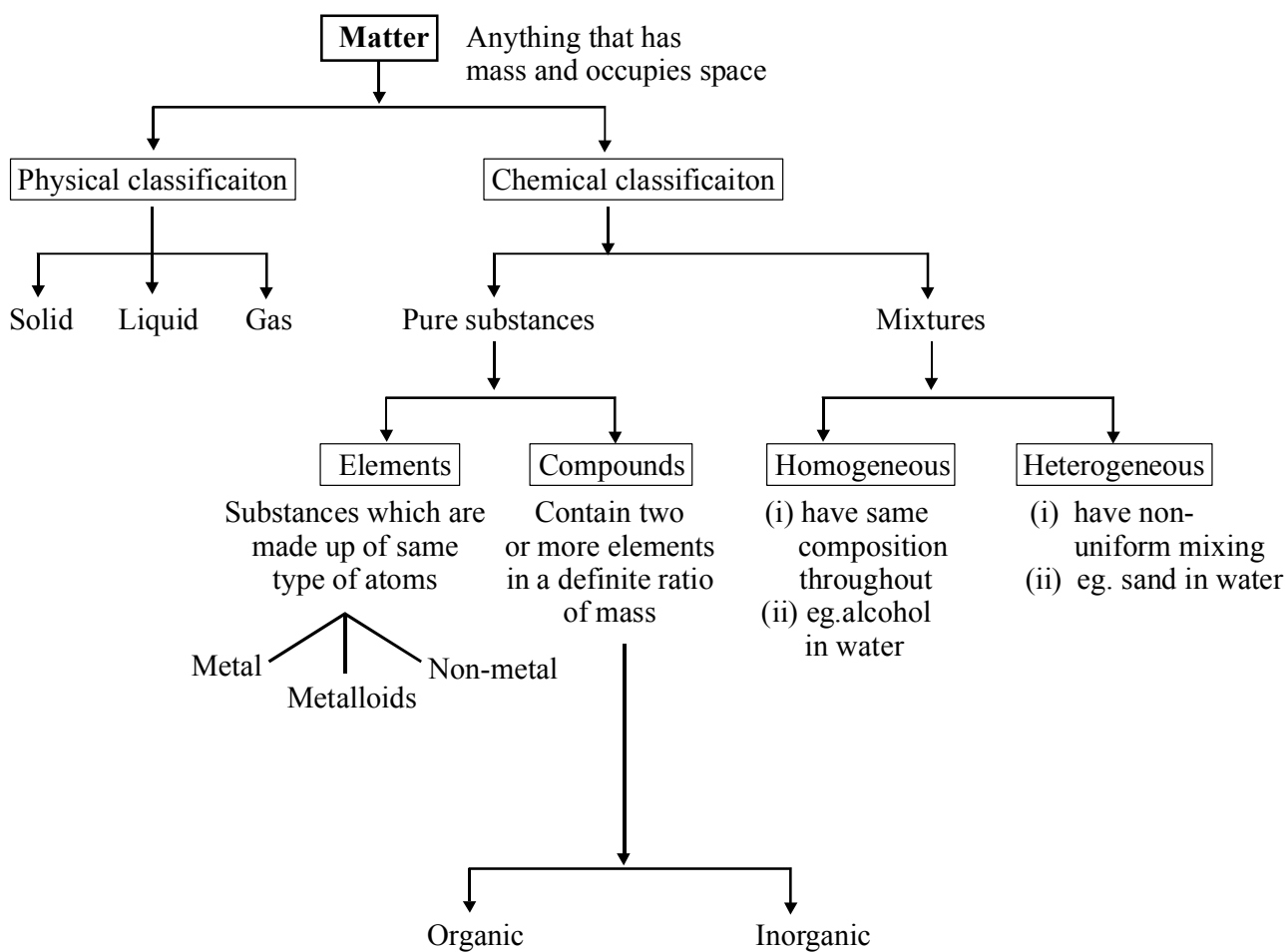


QUANTUM NUMBER & ELECTRONIC CONFIGURATION

MATTER & ITS CLASSIFICATION



Example.1 Which of the following is homogeneous mixture :

- (A) Oil + Water (B) Milk
(C) Salt dissolved in water (D) All of these

Example.2 Which of the following molecule is tetra-atomic :

- (A) CH_2Cl_2 (B) NH_3 (C) H_2O (D) Both (B) and (C)

ATOM : An atom is the smallest particle of an element (made up of still smaller particle like electrons, protons, neutrons etc.) which can take part in a chemical reaction. It may or may not exist free in nature.

Name of particle	Mass	Nature of charge	Amount of charge	Presence in the atom
(i) Electron symbol = (e) Notation = ${}_{-1}\text{e}^{\circ}$ Discoverer J.J. Thomson (1897)	$9.11 \times 10^{-28} \text{ g}$ $\frac{1}{1837}$ th of H-atom	Negatively charged	-1.602×10^{-19} Coulomb or $-4.8 \times 10^{-10} \text{ e.s.u}$	Outside the nucleus
(ii) Proton symbol = (p) Notation = $({}_1\text{H}^1)$ Discoverer Rutherford (1911)	$1.6725 \times 10^{-24} \text{ g}$	Positively charged	$+ 1.602 \times 10^{-19}$ coulomb $+ 4.8 \times 10^{-10} \text{ e.s.u.}$	Inside the nucleus of an atom
(ii) Neutron symbol = (n) Notation = $({}_0\text{n}^1)$ Discoverer J. Chadwick (1932)	$1.675 \times 10^{-24} \text{ g}$	Neutral	0	Inside the nucleus of an atom

Representation of atom : ${}_Z\text{X}^A$

A → Mass number : (total number of protons + total number of neutrons present in an atom.)

Z → Atomic number : (total number of protons present in an atom.)

⇒ **Isotope** : Atoms of given element which have same atomic number but different mass number are called isotope : e.g. ${}_1\text{H}^1$, ${}_1\text{H}^2$, ${}_1\text{H}^3$ etc.

⇒ **Isobar** : Atoms of different elements with the same mass number but different atomic number .
e.g. ${}_{18}\text{Ar}^{40}$, ${}_{19}\text{K}^{40}$ and ${}_{20}\text{Ca}^{40}$

⇒ **Iso-electronic species** : Species (atom, molecules or ions) having same number of electrons are called iso-electronic e.g. H^- , He, Li^+ and Be^{2+} have 2 valence electrons each.

Note : Now a days this concept is extended to consider the same valence shell electron also.

⇒ **Iso-sters** : Species having same number of electrons & same number of atoms. eg. N_2O , CO_2

⇒ **Iso-diaphers** : Species having same difference in number of neutrons and protons or same number of excess of neutron. eg. $^{19}_9\text{F}$, $^{23}_{11}\text{Na}$

⇒ **Orbital** : An orbital is defined as that zone in space where electron is most likely to be found. The orbitals are characterized by a set of 3 quantum numbers (n, l, m).

QUANTUM NUMBERS : Quantum numbers give complete information about an electron or orbital in an atom.

1. Principal Quantum number (n) :

- Permissible value of **n** → 1 to ∞
- It represents shell number/energy level
- The energy states corresponding to different principal quantum numbers are denoted by letters K, L, M, N etc.

n	:	1	2	3	4	5	6
Designation of shell	:	K	L	M	N	O	P

- It indicates the distance of an electron from the nucleus.
- It also determines the energy of the electron. In general higher the value of 'n', higher is the energy of a electron.
- It give an idea of total number of orbitals & electron (which may) present in a shell & that equal to **n²** & **2n²** respectively.

2. Azimuthal Quantum number (l) :

- The values of **l** depends upon the value of 'n' and possible values are '0' to (n-1) .
- It gives the name of subshells associated with the energy level and number of subshells within an energy level.
- The different value of 'l' indicates the shape of orbitals and designated as follows :

Value	Notation	Name	Shape
$l = 0$	s	Sharp	Spherical
$l = 1$	p	Principal	Dumbell
$l = 2$	d	Diffused	Double Dumbell
$l = 3$	f	Fundamental	Complex

- It also determines the energy of orbital along with n.
For a particular energy level/shell energy of subshell is in the following order → **s < p < d < f**
- It gives the total number of orbitals in a subshell & that equals to **(2l + 1)** and number of electron in a subshell = **2(2l + 1)**

3. Magnetic Quantum number (m or m_l) :

- (i) The value of m depends upon the value of l and it may have integral value $-l$ to $+l$ including zero.
- (ii) It gives the number of orbitals in a given subshell and orientation of different orbitals in space.
e.g. for $n = 4$, $l = 0$ to 3 .

l	0	1	2	3
m	0	+1, 0, -1	+2, 1, 0, -1, -2	+3, +2, +1, 0, -1, -2, -3
Possible Orientation	1	3	5	7
Orbitals	s	p_x, p_y, p_z	$d_{z^2}, d_{x^2-y^2}$ d_{xy}, d_{yz}, d_{xz}	Not in syllabus

- (iii) The orbitals having same value of n and l but different value of m , have same energy in absence of external electric & magnetic field. These orbitals having same energy of a particular subshell is known as Degenerate orbitals.

4. Spin Quantum number (s) OR magnetic spin quantum number (m_s) :

- (i) While moving around the nucleus, the electron always spins about its own axis either clockwise or anticlockwise. The magnetic spin quantum number represents the direction of electron spin (rotation) around its own axis (clockwise or anticlockwise).
- (ii) There are two possible values of m_s are $+\frac{1}{2}$ & $-\frac{1}{2}$ and represented by the two arrows \uparrow (spin up) and \downarrow (spin down).

RULES FOR FILLING ELECTRONS :

1. Pauli's exclusion principle

'No two electrons in an atom can have same values of all the four quantum numbers.

An orbital accommodates two electron with opposite spin. These two electrons have same values of principal, azimuthal and magnetic quantum number but the fourth, i.e. magnetic spin quantum number will be different. i.e.

For K, shell ($n = 1$)

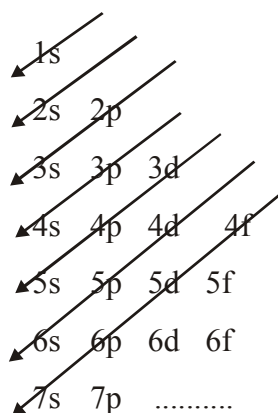
$$l = 0, m = 0$$

For 1st Electron $n = 1, l = 0, m = 0, m_s = +\frac{1}{2}$

For 2nd Electron $n = 1, l = 0, m = 0, m_s = -\frac{1}{2}$

2. Aufbau Principle (Means Building up) :

The electrons are added progressively to the various orbitals in the order of increasing energies starting with the orbital of the lowest energy



$$1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f < 6d < 7p$$

Alternatively, the order of increase of energy of orbitals can be calculated from $(n + l)$ rule.

- (i) Lower the value of $(n + l)$ for an orbital, the lower will be its energy.
- (ii) If two orbitals have the same $(n + l)$ value, then orbital with lower value of n has the lower energy.

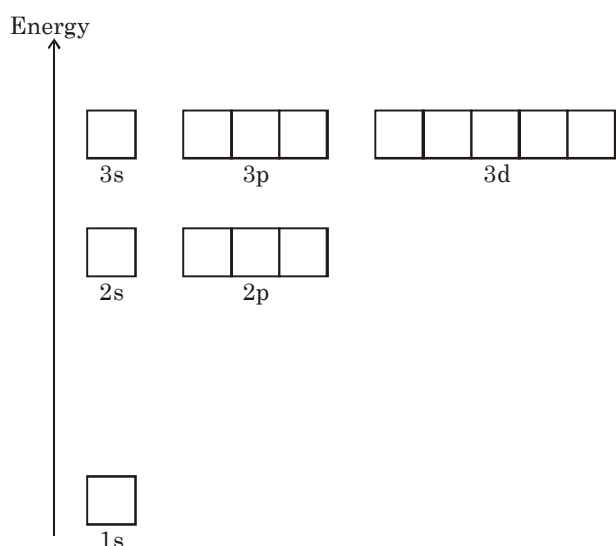
e.g. $2p$ & $3s$

For $2p$, $n = 2$, $l = 1$, $(n + l) = 2 + 1 = 3$

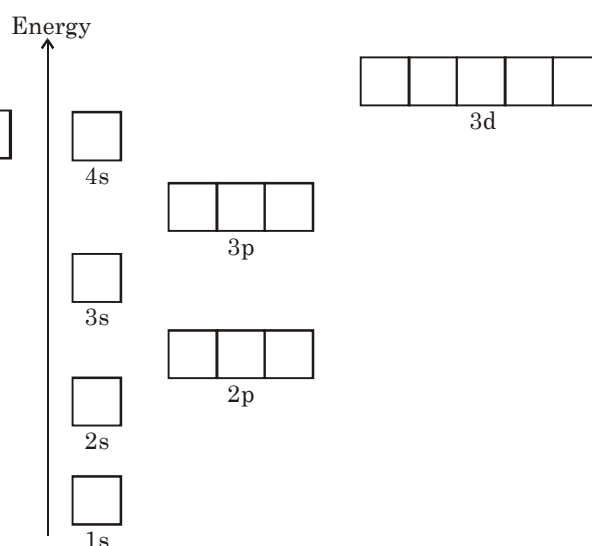
For $3s$, $n = 3$, $l = 0$, $(n + l) = 3 + 0 = 3$

Then for $2p$, n is lesser than for $3s$, so $2p$ has lower energy than $3s$.

