decreases & hence bond energy increases so both assertion & reason are true & reason are the correct explanation of assertion.

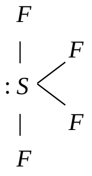
20. (c) Electron affinity is experimentally measurable while electronegativity is a relative number so assertion is true but reason are false.

21. (b) Assertion & reason both are correct but reason is not the correct explanation of assertion sulphur has five electrons pairs whose arrangement should be trigonal bipyramidal according to VSEPR theory. Two structure are possible



(a)

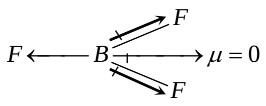
Lone pair in the axial position (three l.p – b.p repulsion at



(b)

Lone pair in the equatorial position (two L.p – b.p

22. (e) BF_3 has zero dipole moment because of its structure.



H_2S has two lone pairs on sulphur atom & hence. It has irregular shape.

Thus it possess dipole moment. So assertion is false but reason are true.

23. (d) Both assertion & reason are false because pairs of electron will have different spins. Electrons are equally shared between them.

24. (d) In B_2, total number of electrons = 10

$B_2 \rightarrow \sigma(1s)^2\ \sigma^*(1s^2)\ \sigma(2s)^2\ \sigma^*(2s)^2\ \sigma(2p_x)^1\ \pi(2p_y)^1$

Presence of unpaired electron shows the paramagnetic nature.

The highest occupied molecular orbital is of π-type.

25. (a) Both assertion & reason are true & reason is the correct explanation of the assertion because. At any given instant, at room temperature each water molecules forms hydrogen bonds with other water molecules. The H_2O molecules are in continuous motion.

So hydrogen bonds are constantly & rapidly broken & formed. In Ice H_2O molecules are however fixed in the space lattice.

26. (a) Both assertion & reason are true & reason is the correct explanation of assertion, because helium molecule is formed by linking two helium atoms. both have $1s$ orbitals. These will combine to form two molecular orbitals σ ($1s$) & σ^* ($1s$) four available electrons are accommodated as $\sigma(1s)^2$ & $\sigma^*(1s)^2$.

Chemical Bonding

SET Self Evaluation Test -3

1. Nature of the bond formed between two elements depends on the

(a) Oxidation potential
(b) Electronegativity
(c) Ionization potential
(d) Electron affinity

2. Two elements X and Y have following electronic configurations $X = 1s^2, 2s^2\,2p^6, 3s^2\,3p^6, 4s^2$ and $Y = 1s^2, 2s^2\,2p^6, 3s^2\,3p^5$. The expected compound formed by combination of X and Y is **[BHU 1990]**

(a) XY_2
(b) X_5Y_2
(c) X_2Y_5
(d) XY_5

3. Electricity do not pass through ionic compounds

(a) In solution
(b) In solid state
(c) In melted state
(d) None of these

4. From the following which compound on heating readily sublimes

(a) $NaCl$
(b) $MgCl_2$
(c) $BaCl_2$
(d) $AlCl_3$

5. Which one in the following contains ionic as well as covalent bond **[IIT 1979; CPMT 1983; DPMT 1983]**

(a) CH_4
(b) H_2
(c) KCN
(d) KCl

6. The solution of sugar in water contains **[NCERT 1972; MP PET 2000]**

(a) Free atoms
(b) Free molecules
(c) Free ions
(d) Free atoms and free molecules

7. In which of the following reactions, there is no change in the valency **[NCERT 1974; CPMT 1971, 78]**

(a) $4KClO_3 \rightarrow 3KClO_4 + KCl$
(b) $SO_2 + 2H_2S \rightarrow 2H_2O + 3S$
(c) $BaO_2 + H_2SO_4 \rightarrow BaSO_4 + H_2O_2$
(d) $2BaO + O_2 \rightarrow 2BaO_2$

8. The octet rule is not followed in **[BHU 1981]**

(a) F_2
(b) NaF
(c) CaF_2
(d) BF_3

9. Sodium chloride is an ionic compound whereas hydrogen chloride is a gas because **[KCET 2002]**

(a) Sodium is reactive
(b) Covalent bond is weaker than ionic bond
(c) Hydrogen chloride is a gas
(d) Covalent bond is stronger than ionic bond

10. Which one of the following molecules has a coordinate bond **[CPMT 1988, 94]**

(a) NH_4Cl
(b) $AlCl_3$
(c) $NaCl$
(d) Cl_2

11. Co-ordinate bond is absent in **[RPMT 2002]**

(a) $BH_4^{\ominus}$
(b) CO_3^{-2}
(c) H_3O^+
(d) $NH_4^{\oplus}$

12. The dipole moment of chlorobenzene is 1.73 D. The dipole moment of p-dichlorobenzene is expected to be **[CPMT 1991]**