- (iii) $1s < 2s = 2p < 3s = 3p = 3d < 4s = 4p = 4d = 4f \dots$ energy order of different orbitals for single electron system like H , He^+ , Li^{+2} etc.



(A) For single electron or hydrogenic atom



(B) Multi electronic atoms

Energy level diagram for few electronic shells :

Example.4 Write the increasing order of energies of 4s, 3p, 4p and 3d.

Ans. For 4s, $n = 4, l = 0, (n + l) = 4$
 For 3p, $n = 3, l = 1, (n + l) = 4$
 For 4p, $n = 4, l = 1, (n + l) = 5$
 For 3d, $n = 3, l = 2, (n + l) = 5$
 $\Rightarrow 3p < 4s < 3d < 4p$ increasing order

3. *Hund's rule of maximum multiplicity :*

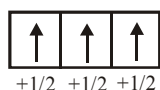
This rule deals with the filling of electrons into the orbitals belonging to the same subshell i.e. orbitals of equal energy, called degenerate orbitals.

“Electrons are distributed among the orbitals of a subshell in such a way as to give the maximum number of unpaired electron with parallel spins.”

“Pairing of electrons in the orbitals belonging to the same subshell (p, d, f) does not take place until each orbital belonging to that subshell has got one electron each i.e. singly occupied. Moreover, the singly occupied orbitals must have the electrons with the parallel spin multiplicity”

Multiplicity = $2|S| + 1$, where S = Total spin.

i.e.

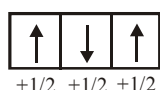


Find total spin & multiplicity

$$\text{Total spin } S = \frac{1}{2} + \frac{1}{2} + \frac{1}{2} = \frac{3}{2}$$

$$\text{Multiplicity} = 2 \times \frac{3}{2} + 1 = 4$$

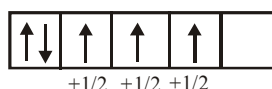
i.e.



$$\text{Total spin } S = \frac{1}{2} - \frac{1}{2} + \frac{1}{2} = \frac{1}{2}$$

$$\text{Multiplicity} = 2 \times \frac{1}{2} + 1 = 2$$

i.e.



$$\text{Total spin } S = \frac{1}{2} + \frac{1}{2} + \frac{1}{2} = \frac{3}{2}$$

$$\text{Multiplicity} = 2 \times \frac{3}{2} + 1 = 4$$

i.e.

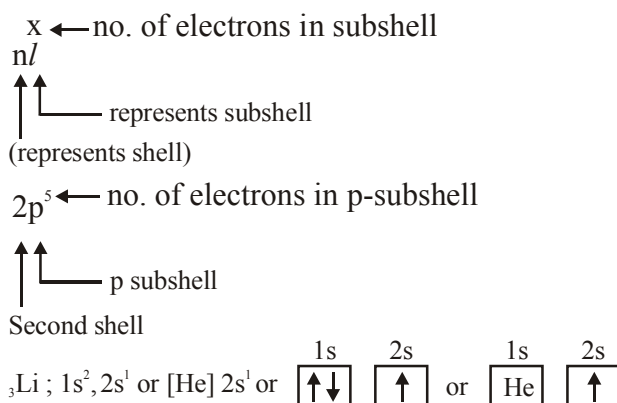


$$\text{Total spin} = 5 \times \frac{1}{2} = \frac{5}{2}$$

$$\text{Multiplicity} = 2 \times \frac{5}{2} + 1 = 6$$

ELECTRONIC CONFIGURATION OF ATOMS :

The distribution of electrons in various shells, subshells and orbitals, in an atom of an element, is called its electronic configuration.

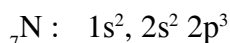


Electronic configuration :

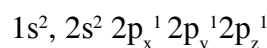
Example.5

Nitrogen

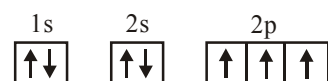
Ans.



[Orbital notation method]

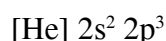


or



[Orbital diagram method]

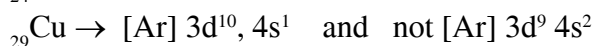
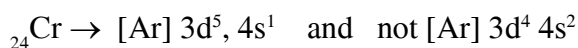
or



[Condensed form]

Extra stability of Half-filled and fully-filled orbitals.

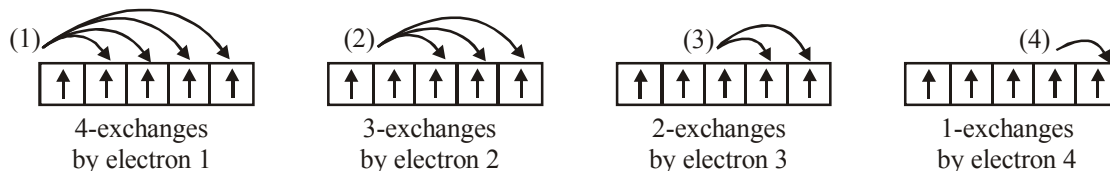
The electronic configuration of most of the atoms follows the Aufbau's rule. However, in certain elements such as Cr, Cu etc. Where the two subshells (4s and 3d) differ slightly in their energies ($4s < 3d$), an electron shifts from a subshell of lower energy (4s) to a subshell of higher energy (3d), provided such a shift results in all orbitals of the subshell of higher energy getting either completely filled or half-filled.



It has been found that there is extra stability associated with these electronic configuration. This stabilization is due to the following two factors.

- (i) **Symmetrical distribution of electron :** It is well known that symmetry leads to stability. The completely filled or half-filled subshell have symmetrical distribution of electron in them and are therefore more stable. This effect is more dominant in d and f-orbitals. This means three or six electrons in p-subshell, 5 or 10 electrons in d-subshell and 7 or 14 in f-subshell forms a stable arrangement.

- (ii) **Exchange energy** : This stabilizing effect arises whenever two or more electrons with the same spin are present in the degenerate orbitals of a subshell. These electrons tend to exchange their positions and the energy released due to this exchange is called exchange energy. The number of exchanges that can take place is maximum when the subshell is either half filled or fully filled. As a result the exchange energy is maximum and so is the stability.



Total exchange pairs = 10

$$\frac{n(n-1)}{2} \rightarrow \text{Number of exchange pairs}$$

$n \rightarrow$ Number of electron with parallel spins.



Exceptional electronic configuration

S.No.	Element	Z	Configuration
1	Cr	24	[Ar]4s ¹ 3d ⁵
2.	Cu	29	[Ar]4s ¹ 3d ¹⁰
3.	Nb	41	[Kr]5s ¹ 4d ⁴
4.	Mo	42	[Kr]5s ¹ 4d ⁵
5.	Ru	44	[Kr]5s ¹ 4d ⁷
6.	Rh	45	[Kr]5s ¹ 4d ⁸
7.	Pd	46	[Kr]4d ¹⁰
8.	Ag	47	[Kr]5s ¹ 4d ¹⁰
9.	La	57	[Xe]6s ² 5d ¹
10.	Pt	78	[Xe]6s ¹ 4f ¹⁴ 5d ⁹
11.	Au	79	[Xe]6s ¹ 4f ¹⁴ 5d ¹⁰
12.	Ac	89	[Rn]7s ² 6d ¹
13.	Th	90	[Rn]7s ² 6d ²

MAGNETIC PROPERTIES :

❖ Paramagnetism :

- The substances which are weakly attracted by magnetic field are paramagnetic and this phenomenon is known as paramagnetism.
- Their magnetic character is retained till they are in magnetic field and lose their magnetism when removed from magnetic field.

❖ Diamagnetism :

- The substances which are weakly repelled by magnetic field are diamagnetic and this phenomenon is known as diamagnetism.
- Diamagnetic substances lack unpaired electrons and their spin magnetic moment is zero e.g., NaCl, N₂O₄ etc.

❖ Spin magnetic moment :

The spin magnetic moment of electron (excluding orbit magnetic moment) is given by :

$$\mu = \sqrt{n(n+2)} \text{ B.M.}$$

Where n is number of unpaired electron in species.

The magnetic moment is expressed in Bohr magneton (B.M.)

Example.6 A compound of vanadium has magnetic moment of 1.73 BM. Work out the electronic configuration of vanadium ion in the compound.

Ans. Vanadium belongs to 3d series with Z = 23. The magnetic moment of 3d series metal is given by spin only formula.

$$\mu = \sqrt{n(n+2)} \text{ BM (BM = Bohr's magneton)}$$

$$\therefore 1.73 = \sqrt{3}$$

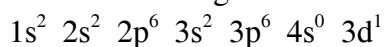
$$\Rightarrow n(n+2) = 3 \Rightarrow n = 1$$

\Rightarrow Magnetic moment correspond to one unpaired electron.

\Rightarrow Electronic configuration of vanadium atom 1s² 2s² 2p⁶ 3s² 3p⁶ 4s² 3d³.

For one unpaired electron 4 electron must be removed in which first 2 electron are lost from 4s orbital (outermost).

Electronic configuration of V⁴⁺



Nodal Planes of different orbitals :

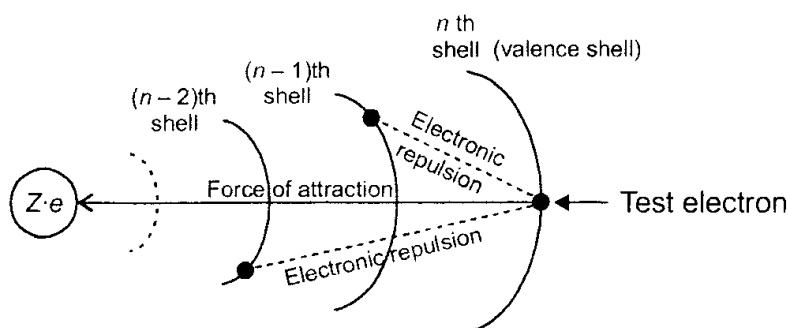
Nodal plane is a plane at which the probability of finding an electron becomes zero.

eg.	Orbital	Nodal plane	Orbital	Nodal plane
	s	None	d _{xy}	XZ & YZ planes
	p _x	YZ plane	d _{yz}	XZ & XY planes
	p _y	XZ plane	d _{xz}	XY & YZ planes
	p _z	XY plane	d _{x²-y²}	Planes perpendicular to XY plane, passing through origin (nucleus) and inclined at 45° to X & Y axis.
			d _{z²}	None (two nodal cones are available)

SCREENING EFFECT (σ) AND EFFECTIVE NUCLEAR CHARGE (Z_{eff})

- Valence shell electron suffer force of attraction due to nucleus and force of repulsion due to inner shell electrons.
- The decrease in force of attraction on valence electron due to inner shell electron is called screening effect or shielding effect. (i.e. total repulsive force is called shielding effect.)
- Due to screening effect, valence shell electron experiences less force of attraction by nucleus.
- Due to screening effect, net attractive force felt by the electron is measured by effective nuclear charge, Z_{eff}
- If nuclear charge = Z , then effective nuclear charge = $Z - \sigma$ (Where σ 'sigma' is called screening constant/shielding constant)

$$\text{So, } Z_{\text{eff}} = Z - \sigma$$



CALCULATION OF σ (using Slater's rule)

To calculate the shielding constant (σ) :

- Write the electronic configuration of the element in the following order and groupings :
(1s), (2s, 2p), (3s, 3p), (3d), (4s, 4p), (4d), (4f), (5s, 5p), etc.

For s and p electrons :

- Electrons in any group to the right of the (ns, np) group contribute nothing to the shielding constant.
(n-shell no. of the electron for which σ is calculated)
- All of the other electrons in the (ns, np) group, shield the concern electron to an extent of 0.35 each. (Except for the 1s orbital for which value is 0.30).
- All electrons in the (n - 1) shell shield to an extent of 0.85 each.
- All electrons (n - 2) or lower group shield completely ; that is, their contribution is 1.00 each.

For d and f electrons :

- Electrons in any group to the right of the nd or nf group contribute nothing to the shielding constant.
- All the other electrons in the nd or nf group, shield the valence electron to an extent of 0.35 each.
- All electrons in groups lying to the left of the nd or nf group contribute 1.00.

(Effective Nuclear charge of elements of second period)						
Element	Electronic Configuration	Z	σ of ns & np electron	σ (n-1) orbital	Total Screening Constant	Effective nuclear charge#
			(a)	(b)	(a + b)	$Z^* = Z - \sigma$
${}_3\text{Li}$	$1s^2 2s^1$	3	—	$0.85 \times 2 = 1.70$	1.70	1.30
${}_4\text{Be}$	$1s^2, 2s^2$	4	$1 \times 0.35 = 0.35$	$0.85 \times 2 = 1.70$	2.05	1.95
${}_5\text{B}$	$1s^2, 2s^2, 2p^1$	5	$2 \times 0.35 = 0.70$	$0.85 \times 2 = 1.70$	2.40	2.60
${}_6\text{C}$	$1s^2, 2s^2, 2p^2$	6	$3 \times 0.35 = 1.05$	$0.85 \times 2 = 1.70$	2.75	3.25
${}_7\text{N}$	$1s^2, 2s^2, 2p^3$	7	$4 \times 0.35 = 1.40$	$0.85 \times 2 = 1.70$	3.10	3.90
${}_8\text{O}$	$1s^2, 2s^2, 2p^4$	8	$5 \times 0.35 = 1.75$	$0.85 \times 2 = 1.70$	3.45	4.55
${}_9\text{F}$	$1s^2, 2s^2, 2p^5$	9	$6 \times 0.35 = 2.10$	$0.85 \times 2 = 1.70$	3.80	5.20

Calculated for valence electron.

Key Points :

- From left to right in a period Z_{eff} increases
- For s and p-block elements, Z_{eff} in a period increases by 0.65 where atomic number increases by 1, and hence atomic size decreases considerably.
- In transition series Z increase by + 1 but screening constant increases by 0.85 So Z_{eff} is increased by 0.15
($1 - 0.85 = 0.15$) [Because e^- enters in (n - 1) orbit which has value of $\sigma = 0.85$]
- From top to bottom in a group Z_{eff} remain constant for s-block elements, after Li and Be.

Element	Li	Na	K	Rb	Cs	Fr
Z_{eff}	1.30	2.20	2.20	2.20	2.20	2.20

Example-7 :

What is the effective nuclear charge at the periphery of nitrogen atom when an extra electron is added during the formation of an anion. Also find the value of Z_{eff} when the atom is ionized to N^+ .

Ans. Ground state electron configuration of $\text{N}(Z = 7) = 1s^2 2s^2 2p^3$

Electron configuration of $\text{N}^- = (1s^2) (2s^2 2p^4)$

Shielding constant for the last 2p electron,

$$\sigma = [(2 \times 0.85) + (5 \times 0.35)] = 3.45$$

$$\text{So } Z_{\text{eff}} = Z - \sigma = 7 - 3.45 = 3.55$$

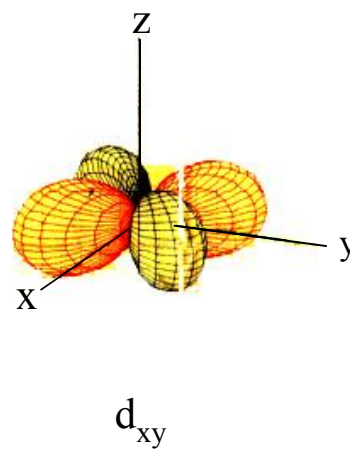
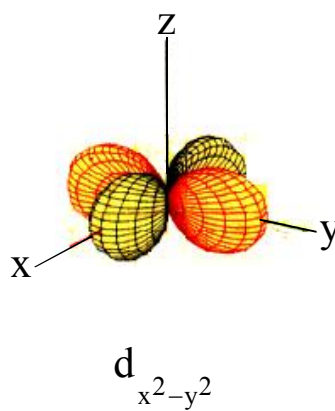
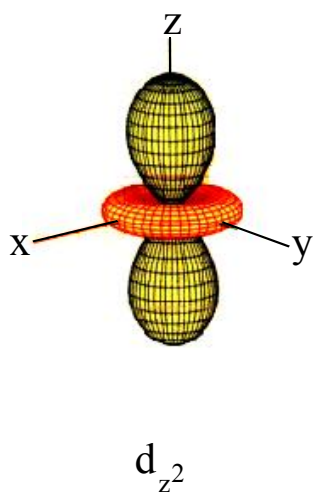
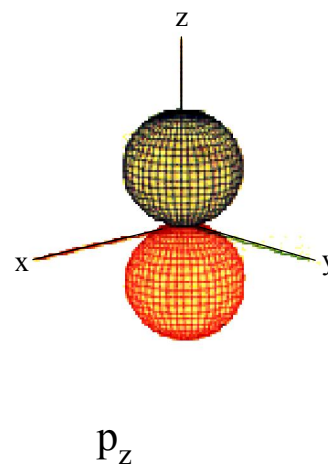
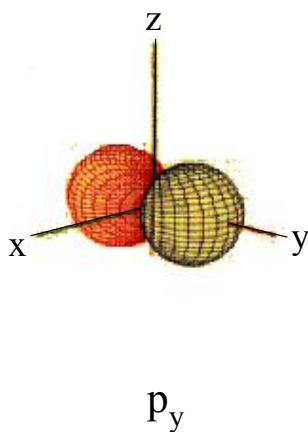
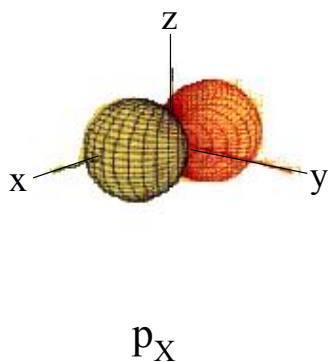
Electron configuration of $\text{N}^+ = (1s^2) (2s^2 2p^2)$

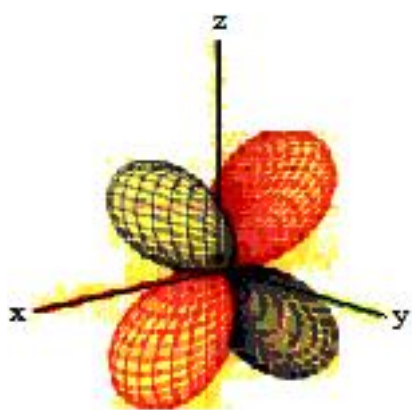
Shielding constant for the last 2p electron,

$$\sigma = [(2 \times 0.85) + (3 \times 0.35)] = 2.75$$

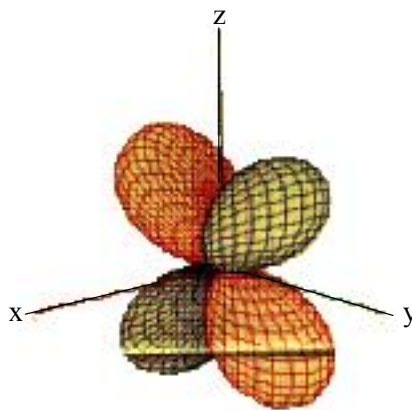
$$\text{So } Z_{\text{eff}} \text{ for last electron on } \text{N}^+ = 7 - 2.75 = 4.25$$

SHAPES OF ATOMIC ORBITALS

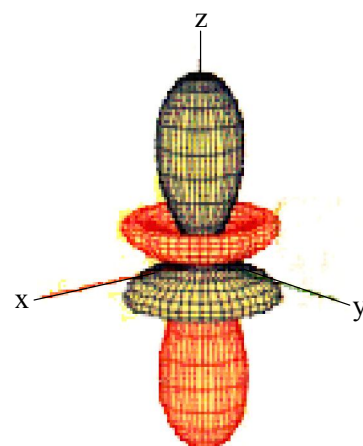




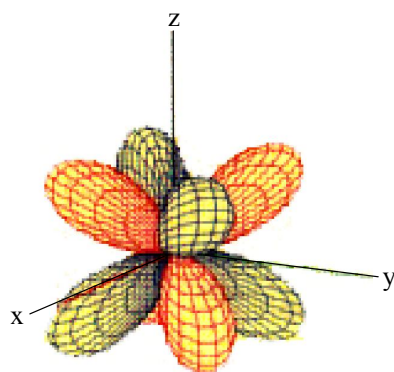
d_{xz}



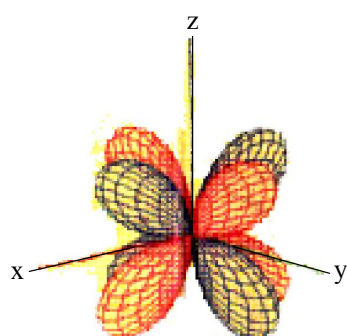
d_{yz}



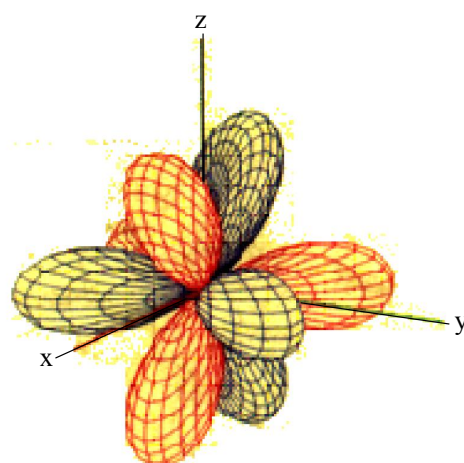
f_{z^3}



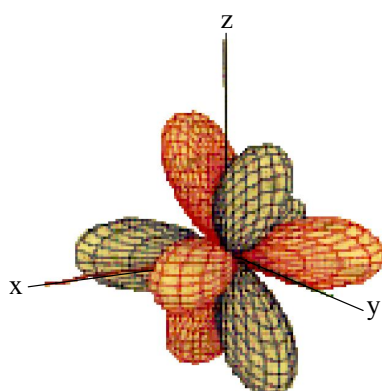
f_{xyz}



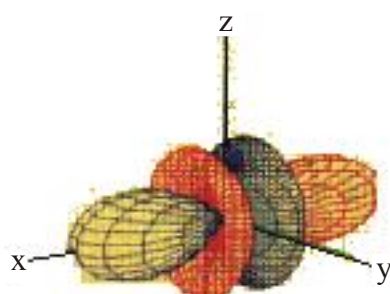
$f_{z(x^2-y^2)}$



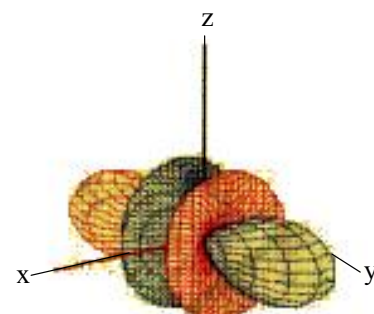
$f_{x(y^2-z^2)}$



$f_{y(z^2-x^2)}$



f_{x^3}



f_{y^3}

EXERCISE # O-1

General Introduction :

- The total number of neutrons in dipositive zinc ion with mass number 70 is
(A) 34 (B) 40 (C) 36 (D) 38 QN0001
- It is known that atom contain protons, neutrons and electrons. If the mass of neutron is assumed to half of its original value where as that of proton is assumed to be twice of its original value then the atomic mass of $^{14}_6\text{C}$ will be -
(A) same (B) 25% more (C) 14.28 % more (D) 28.5% less QN0002
- Two monoatomic cations x^{\oplus} and y^{2+} are isoelectronic then select the correct statement : (Both elements are consecutive)
(A) Both element x and y have same number of electrons
(B) Total number of valence electrons are more in element x, than element 'y'
(C) Total number of valence electrons are more in element y, than element 'x'
(D) Both (A) and (B) are correct QN0003
- Which of the following sets contain only isoelectronic ions?
(A) Zn^{2+} , Ca^{2+} , Ga^{3+} , Al^{3+} (B) K^+ , Ca^{2+} , Sc^{3+} , Cl^-
(C) P^{3-} , S^{2-} , Cl^- , Zn^{+2} (D) Ti^{4+} , Ar , Cr^{3+} , V^{5+} QN0004

Quantum number

- Which quantum number will determine the shape of the orbital
(A) Principal quantum number (B) Azimuthal quantum number
(C) Magnetic quantum number (D) Spin quantum number QN0005
- In Palladium (Atomic no.—46), number of electron having ($\ell = 2$) will be -
(A) 20 (B) 18 (C) 16 (D) 22 QN0006
- For an electron present in which of the following orbital for which ($n + l + m + s$) value is maximum. Consider maximum possible value for 'm' and minimum possible value of m_s (where ever applicable).
(A) 3p (B) 5p (C) 4d (D) 5s QN0007
- Choose the correct option for the quantum numbers of the last electron of K^+ .
(A) 4, 0, 0, $+1/2$ (B) 3, 1, -1 , $-1/2$ (C) 4, 1, 0, $-\frac{1}{2}$ (D) 3, 0, 1, $\frac{1}{2}$ QN0008
- Find the sum of maximum number of electrons having $+1$ and -1 value of 'm' in Ti (Atomic number = 22)
(A) 6 (B) 8 (C) 10 (D) 12 QN0009