(a) 3.46 D
(b) 0.00 D
(c) 1.73 D
(d) 1.00 D

13. Polarization of electrons in acrolein may be written as **[IIT 1988]**

(a) $\overset{\delta^-}{C}H_2 = CH - \overset{\delta^+}{C}H = O$
(b) $\overset{\delta^-}{C}H_2 = CH - CH = \overset{\delta^+}{O}$
(c) $\overset{\delta^-}{C}H_2 = \overset{\delta^+}{C}H - CH = O$
(d) $\overset{\delta^+}{C}H_2 = CH - CH = \overset{\delta^-}{O}$

14. The order of dipole moments of the following molecules is **[Roorkee 2000]**

(a) $CHCl_3 > CH_2Cl_2 > CH_3Cl > CCl_4$
(b) $CH_2Cl_2 > CH_3Cl > CHCl_3 > CCl_4$
(c) $CH_3Cl > CH_2Cl_2 > CHCl_3 > CCl_4$
(d) $CH_2Cl_2 > CHCl_3 > CH_3Cl > CCl_4$

15. The electronegativity of C, H, O, N and S are 2.5, 2.1, 3.5, 3.0 and 2.5 respectively. Which of the following bond is most polar

(a) $O-H$
(b) $S-H$
(c) $N-H$
(d) $C-H$

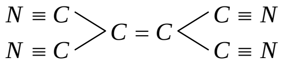
16. Which of the following bond has the most polar character **[DPMT 1982; CBSE PMT 1992; CPMT 1999]**

(a) $C-O$
(b) $C-Br$
(c) $C-S$
(d) $C-F$

17. The geometry of H_2S and its dipole moment are **[IIT 1999]**

(a) Angular and non-zero
(b) Angular and zero
(c) Linear and non-zero
(d) Linear and zero

18. How many σ and π bonds are there in the molecule of tetracyanoethylene



[NCERT 1980; MP PMT 1986, 95;Orissa JEE 1997]

(a) Nine σ and nine π (b) Five σ and nine π

(c) Nine σ and seven π (d) Five σ and eight π

19. The shape of H_3O^+ ion is **[EAMCET 1993; CPMT 2001]**

(a) Linear (b) Angular

(c) Trigonal planar (d) Triangular pyramidal

20. The hybridization in sulphur dioxide is **[IIT 1986; DPMT 1990]**

(a) sp (b) sp^3

(c) sp^2 (d) dsp^2

21. The number and type of bonds between two carbon atoms in CaC_2 are

(a) One sigma (σ) and one pi (π) bonds

(b) One sigma (σ) and two pi (π) bonds

(c) One sigma (σ) and one and a half pi (π) bonds

(d) One sigma (σ) bond

22. Which of the following resonating structures of N_2O is the most contributing **[Roorkee Qualifying 1998]**

(a) $N \equiv N - O$ (b) $N - N \equiv O$

(c) $N = N - O$ (d) $N - N = O$

23. The hybridization of atomic orbitals of nitrogen in NO_2^+, NO_3^-, and NH_4^+ are

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

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

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

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

24. The molecule having one unpaired electron is

[IIT 1985; MP PMT 1989]

(a) NO (b) CO

(c) CN^- (d) O_2

25. The geometry of ClO_3^-, according to valence shell electron pair repulsion (VSEPR) theory will be

[KCET 1996; MP PET 1997]

(a) Planar triangle (b) Pyramidal

(c) Tetrahedral (d) Square planar

26. Which of the following halogens has the highest bond energy **[CPMT 1988]**

(a) F_2 (b) Cl_2

(c) Br_2 (d) I_2

27. What bond order does O_2^{2-} have **[Pb. PMT 2001]**

(a) 3 (b) 2

(c) 1 (d) 1/2

28. In the process, $O_2^+ \rightarrow O_2^{+2} + e$ the electron lost is from

[Orissa JEE 2002]

(a) Bonding π-orbital (b) Antibonding π-orbital

(c) $2p_z$ orbital (d) $2p_x$ orbital

29. The maximum number of hydrogen bonds formed by a water molecule in ice is

[IIT 1996]

[MP PET 1993; AFMC 2002;UPSEAT 1999, 2001, 02]

(a) 4 (b) 3

(c) 2 (d) 1

30. Hydrogen bonding is not present in

[AIIMS 1998; MP PET/PMT 1998]

(a) Glycerine

(b) Water

(c) Hydrogen sulphide

(d) Hydrogen fluoride

31. The bonds in $K_4[Fe(CN)_6]$ are

[IIT Screening 2000]

(a) All ionic

(b) All covalent

(c) Ionic and covalent

(d) Ionic, covalent and coordinate covalent

32. In which of the following ionic, covalent and coordinate bonds are present

(a) Water

(b) Ammonia

(c) Sodium cyanide

(d) Potassium bromide

AS Answers and Solutions

(SET -3)

1. (b) If the two elements have similar electronegativities,the bond between them will be covalent, while a large difference in electronegativities leads to an ionic bond.