10. The number of electrons in Ca having minimum value of $\left| \frac{n}{\ell \times m_\ell} \right|$ is.

(Consider only non-zero values of ℓ and m)

- (A) 6 (B) 3 (C) 4 (D) None of these

QN0010

Electronic Configuration

11. A neutral atom of an element has two K, eight L, nine M and two N electrons then electronic configuration of the element is

- (A) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^1$ (B) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1 4s^2$
(C) $1s^2 2s^2 2p^6 3s^2 3d^2 3p^6 4s^1$ (D) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$

QN0011

12. The explanation for the presence of three unpaired electrons in the nitrogen atom can be given by

- (A) Pauli's exclusion principle (B) Hund's rule
(C) Aufbau's principle (D) Uncertainty principle

QN0012

13. If the nitrogen atom had electronic configuration $1s^7$, it would have energy lower than that of normal ground state configuration $1s^2 2s^2 2p^3$, because the electrons would be closer to the nucleus. Yet $1s^7$ is not observed because it violates :—

- (A) Uncertainty principle (B) Hund's rule
(C) Pauli's exclusion principle (D) Bohr postulate of stationary orbits

QN0013

Effective Nuclear charge (Z_{eff}) :

14. The Z_{eff} for (as Slater's rule)

3d electron of Cr

4s electron of Cr

3d electron of Cr^{3+}

3s electron of Cr^{3+} are in the order respectively

- (A) 4.6, 2.95, 4.95, 8.05 (B) 4.95, 2.95, 4.6, 8.05
(C) 4.6, 2.95, 5.3, 12.75 (D) none of these

QN0014

15. Total number of possible shells in uranium atom (atomic no. $z = 92$)

- (A) 7 (B) 1 (C) 6 (D) None of these

QN0015

16. Which of the following has the maximum number of unpaired electrons ?

- (A) Mg^{2+} (B) Ti^{3+} (C) V^{3+} (D) Fe^{2+}

QN0016

17. Gaseous state electronic configuration of nitrogen atom can be represented as :

- (A) $\uparrow\downarrow \uparrow\downarrow \uparrow \uparrow \uparrow$ (B) $\uparrow\downarrow \uparrow\downarrow \uparrow \downarrow \uparrow$
(C) $\uparrow\downarrow \uparrow\downarrow \uparrow \downarrow \downarrow$ (D) $\uparrow\downarrow \uparrow\downarrow \downarrow \downarrow \uparrow$

QN0017

EXERCISE # O-2

General Introduction :

1. Isotones are :
 (A) The atoms of different elements
 (B) Have same number of neutrons
 (C) Have same number of (neutrons + protons)
 (D) Have same difference of mass number and atomic number

QN0018

Quantum number

2. For an electron present in which of the following orbital for which $(n + l)$ value is maximum.
 (A) 3p (B) 5p (C) 4d (D) 5s
3. Correct set of four quantum numbers for valence electron of rubidium ($Z = 37$) is

QN0019

- (A) $5, 0, 0, +\frac{1}{2}$ (B) $5, 0, 0, -\frac{1}{2}$ (C) $5, 1, 1, +\frac{1}{2}$ (D) $6, 0, 0, +\frac{1}{2}$

QN0020

4. The correct set of quantum numbers for the unpaired electron of chlorine atom is

- | | n | ℓ | m | | n | ℓ | m |
|-----|-----|--------|-----|-----|-----|--------|-----|
| (A) | 2 | 1 | 0 | (B) | 2 | 1 | 1 |
| (C) | 3 | 1 | 1 | (D) | 3 | 1 | 0 |

QN0021

5. Which of the following sets of quantum numbers represent an impossible arrangement ?

- | | n | ℓ | m | m_s | | n | ℓ | m | m_s |
|-----|-----|--------|-----|---------------|-----|-----|--------|-----|---------------|
| (A) | 3 | 3 | -2 | $\frac{1}{2}$ | (B) | 4 | 0 | 0 | $\frac{1}{2}$ |
| (C) | 3 | 2 | -3 | $\frac{1}{2}$ | (D) | 5 | 3 | 0 | $\frac{1}{2}$ |

QN0022

6. The quantum numbers for the 19th electron of Cr ($Z = 24$) are

- (A) $n = 3, \ell = 0, m = 0, m_s = +\frac{1}{2}$ (B) $n = 4, \ell = 0, m = 0, m_s = +\frac{1}{2}$
 (C) $n = 3, \ell = 2, m = 2, m_s = +\frac{1}{2}$ (D) $n = 4, \ell = 0, m = 0, m_s = -\frac{1}{2}$

QN0023

7. The maximum number of electron having $n \times \ell \times m = 0$ in Zn^{2+} is equal to the -

- (A) Atomic number of Mg
 (B) 12
 (C) Total number of electron in Zn which have $n + \ell = 0$
 (D) 'p' electrons in Ar

QN0024

Electronic Configuration

8. The species which have same number of electrons in outer most and penultimate shell -
 (A) Ca (B) Ar (C) V^{+3} (D) Sc^{3+} QN0025
9. Which sub-shell fill completely before the 4f?
 (A) 6s (B) 5p (C) 5d (D) 4d QN0026
10. The electronic configuration of a carbon atom is $1s^2, 2s^2, 2p^2$ and consider the following four arrangements of the 2p electrons. Which arrangement have lowest energy ?
 (A)

$\uparrow\downarrow$		
----------------------	--	--

 (B)

\uparrow	\uparrow	\downarrow
------------	------------	--------------

 (C)

\uparrow	\uparrow	
------------	------------	--

 (D)

\uparrow		\uparrow
------------	--	------------

QN0027
11. Hund's rule is applicable for :-
 (A) d-subshell (B) p-subshell (C) s-subshell (D) f-subshell QN0028
12. Which of the following has maximum number of unpaired electron.
 (A) Fe (B) Fe (II) (C) Fe (III) (D) Mn (II) QN0029
13. $Mn (Z = 25) = 1s^3 1p^9 2s^3 2p^9 2d^1$
 Which of the following change is required so that Mn have above ground state electronic configuration :
 (A) Change in the value of ℓ (azimuthal quantum number) for any subshell
 (B) Change in the possible values of ℓ (azimuthal quantum number)
 (C) Change in the Pauli rule
 (D) Change in the $(n + \ell)$ rule QN0030
14. The number of d- electrons in Mn^{2+} is equal to that of
 (A) p-electrons in N (B) s-electron in Na
 (C) d-electrons in Fe^{+3} (D) p-electrons in O^{-2} QN0031
15. Select incorrect statement(s) :
 (A) d_{z^2} orbital has different shape from rest of all d-orbitals
 (B) For the formation of cation electrons are always removed from 4s.
 (C) Zinc is a p-block element.
 (D) Principal quantum number depend upon the value of azimuthal quantum number QN0032

EXERCISE # S-1

Integer Answer Type (0 to 9) :

1. Find total no. of orbitals in nickel which have $|m| \leq 1$ and at least one electron is present, where 'm' is magnetic quantum number.

(Given your ans. as sum of digits for example. If your ans is 57 then $5 + 7 = 12$ and $1 + 2 = 3$)

QN0033

2. Minimum number of electrons having $m_s = \left(-\frac{1}{2}\right)$ in Cr is "_____".

QN0034

3. How many elements are possible for the Ist period of periodic table if azimuthal quantum number can have integral values from 0 to $(n + 1)$. [n = shell number & other rules are remaining same to form periodic table.

QN0035

4. Find number of unpaired electrons when Fe does not follow $(n + \ell)$ rule and filling of electron takes place shell after shell and Hund's rule is also not obeyed.

QN0036

5. Find the maximum number of electrons having same Z_{eff} value for sulphur atom

QN0037

6. Find the sum of maximum unpaired e^- present in one 5g & one 6g orbital.

QN0038

7. Find out the maximum number of electrons that can involve in the shielding of an electron, having quantum numbers : $n = 2, \ell = 1, m = 0, m_s = +\frac{1}{2}$, in an atom.

QN0039

8. Find the sum of minimum and maximum possible value of x in Fe^{+x} ion, if magnetic moment of $\text{Fe}^{+x} = 4.89$ B.M.

QN0040

EXERCISE # S-2

Paragraph for Question 1 to 3

The general electronic configuration of outer most and penultimate shell is given as $(n-1)s^2 (n-1)p^6 (n-1)d^x ns^2$. Then for an element with $n = 4$ and $x = 6$.

1. The number of protons present in the divalent cation of the element of above configuration is :-
 (A) 24 (B) 25 (C) 26 (D) 27

QN0041

2. The element is :
 (A) Mn (B) Fe (C) Co (D) Li

QN0041

3. The number of unpaired electrons in the divalent cation of the given element in isolated gaseous state is :-
 (A) 0 (B) 3 (C) 4 (D) 1

QN0041

Paragraph for Question 4 & 5

Consider a hypothetical atom where $p_x, p_y, p_z, d_{xy}, d_{xz}, d_{yz}$ and $d_{x^2-y^2}$ orbitals are present for principal quantum number $n = 4$.

4. Find the number of other orbital which lobes are fully present in the nodal plane of p_x orbital :-
 (A) 2 (B) 4 (C) 3 (D) 5

QN0042

5. Which of the following orbitals lobe is not present at all either in the nodal plane of p_x orbital or in the nodal plane of p_y orbital.
 (A) d_{xy} (B) d_{yz} (C) $d_{x^2-y^2}$ (D) p_z

QN0042

Paragraph for Question 6 & 7

Isotopes, Isobars and Iso-diaphers are some basic definitions related to the atom, which are based upon the variation in no. of electron, proton or neutrons.

6. Which of the following pair represents the Isobar species :-
 (A) ${}_{18}\text{Ar}^{40}, {}_6\text{C}^{12}$ (B) ${}_8\text{O}^{16}, {}_7\text{N}^{14}$ (C) $\text{N}_2\text{O}, \text{CO}_2$ (D) None of these

QN0043

7. Which of the following pair is correct for isosters :-
 (A) $\text{N}_2\text{O}, \text{CH}_4$ (B) $\text{N}_2\text{O}, \text{CO}_2$ (C) CO_2, SO_2 (D) $\text{N}_2\text{O}, \text{HOCl}$

QN0043

- | | | |
|----|-----------------------------------|--|
| 8. | Column-I
Element | Column-II
Max. value of n and ℓ respectively ; consider filled subshell only |
| | (P) P | (1) 6, 2 |
| | (Q) N | (2) 3, 1 |
| | (R) Pb | (3) 6, 3 |
| | (S) Cs | (4) 2, 1 |

Code :

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

QN0044

9. Match the following:

Column-I

- (P) Same number of unpaired electrons are present in (excluding zero)
 (Q) Same number of electrons in s & p subshells.
 (R) Same number of electrons with the $l = 1$
 (S) Same number of total electrons

Column-II

- (1) Na^+ , Mg^{2+} , F^-
 (2) F^- , Mg , O^{2-}
 (3) Mg , Ne , O^{2-}
 (4) Li , Na , K

Code :

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

QN0045

10. Match the following :

Column-I (Orbital)

- (P) s
 (Q) p_x
 (R) d_{xy}
 (S) $d_{x^2-y^2}$

Column-II (Property)

- (1) Have electron density at all three axes
 (2) YZ plane is nodal plane
 (3) dumbell shape
 (4) have azimuthal quantum no. $\ell = 2$

Code :

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

QN0046

Match The Column :

11. Match the following :

Column-I (e^- configuration)

- (A) d^8
 (B) d^{10}
 (C) d^6
 (D) d^5

Column-II (Property)

- (P) Symmetrical distribution
 (Q) Unsymmetrical distribution
 (R) No of exchange pair are maximum among these
 (S) two electrons must be present in $d_{x^2-y^2}$ orbital
 (T) at least one electron is present in orbital having $m = -1$

QN0047

12. Column-I

- (A) Zn^{2+}
(B) Ga^+
(C) Fe^{3+}
(D) Br^-

Column-II

- (P) Diamagnetic
(Q) Spin magnetic moment = $\sqrt{35}$ BM
(R) 18 e^- in outer most shell
(S) 3d subshell is fully filled
(T) All the orbital of outer most shell are fully filled

QN0048

MATCHING LIST TYPE 1 × 3 Q. (THREE LIST TYPE Q.)

Column - I	Column - II	Column - III
(A) Paramagnetic set	(i) $\text{Na}^+, \text{Mg}^{+2}, \text{F}^-$	(P) same value of principal quantum number for last electron
(B) Isoelectronic set	(ii) Li, Na, K	(Q) The non zero number(s) of $e^-(s)$ for $n = 3$ and $\ell \geq 1$ is
(C) The set for which value(s) of spin multiplicity is ≥ 1	(iii) $\text{Fe}^{+3}, \text{Co}^{+2}, \text{Ni}^{+2}$	(R) The value of " m_s " must be $+\frac{1}{2}$ for last electron
(D) The set of elements belongs to same period in periodic table	(iv) $\text{S}^{+2}, \text{Cl}^-, \text{P}^{-3}$	(S) Set for which the value of $m = \pm 2$ is possible for electron(s)

13. Which one of the following options is the **CORRECT** combination?

- (A) (A, i, P) (B) (B, iv, S) (C) (D, iii, S) (D) (C, iii, R)

QN0049

14. Which one of the following options is the **INCORRECT** combination?

- (A) (A, iii, P) (B) (C, ii, P) (C) (B, i, P) (D) (B, iv, Q)

QN0049

15. Which one of the following options is the **CORRECT** set of species with number of nodal planes for filled/partially filled orbitals is ≤ 1 for all given species in set?

- (A) (B, ii, R) (B) (B, iv, P) (C) (A, i, Q) (D) (D, iii, S)

QN0049

EXERCISE # JEE-MAIN

1. The electrons identified by quantum numbers n and ℓ :-

[JEE-1999, AIEEE-2012, JEE-MAIN, (ONLINE)-2012]

- (a) $n = 4, \ell = 1$ (b) $n = 4, \ell = 0$ (c) $n = 3, \ell = 2$ (d) $n = 3, \ell = 1$

Can be placed in order of increasing energy as

- (1) (a) < (c) < (b) < (d) (2) (c) < (d) < (b) < (a)
(3) (d) < (b) < (c) < (a) (4) (b) < (d) < (a) < (c)

QN0050

2. Which of the following paramagnetic ions would exhibit a magnetic moment (spin only) of the order of 5 BM ?

[JEE-MAIN, (ONLINE)-2012]

(At. No : Mn = 25, Cr = 24, V = 23, Ti = 22)

- (1) V^{2+} (2) Ti^{2+} (3) Mn^{2+} (4) Cr^{2+}

QN0051

3. In an atom how many orbital (s) will have the quantum numbers; $n = 3, l = 2$ and $m_l = +2$?

[JEE-MAIN, (ONLINE)-2013]

- (1) 1 (2) 5 (3) 3 (4) 7

QN0052

4. The numbers of protons, electrons and neutrons in a molecule of heavy water are respectively

[JEE-MAIN, (ONLINE)-2013]

- (1) 10, 10, 10 (2) 8, 10, 11
(3) 10, 11, 10 (4) 11, 10, 10

QN0053

5. Given

[JEE-MAIN, (ONLINE)-2013]

- (a) $n=5, m_l = +1$ (b) $n = 2, l = 1, m_l = -1, m_s = -1/2$

The maximum number of electron(s) in an atom that can have the quantum numbers as given in (a) and (b) are respectively :

- (1) 8 and 1 (2) 25 and 1 (3) 2 and 4 (4) 4 and 1

QN0054

6. The correct set of four quantum numbers for the valence electrons of rubidium atom ($Z = 37$) is:

[JEE(Main)-2014]

- (1) $5, 1, 1, +\frac{1}{2}$ (2) $5, 0, 1, +\frac{1}{2}$ (3) $5, 0, 0, +\frac{1}{2}$ (4) $5, 1, 0, +\frac{1}{2}$

QN0055

7. If the principal quantum number $n = 6$, the correct sequence of filling of electrons will be:-

[JEE-MAIN, (ONLINE)-2015]

- (1) $ns \rightarrow (n-1)d \rightarrow (n-2)f \rightarrow np$ (2) $ns \rightarrow np \rightarrow (n-1)d \rightarrow (n-2)f$
(3) $ns \rightarrow (n-2)f \rightarrow (n-1)d \rightarrow np$ (4) $ns \rightarrow (n-2)f \rightarrow np \rightarrow (n-1)d$

QN0056

8. The total number of orbitals associated with the principal quantum number 5 is :

[JEE-MAIN, (ONLINE)-2016]

- (1) 25 (2) 5 (3) 20 (4) 10

QN0057

9. The group having isoelectronic species is :- [JEE-MAIN 2017]

- (1) O^{2-} , F^- , Na^+ , Mg^{2+} (2) O^- , F^- , Na , Mg^+
(3) O^{2-} , F^- , Na , Mg^{2+} (4) O^- , F^- , Na^+ , Mg^{2+}

QN0058

10. The isotopes of hydrogen are : [JEE-MAIN ONLINE 2019]

- (1) Tritium and protium only
(2) Deuterium and tritium only
(3) Protium and deuterium only
(4) Protium, deuterium and tritium

QN0059

11. The quantum number of four electrons are given below - [JEE-MAIN ONLINE 2019]

- I. $n = 4$, $l = 2$, $m_l = -2$, $m_s = -\frac{1}{2}$
II. $n = 3$, $l = 2$, $m_l = 1$, $m_s = +\frac{1}{2}$
III. $n = 4$, $l = 1$, $m_l = 0$, $m_s = +\frac{1}{2}$
IV. $n = 3$, $l = 1$, $m_l = 1$, $m_s = -\frac{1}{2}$

The correct order of their increasing energies will be -

- (1) $IV < III < II < I$ (2) $IV < II < III < I$
(3) $I < II < III < IV$ (4) $I < III < II < IV$

QN0060

12. The isoelectronic set of ions is : [JEE-MAIN ONLINE 2019]

- (1) N^{3-} , Li^+ , Mg^{2+} and O^{2-} (2) Li^+ , Na^+ , O^{2-} and F^-
(3) F^- , Li^+ , Na^+ and Mg^{2+} (4) N^{3-} , O^{2-} , F^- and Na^+

QN0061

13. The number of orbitals associated with quantum numbers $n = 5$, $m_s = +\frac{1}{2}$ is :

[JEE-MAIN ONLINE 2020]

- (1) 11 (2) 25 (3) 15 (4) 50

QN0062

14. Hydrogen has three isotopes (A), (B) and (C). If the number of neutron(s) in (A), (B) and (C) respectively, are (x), (y) and (z), the sum of (x), (y) and (z) is : [JEE-MAIN ONLINE 2020]

- (1) 4 (2) 3 (3) 2 (4) 1

QN0063

EXERCISE # JEE-ADVANCED

1. The maximum number of electrons that can have principal quantum number, $n = 3$, and spin quantum number, $m_s = -1/2$, is
[JEE 2011]
QN0064
2. In an atom, the total number of electrons having quantum numbers $n=4$, $|m_\ell| = 1$ and $m_s = -\frac{1}{2}$ is:
[JEE Advanced 2014]
QN0065
3. Not considering the electronic spin the degeneracy of the second excited state ($n = 3$) of H-atom is 9, where the degeneracy of the second excited state of H^- is [JEE Advanced 2015]
QN0066

ANSWER KEY

EXERCISE # O-1

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	B	C	C	B	B	A	C	B	C	C
Que.	11	12	13	14	15	16	17			
Ans.	B	B	C	C	D	D	A			

EXERCISE # O-2

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	A, B, D	B, C	A, B	C, D	A, C	B, D	A, B, D	B, D	A, B, D	C, D
Que.	11	12	13	14	15					
Ans.	A, B, D	C, D	B, C, D	B, C	B, C, D					

EXERCISE # S-1

Que.	1	2	3	4	5	6	7	8		
Ans.	4	9	8	0	8	2	9	6		

EXERCISE # S-2

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	C	B	C	C	A	D	B	D	C	B
Que.	11					12				
Ans.	(A)-Q, T (B)-P, R, S, T (C)-Q, T (D)-P, T					(A)-P, R, S, T (B)-P, S (C)-Q (D)-P, S				
Que.	13	14	15							
Ans.	C	B	B							

EXERCISE # JEE-MAIN

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	3	3	1	1	1	3	3	1	1	4
Que.	11	12	13	14						
Ans.	2	4	2	2						

EXERCISE # JEE-ADVANCED

Que.	1	2	3							
Ans.	9	6	3							

PART-A (PERIODIC TABLE)

INTRODUCTION :

The arrangement of all the known elements according to their properties in such a way that the elements of similar properties are grouped together in a tabular form is called periodic table.

Development of periodic table :

(A) LAVOISIER CLASSIFICATION OF ELEMENTS

At first Lavoisier classified the elements into two categories.

- Metal
- Non-metal

Note : This classification cannot categorise the metalloid variety.

(B) DOBEREINER'S TRIAD RULE [1817]

- He made groups of three elements having similar chemical properties called TRIAD.
- In Dobereiner triad, atomic weight of middle element is nearly equal to the average atomic weight of first and third element.

e.g.

Cl	Br	I	
35.5	80.0	127	$\frac{35.5 + 127}{2} = 81.25$

Ca	Sr	Ba	
40	87.5	137	$\frac{40 + 137}{2} = 88.5$

Li	Na	K	
7	23	39	At. wt of Na = $\frac{7 + 39}{2} = 23$

- Other examples – (K, Rb, Cs), (P, As, Sb), (S, Se, Te), (H, F, Cl), (Sc, Y, La)

(C) NEWLAND'S OCTAVE RULE [1865]

- He arranged the elements in the increasing order of their atomic mass and observed that properties of every 8th element was similar to the 1st one, like in the case of musical vowels notation.

Sa	Re	Ga	Ma	Pa	Dha	Ni	Sa
1	2	3	4	5	6	7	8

- At that time inert gases were not known.

Li	Be	B	C	N	O	H
Na	Mg	Al	Si	P	S	F
K	Ca					Cl

- The properties of Li are similar to 8th element i.e. Na, Be are similar to Mg and so on.

Drawbacks or Limitations :

- This rule is valid only upto Ca. because after Ca due to filling of d-orbitals there is difference of 18 elements instead of 8 element.
- After the discovery of inert gas this law had to be dropped out.
- He failed in the case of heavier metals as Fe has been placed along with O and S.

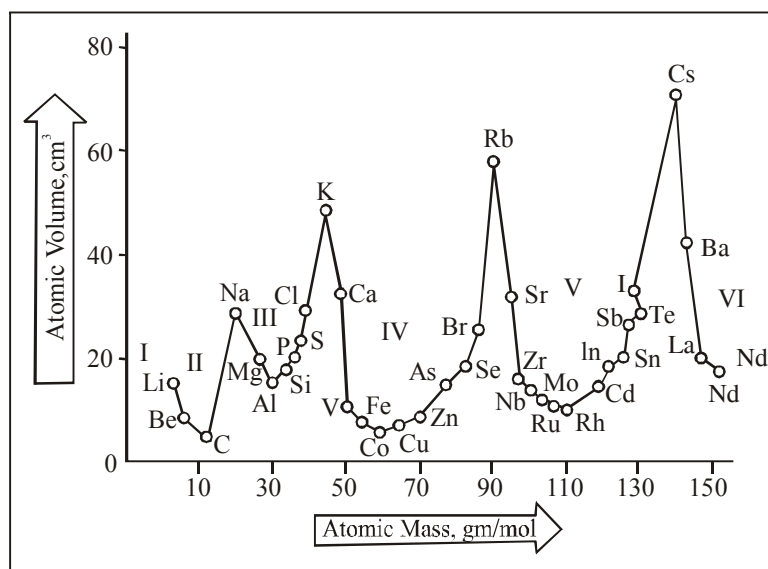
(D) LOTHER MEYER'S CURVE [1869]

- (i) He plotted a curve between atomic weight and atomic volume of different elements.
- (ii) The following observations can be made from the curve –
 - (a) Most electropositive elements i.e. alkali metals (Li, Na, K, Rb, Cs etc.) occupy the peak portions of the curve.
 - (b) Less electropositive i.e. alkaline earth metals (Be, Mg, Ca, Sr, Ba) occupy the descending portions of the curve.
 - (c) Metalloids (B, Si, As, Te, At etc.) and transition metals occupy bottom part of the curve.
 - (d) Most electronegative i.e. halogens (F, Cl, Br, I) occupy the ascending portion of the curve.

Note : Elements having similar properties occupy similar portions of the curve.

Conclusion :

On the basis of this curve, Lotser Meyer proposed that the physical properties of the elements are periodic function of their atomic weight and this became the basis of Mendeleev's periodic table.



(E) MENDELEEV'S PERIODIC TABLE [1869]

- (i) **Mendeleev's periodic law** – The physical and chemical properties of elements are the periodic function of their atomic weight
- (ii) **Characteristic of Mendeleev's periodic table** –
 - (a) It is based on atomic weight
 - (b) 63 elements were known, noble gases were not discovered.
 - (c) He was the first scientist to classify the elements in a systematic manner i.e. in horizontal rows and in vertical columns.
 - (d) Horizontal rows are called periods and there were 7 periods in Mendeleev's Periodic table.
 - (e) Vertical columns are called groups and there were 8 groups in Mendeleev's Periodic table.
 - (f) Each group upto VIIth is divided into A & B subgroups. 'A' sub group elements are called normal elements and 'B' sub group elements are called transition elements.
 - (g) The VIIIth group consists of 9 elements in three rows.
 - (h) The elements belonging to same group exhibit similar properties.