2. (a) From electronic configuration valencies of X and Y are + 2 and –1 respectively so formula of compound is XY_2.

3. (b) Ionic compounds can't pass electricity in solid state because they don't have mobile ion in solid state.

4. (d) $AlCl_3$ sublimes readily on heating.

5. (c) Structure of KCN is $[K^+(C^- \equiv \ddot{N})]$.

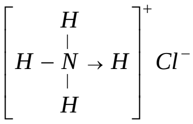
6. (b) Sugar is an organic compound which is covalently bonded so in water it remains as free molecules.

7. (c) In the reaction $\overset{+2}{Ba}O_2 + H_2\overset{+6}{S}O_4 \rightarrow \overset{+2}{Ba}\overset{+6}{S}O_4 + H_2O$ valency is not changing.

8. (d) BF_3 does not have octet, it has only six electrons so it is electron deficient compound.

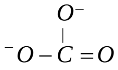
9. (b) $NaCl$ is a ionic compound because it consists of more elelctronegativity difference compare to HCl.

10. (a) NH_4Cl has a coordinate bond besides covalent and ionic bonds



$$\left[\begin{array}{c} H \\ | \\ H-N\rightarrow H \\ | \\ H \end{array}\right]^+ Cl^-$$

11. (b)



$$^-O-\overset{\overset{\displaystyle O^-}{|}}{C}=O$$

has covalent bonds only.

12. (b) Due to symmetry dipole moment of *p*-dichloro benzene is zero.

13. (d)

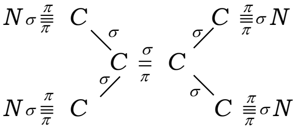
14. (d) CCl_4 has zero dipole moment because of symmetric tetrahedral structure. CH_3Cl has slightly higher dipole moment which is equal to $1.86D$. Now CH_3Cl has less electronegativity then CH_2Cl_2. But CH_2Cl_2 has greater dipole moment than $CHCl_3$.

15. (a) More the difference in electronegativity of atoms. Bond between them will be more polar.

16. (d) $C-F$ bond has the most polar character due to difference of their electronegativity.

17. (a) H_2S has angular geometry and have some value of dipole moment.

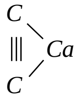
18. (a)



9π and 9σ bonds.

19. (d) H_3O^+ has sp^3 hybridization and its shape is triangular pyramidal due to lone pair on oxygen.

20. (c) SO_2 molecule has sp^2 hybridisation.

21. (b) In  two carbons are joined with 1σ and 2π bonds.

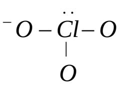
22. (a) In N_2O molecule $N\equiv N-O$ structure is most contributed.

23. (b) The shape of NO_2^+, NO_3^- and NH_4^+ are linear trigonal planar and tetrahedral respectively. Thus the hybridization of atomic orbitals of nitrogen in these species are sp, sp^2 and sp^3 respectively.

24. (a) NO has one unpaired electron with Nitrogen.

$$:\underset{\cdot}{N}::\underset{\cdot\cdot}{\overset{\cdot\cdot}{O}}:$$

25. (b)



$$^-O-\underset{\underset{\displaystyle O}{|}}{\overset{\cdot\cdot}{Cl}}-O$$

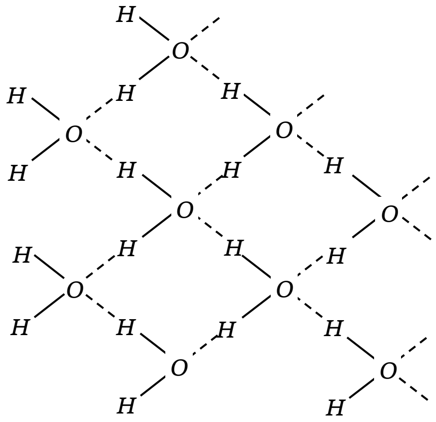
26. (b) Bond energy of Cl_2 is highest among all halogen molecule. Bond energies of F_2, Cl_2, Br_2, I_2 are 37, 58, 46 and 36 $Kcal\ mol^{-1}$ respectively.

27. (c) O_2^{2-} have bond order one

$$\text{B.O.} = \frac{1}{2}[10-8] = \frac{2}{2} = 1.$$

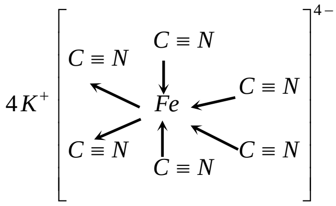
28. (b) Electron lost from antibonding π orbital.

29. (a) In ice each water molecule forms four hydrogen bond through which each water molecule is tetrahedrally attached with other water molecule.



30. (c) Hydrogen bonding is present in molecules which have F, O, or N atoms.

31. (d) Structure of $K_4[Fe(CN)_6]$ is



32. (c) Sodium cyanide contain ionic, covalent and coordinate bond.