(iii) Merits or advantages of Mendeleev's periodic table –

- (a) **Study of elements** – For the first time, all known elements were classified in groups according to their similar properties. So study of the properties of elements became easier.
- (b) **Prediction of new elements** – It gave encouragement to the discovery of new elements as some gaps were left in it.

Sc (Scandium), Ga (Gallium), Ge (Germanium), Tc (Technetium) were the elements whose position and properties were well defined by Mendeleev even before their discoveries and he left the blank spaces for them in his table.

e.g. - Blank space at atomic weight 72 in silicon group was called Eka silicon (means properties like silicon) and element (*discovered later*) was named Germanium .

Similarly other elements discovered after mendeleev periodic table were :

Eka aluminium – Gallium(Ga)

Eka Boron – Scandium (Sc)

Eka Silicon – Germanium (Ge)

Eka Manganese – Technetium (Tc)

- (c) **Correction of doubtful atomic weights**—Corrections were done in atomic weight of some elements.

$$\text{Atomic Weight} = \text{Valency} \times \text{Equivalent weight.}$$

Initially, it was found that equivalent weight of Be is 4.5 and it is trivalent ($V = 3$), so the weight of Be was 13.5 and there is no space in Mendeleev's table for this element. So, after correction, it was found that Be is actually divalent ($V = 2$). So, the weight of Be became $2 \times 4.5 = 9$ and there was a space between Li and B for this element in Mendeleev's table.

Corrections were done in atomic weight of elements are – U, Be, In, Au, Pt.

(iv) Demerits of Mendeleev's periodic table –

- (a) **Position of hydrogen** – Hydrogen resembles both, the alkali metals (IA) and the halogens (VIIA) in properties so Mendeleev could not decide where to place it.
- (b) **Position of isotopes** – As atomic weight of isotopes differs, they should have been placed in different position in Mendeleev's periodic table. But there was no such place for isotopes in Mendeleev's table.
- (c) **Anomalous pairs of elements** – There were some pair of elements which did not follow the increasing order of atomic wts.

eg : Ar and Co were placed before K and Ni respectively in the periodic table, but having higher atomic weights.

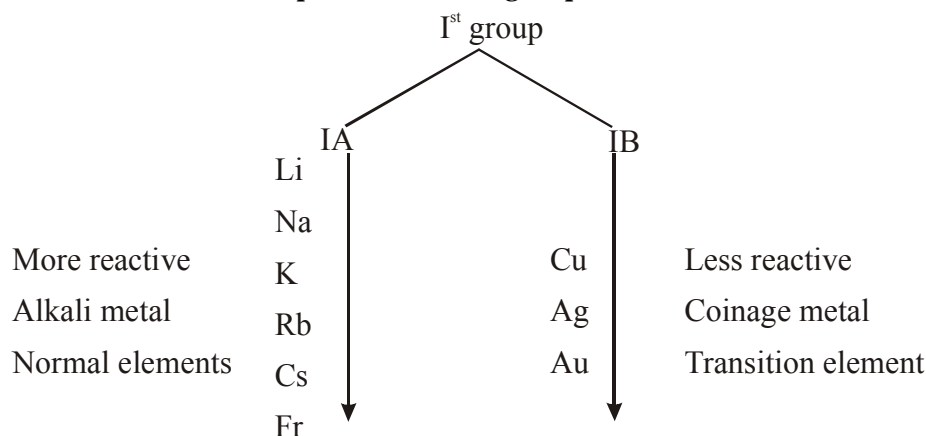
$$\begin{array}{cc} \left(\begin{array}{cc} \text{Ar} & \text{K} \\ 39.9 & 39.1 \end{array} \right) & \left(\begin{array}{cc} \text{Te} & \text{I} \\ 127.5 & 127 \end{array} \right) \\ \text{in modified mendeleev P.T.} & \\ \left(\begin{array}{cc} \text{Co} & \text{Ni} \\ 58.9 & 58.6 \end{array} \right) & \left(\begin{array}{cc} \text{Th} & \text{Pa} \\ 232 & 231 \end{array} \right) \end{array}$$

(d) Like elements were placed in different groups.

There were some elements like Platinum (Pt) and Gold (Au) which have similar properties but were placed in different groups in Mendeleev's table.

Pt	Au
VIII	IB

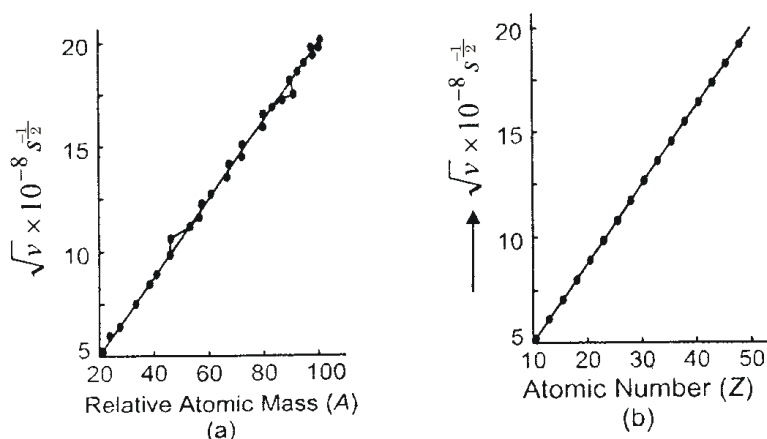
(e) Unlike elements were placed in same group.



Cu, Ag and Au placed in Ist group along with Na, K etc. While they differ in their properties (Only similar in having ns^1 electronic configuration)

(F) MODERN PERIODIC TABLE (MODIFIED MENDELEEV PERIODIC TABLE)

- (i) It was proposed by **Moseley (1913)**.
- (ii) Modern periodic table is based on atomic number.
- (iii) Moseley did an experiment in which he bombarded high speed electron on different metal surfaces and obtained X-rays.



Moseley's Experiment

He found out that $\sqrt{\nu} \propto Z$ (where ν = frequency) of X-rays from this experiment, Moseley concluded that the physical and chemical properties of the elements are periodic function of their atomic number. It means that when the elements are arranged in the increasing order of their atomic number, elements having similar properties gets repeated after a regular interval. This is also known as '**Modern Periodic Law**'.

- (iv) **Modern periodic law** – The physical & chemical properties of elements are a periodic function of their atomic number.
- (v) **Characteristics of modern periodic table** –
 - (a) 9 vertical columns called groups.
 - (b) IA to VIIA, IB to VIIB, VIII and 0
 - (c) Inert gases were introduced in periodic table by Ramsay.
 - (d) 7 horizontal series called periods.

(G) LONG FORM / PRESENT FORM OF MODERN PERIODIC TABLE

(It is also called as 'Bohr-Burry & Rang, Werner Periodic Table.)

- (i) It is based on the Bohr-Burry electronic configuration concept and atomic number.
- (ii) This model was proposed by Rang & Werner
- (iii) It consists of 7 horizontal periods and 18 vertical columns (groups)
- (iv) According to I. U. P. A. C. 18 vertical columns are named as 1st to 18th group.
- (v) The co-relation between the groups in long form of periodic table and in modern form of periodic table are given below.

IA, IIA, IIIB, IVB, VB, VIB, VIIB, VIII, IB, IIB, IIIA, IVA, VA, VIA, VIIA, 0

1 2 3 4 5 6 7 8, 9, 10 11 12 13 14 15 16 17 18

- (vi) Elements belonging to same group have same no. of electrons in the outermost shell so their properties are similar.

Description of periods :

Period	n	Sub shell	No. of elements	Element	Name of Period
1.	1	1s	2	${}_1\text{H} - {}_2\text{He}$	Shortest
2.	2	2s, 2p	8	${}_3\text{Li} - {}_{10}\text{Ne}$	Short
3.	3	3s, 3p	8	${}_{11}\text{Na} - {}_{18}\text{Ar}$	Short
4.	4	4s, 3d, 4p	18	${}_{19}\text{K} - {}_{36}\text{Kr}$	Long
5.	5	5s, 4d, 5p	18	${}_{37}\text{Rb} - {}_{54}\text{Xe}$	Long
6.	6	6s, 4f, 5d, 6p	32	${}_{55}\text{Cs} - {}_{86}\text{Rn}$	Longest
7.	7	7s, 5f, 6d, 7p	32	${}_{87}\text{Fr} - {}_{118}\text{Og}$	Longest

Extended or Long Form of the Periodic Table

		p-Block Elements																0 (18)	
Group	Period																		
1	1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
3	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
4	4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
5	5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
6	6	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
7	7	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

Metals

Non metals

Metalloids

		d-Block Elements																	

CLASSIFICATION OF ELEMENTS INTO s, p, d & f BLOCK ELEMENTS:**s – block :**

- (i) configuration ns^{1-2} (ii) last e^- enters in s orbital
- (iii) two groups I A or 1 ; II A or 2

p – block :

- (i) configuration $ns^2 np^{1-6}$ (ii) last e^- enters in p orbital
- (iii) six groups III A, IV A, V A, VI A, VII A, zero or 13, 14, 15, 16, 17, 18

d – block : [Transition Elements]

- (i) configuration $(n-1)d^{1-10} ns^{0-2}$ (ii) last e^- enters in d orbital
- (iii) their two outermost shell are incomplete
- (iv) 10 groups III B, IV B, V B, VI B, VII B, VIII (Triad), I B, II B or 3, 4, 5, 6, 7, (8, 9, 10), 11, 12 .
- (v) four series 3d, 4d, 5d, 6d belong to 4th, 5th, 6th & 7th period respectively in long form of Periodic table.

f – block : [Inner Transition]

- (i) configuration $(n-2)f^{0-14} (n-1)d^{0-2} ns^2$
- (ii) last e^- enters in f orbital
- (iii) two series 4f Lanthanides & 5f Actinides belong to 6th & 7th period respectively in long form of Periodic table.

Neil Bohr's classification of elements :

Using electronic configuration as the criteria, elements are of four types. The classification of the elements into these groups is dependent on the extent to which the s, p, d and f orbitals are filled.

Inert Gases :

- (a) s – and p-orbitals of the outer most shell of these elements are completely filled. The outermost electronic configuration is $ns^2 np^6$.
- (b) Helium is also inert gas but its electronic configuration is $1s^2$

Representative or Normal Elements :

- (a) Outermost shell of these elements is incomplete. The number of electrons in the outermost shell is less than eight.
- (b) s-and p-block elements except inert gases are called normal or representative elements.

Transition Elements :

- (a) These metals were placed between s-block metals and p-block elements so, are named transition metals.
- (b) Their outermost electronic configuration is similar to d-block elements i.e. $(n-1)d^{1-10} ns^{1-2}$.
- (c) Last two shells of these elements namely outermost and penultimate shells are incomplete.
- (d) The last shell contains one or two electrons and the penultimate shell may contain more than eight and up to eighteen electrons.
- (e) According to definition of transition elements, those elements which have partly filled d-orbitals in neutral state or in any stable oxidation state are called transition elements. According to this definition Zn, Cd and Hg (IIB group) are d-block elements but not transition elements because these elements have d^{10} configuration in neutral as well as in stable +2 oxidation state.

Inner Transition Elements :

- In these elements last three shells i.e. last, penultimate and prepenultimate shells are incomplete.
- These are related to IIIB i.e. group 3.
- The last shell contains two electrons. Penultimate shell may contain eight or nine electrons and pre-penultimate shell contains more than 18, up to 32 electrons.
- Their outmost electronic configuration is similar to f-block element
i.e. $(n-2)f^{0-14}(n-1)d^{0-2}ns^2$

METALS, NON-METALS & METALLOIDS

Apart from classifying elements into s, p, d and f-blocks, there is yet another broad classification of elements based on their properties. The elements can be broadly classified into

(a) Metals:

Majority of the elements in periodic table are metals and appears on the left side of the periodic table.

Properties:

- These are usually solid at room temperature [exception - mercury]
- They have high melting and boiling point [exception Gallium & Cesium have very low melting point (303 K and 302 K respectively)]
- They are good conductor of heat and electricity.
- They are malleable (can be flattened into thin sheets by hammering) and ductile (can be drawn into wires)

(b) Non-Metals:

These are placed at the top right hand side of periodic table. As we move horizontally along a period, the property of elements changes from metallic (on left) to non-metallic (on the right).

Properties :


- These are usually solids or gases at room temperature.
- They have low melting point and boiling point (exception : Boron, Carbon).
- Most Non-metallic solids are brittle and are neither malleable nor ductile.

(c) Metalloids (Semi-metals):

Properties of these elements show the characteristics of both metals and non-metals. Silicon (Si), Germanium(Ge), Arsenic(As), Antimony(Sb) and Tellurium(Te) are metalloids.

ESTIMATING POSITION OF AN ELEMENT FROM ITS ELECTRONIC CONFIGURATION

The last electron enters in which subshell gives idea of its block.

 **Think** : $1s^1$ and $1s^2$ belongs to which block]

Period number = Principal quantum number of valence shell electron in ground state electronic configuration.

Group number for s block = number of valence shell electrons

Group number for p block = 10 + number of valence shell electrons

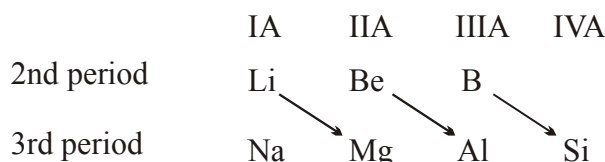
Group number for d block = number of $[ns + (n-1)d]$ electrons

Group number for f-block = 3

 **Use these carefully while locating the position.]**

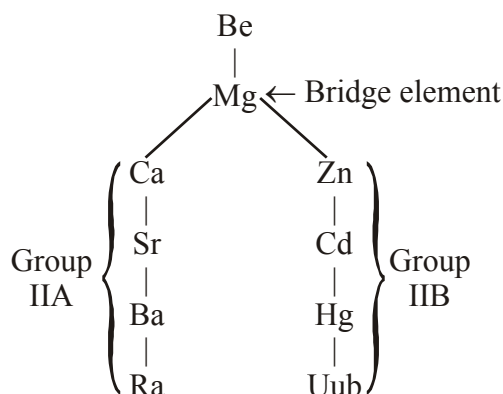
SOME COMMONLY USED TERMS

1. **Noble Gases** : Element of group 18 are called noble gases. These are also called as inert gases because their outermost ns and np orbitals are completely filled (except He and $1s^2$) and these gases are non-reactive in nature under ordinary conditions.
2. **Typical elements** : Elements of second and third period are known as typical elements.
3. **Diagonal relationship** : Properties of elements of second period resemble with the element of third period. This resemblance between properties of 2nd & 3rd period is called diagonal relationship.



4. Bridge elements :

The typical elements of third period are also called bridge elements as the division between two subgroups A and B starts from these elements. In second group Mg acts as a bridge element. The properties of bridge element are some what mixed of the elements of two subgroups as magnesium shows similarities with alkaline earth metals (IIA) on one hand and with zinc metals (IIB) on the other.



IUPAC NOMENCLATURE OF THE ELEMENT :

The names are derived by using roots for the three digits in the atomic number of the element and adding the ending -ium. The roots for the number are

Digit	Name	Abbreviation
0	nil	n
1	un	u
2	bi	b
3	tri	t
4	quad	q
5	pent	p
6	hex	h
7	sept	s
8	oct	o
9	enn	e

Thus element with atomic number 109 will be named as **une** (**u** for 1, **n** for 0 and **e** for 9). Table summarises the names of the elements with atomic number above 100.

PART-B (PERIODIC PROPERTIES)

PERIODICITY :

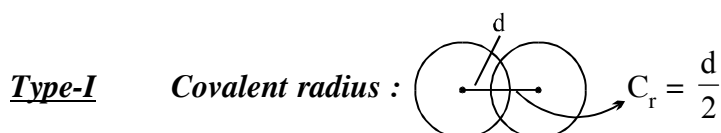
- The regular gradation in properties from top to bottom in a group and from left to right in a period is called periodicity in properties.
- In a period, the ultimate shell remain same, but the number of electrons gradually increases.
- In a group, the number of electrons in the ultimate shell remains same, but the values of n increases.

Cause of periodicity

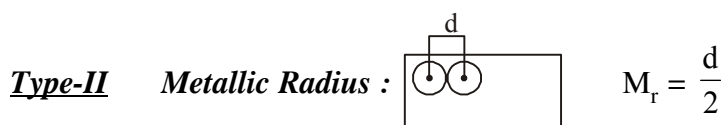
- The cause of periodicity in properties is due to the same outermost shell electronic configuration repeating over regular intervals.
- In the periodic table, elements with similar properties occur at intervals of 2, 8, 8, 18, 18 and 32. These numbers are called magic numbers.

ATOMIC RADIUS :

Since there is a problem in calculating actual size of atom, three types of radii can be defined :

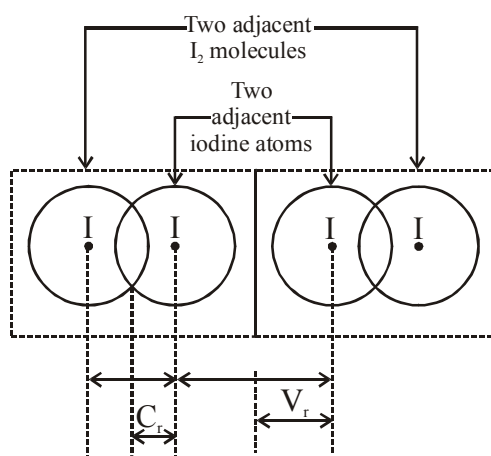


[Used for H_2 , Cl_2 and such molecules]



[Used for metals]

Type-III **VanderWaal's Radius or Collision radius**



VanderWaal's radius = $\frac{1}{2} \times$ Internuclear distance between nuclei of two neighbouring atoms belonging to nearest molecules.

VanderWaal's radius > Metallic radius > Covalent radius

The VanderWaal's radius and covalent radius of chlorine atom are 1.80 \AA and 0.99 \AA respectively.

Ionic Radius

A neutral atom changes to a cation by the loss of one or more electrons and to an anion by the gain of one or more electrons. The magnitude of charge on cation and anion is equal to the number of electrons lost or gained respectively. The ionic radii of the ions present in an ionic crystal may be calculated from the internuclear distance between the two ions.

(a) **Radius of Cation**

Radius of cation is smaller than that of corresponding atom. Since due to removal of electron(s), Z_{eff} increases.

(b) **Radius of an Anion**

Radius of an anion is invariably larger than that of the corresponding atom, since due to addition of electron(s) Z_{eff} decreases.

Factors affecting atomic radius:

- | | |
|--|--|
| (a) Z_{eff} increases, atomic radius decreases | $\text{Li} > \text{Be} > \text{B} > \text{C} > \text{N} > \text{O} > \text{F}$ |
| (b) Number of shell(n) increases, atomic radius increases | $\text{Li} < \text{Na} < \text{K} < \text{Rb} < \text{Cs}$ |
| (c) Screening effect increases, atomic radius increases. | |
| (d) Magnitude of -ve charge increases, atomic radius increases | $\text{O} < \text{O}^- < \text{O}^{2-}$ |
| (e) Magnitude of +ve charge increases, atomic radius decreases | $\text{Mn} > \text{Mn}^{+2} > \text{Mn}^{+3} > \text{Mn}^{+4}$ |
| (f) Bond order increases, atomic radius decreases | $>\text{N}-\text{N}< >-\text{N}=\text{N}- > \text{N}\equiv\text{N}$ |

Periodic Trend :

(a) **For normal elements:**

- (i) **Across a period :** It decreases from left to right in a period as Z_{eff} increases.

Ex. $\text{Ne} > \text{Li} > \text{Be} > \text{B} > \text{C} > \text{N} > \text{O} > \text{F}$

- (ii) **In a group :** It increases from top to bottom in a group as number of shells increases.

Ex. $\text{Li} < \text{Na} < \text{K} < \text{Rb} < \text{Cs}$

 **Note :** In III A group size of Al and Ga is nearly same (transition contraction)

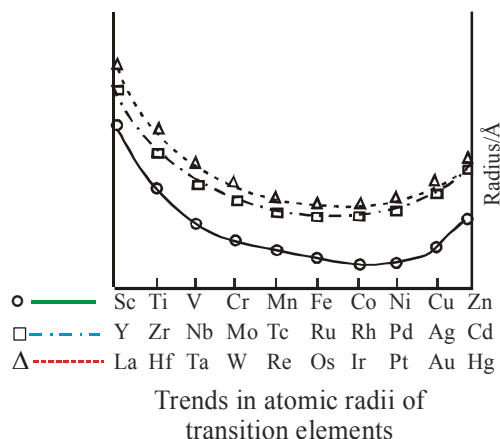
(b) **For inert gases:**

In respective period generally, the atomic radius of inert gas is largest, because for inert gas VanderWaal's radius is defined. The VanderWaal's radius of inert gases also increases on moving from top to bottom in the group.

(c) **For transition elements:**

From left to right in a period:

Element	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Covalent radius (Å)	1.44	1.32	1.22	1.17	1.17	1.17	1.16	1.15	1.17	1.25



In a group :

- (i) The atomic radius of elements increases on moving down the first transition series (3d) to second transition series (4d). This is due to the increases in number of shells with the increase in atomic number.
- (ii) The atomic radii of second (4d) and third (5d) transition series in a group is almost same except Y(39) and La(57)

(d) For inner transition elements:

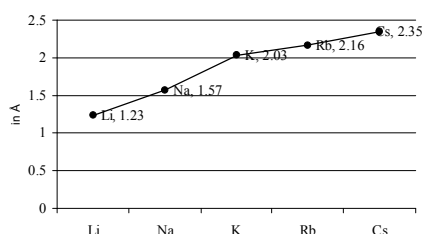
As we move along the lanthanide series, there is a decrease in atomic as well as ionic radius. The decrease in size is regular in ions but not so regular in atoms. This is called lanthanide contraction*.

Exceptions :

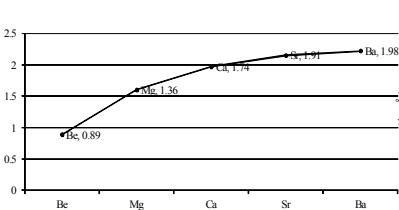
- (1) Noble gases have largest atomic sizes [Vander waal radii]. However, their covalent radii are smaller e.g. Xe.
- (2) Size of Al > Ga, [Z_{eff} increasing]
- (3) Size of Hf & Zr are same (lanthanide contraction)

Graphical representation of atomic radius :

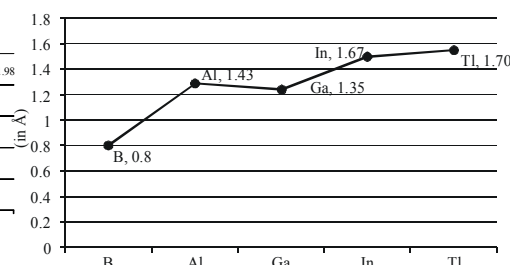
ALKALI METALS



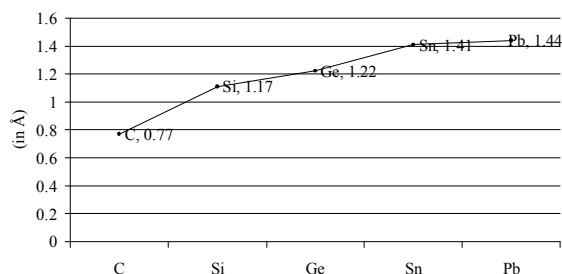
ALKALINE EARTH METALS



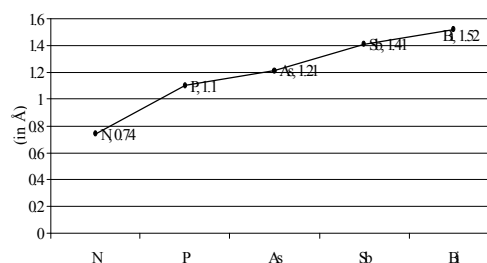
BORON FAMILY



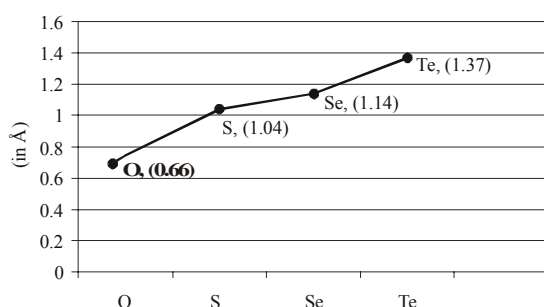
CARBON FAMILY



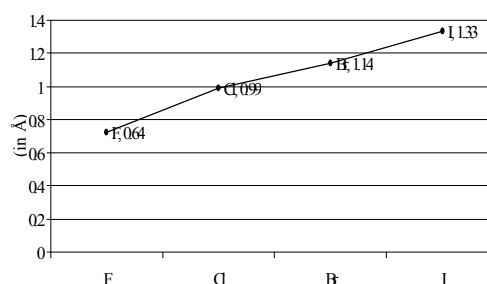
NITROGEN FAMILY (PNICOGENS)



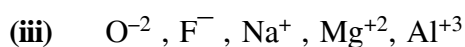
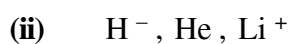
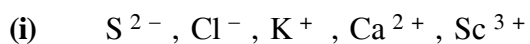
CHALCOGENS



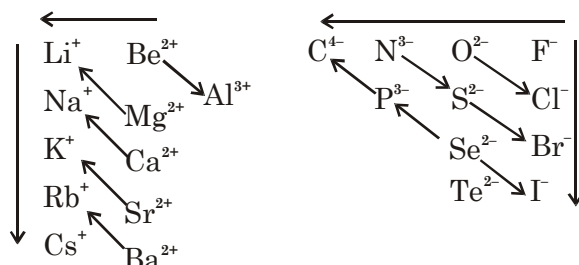
HALOGENS



☺ what can you predict or say about the increment in size along a group and decrement along a period]

ISOELECTRONIC MONOATOMIC SPECIES [Size $\propto 1/Z$]:

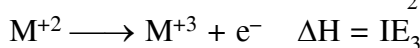
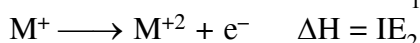
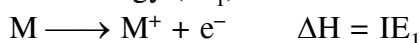
(iv)
$$\frac{\text{radius of cation}}{\text{radius of anion}} = \frac{Z_{\text{eff}} \text{ of Anion}}{Z_{\text{eff}} \text{ of Cation}}$$

Note:- In the direction of arrow (\rightarrow) ionic size increases.**IONISATION ENERGY:**

Amount of energy required to remove the most loosely bonded electron from an isolated gaseous atom from its ground state electronic configuration.

Units: kJ mol^{-1} , k cal mol^{-1} , eV per atom .

Ionisation is endothermic (endoergic) i.e. requires energy. Hence $\Delta H_{\text{ionisation}}$ is +ve.



Successive ionisation energy

$\text{IE}_3 > \text{IE}_2 > \text{IE}_1$ (always)

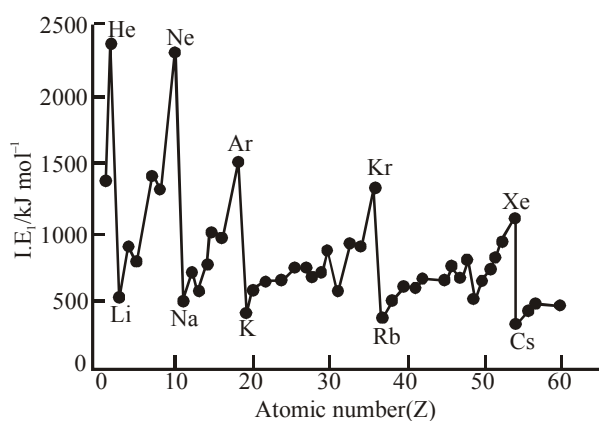
FACTORS AFFECTING IONISATION ENERGY:

- (1) Atomic size: Varies inversely
- (2) Screening effect: Varies inversely
- (3) Nuclear charge (Z): Varies directly
- (4) Special electronic configuration of outermost electron (half filled / fully filled)
- (5) Type of orbitals involved in Ionisation: $s > p > d > f$.

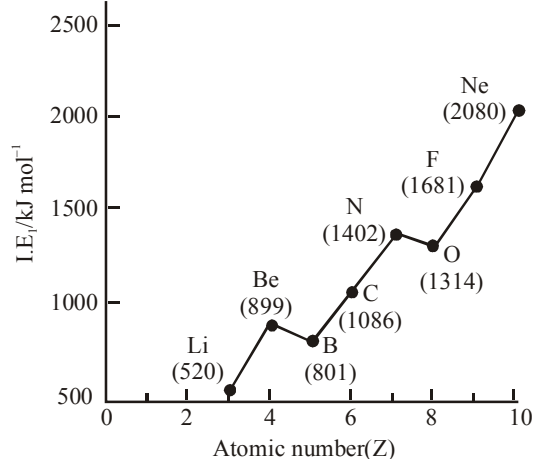
Note: Half filled and full filled inner orbitals, affects d-block and f-block trends.

General Trend: Along period I.E. increases [with some exception] [$Z_{\text{eff}} \uparrow$]

Along a group I.E. decrease [Z_{eff} constant, $n \uparrow$]



Variation of first ionization energy (IE_1) with atomic number for elements with $Z = 1$ to 60



First ionization energy (IE_1) of elements of the second period as a function of atomic number (Z)

Exception :

- (1) Along a period, half filled and fully filled configurations have higher I.E.
e.g. Be > B and N > O.
- (2) along a group, Ga \approx Al

PROPERTIES AFFECTED BY IONISATION ENERGY :

- (1) Metallic character (Varies inversely)
- (2) Reducing power (Varies inversely)
- (3) Tendency to stay in which state A^{+1} , A^{+2} or A^{+3}

Note :

- (a) Helium (He) has the highest ionisation energy (IE_1) among all the elements and Caesium (Cs) has the least (IE_1) value.

- (b) Ionisation potential of inert gases is very high due to most stable s^2p^6 electronic configuration.

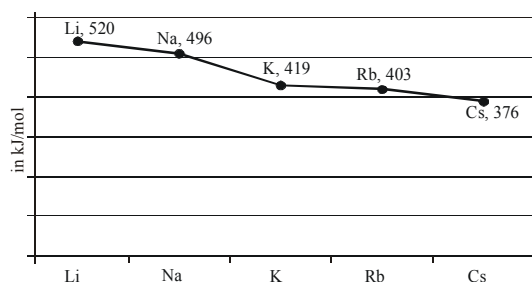
Element	He	Ne	Ar	Kr	Xe	Rn
$IE_1(\text{eV})$	24.5	21.6	15.8	14.0	12.1	10.7

- (c) For isoelectronic species I.E. increases with positive charge and decreases with negative charge.

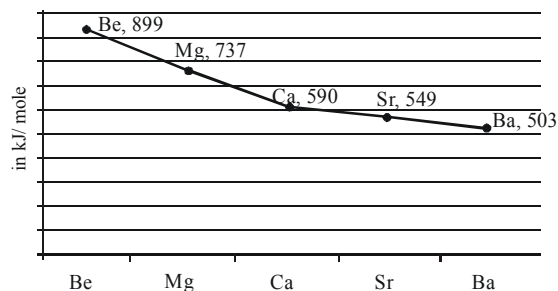
e.g. $Al^{+3} > Mg^{+2} > Na^{+} > F^{-} > O^{-2} > N^{-3}$

Graphical representation of ionisation energy :

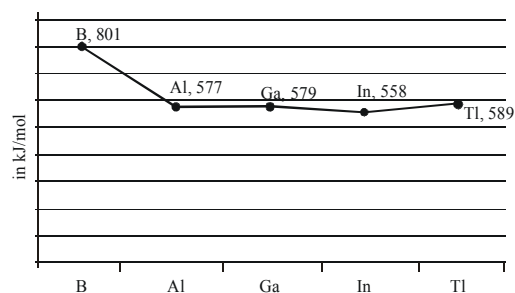
ALKALI METALS



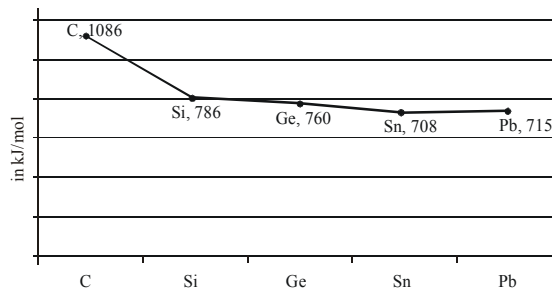
ALKALINE EARTH METALS



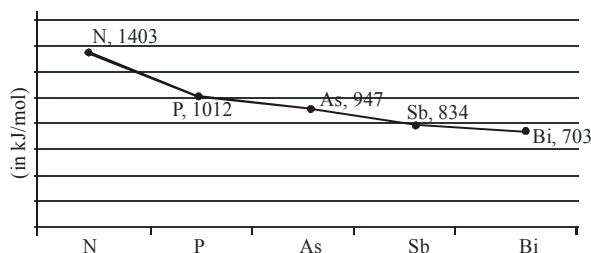
BORON FAMILY



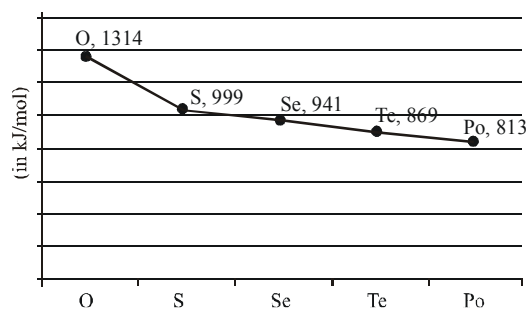
CARBON FAMILY



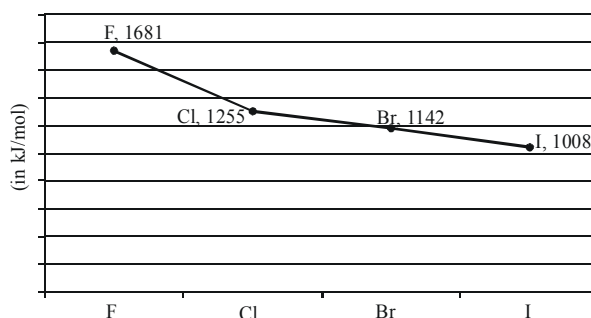
NITROGEN FAMILY (PNICOGENS)



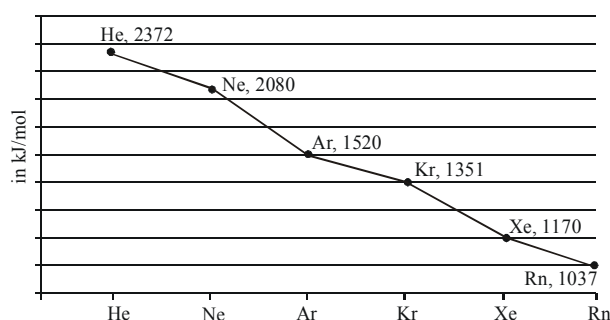
CHALCOGENS



HALOGENS



NOBLE GASES

**Ionisation energy of d-block elements :**

1st, 2nd, 3rd IE's are increasing from left to right for 1st Transition series, but not regularly.

For 2nd IE Cr > Fe > Mn and Cu > Zn

For 3rd IE Mn > Cr > Fe and Zn has highest.

Element	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Atomic number	21	22	23	24	25	26	27	28	29	30
Electronic configuration										
M	3d ¹ 4s ²	3d ² 4s ²	3d ³ 4s ²	3d ⁵ 4s ¹	3d ⁵ 4s ²	3d ⁶ 4s ²	3d ⁷ 4s ²	3d ⁸ 4s ²	3d ¹⁰ 4s ¹	3d ¹⁰ 4s ²
M ²⁺	3d ¹	3d ²	3d ³	3d ⁴	3d ⁵	3d ⁶	3d ⁷	3d ⁸	3d ⁹	3d ¹⁰
M ³⁺	[Ar]	3d ¹	3d ²	3d ³	3d ⁴	3d ⁵	3d ⁶	3d ⁷	—	—
Enthalpy of atomisation, Δ _a H°/kJ mol ⁻¹	326	473	515	397	281	416	425	430	339	126
Ionisation Enthalpy, Δ ₁ H°/kJ mol ⁻¹										
I	631	656	650	653	717	762	758	736	745	906
II	1235	1309	1414	1592	1509	1561	1644	1752	1958	1734
III	2393	2657	2833	2990	3260	2962	3243	3402	3556	3829

ELECTRON AFFINITY & ELECTRON GAIN ENTHALPY (EGE) :

Electron Affinity : Amount of energy released when an electron is added to an isolated gaseous atom.

Units : k J mol⁻¹, k Cal mol⁻¹ and eV per atom.

Addition of electron results in release of energy in most of the cases but for addition of second electron energy is always required. The sum of EA₁ & EA₂ is +ve (energy required)

$$E A \propto \frac{1}{\text{atomic size}} \propto Z_{\text{eff}} \quad (\text{Cl has the highest E.A.})$$

Electron gain Enthalpy (EGE) : When expressed in terms of enthalpy change (ΔH_{eg}) then it is termed as EGE Remember that $\Delta H = -ve$ for exothermic change.

For EA_1 , energy is released

$$\therefore \Delta H_{eg1} = -ve \text{ (Not always)}$$

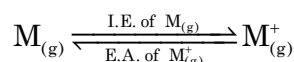
For EA_2, EA_3 energy is required

$$\therefore \Delta H_{eg2} = +ve \text{ (always)}$$

In general $EA_1 + EA_2$, energy is required.

$$\therefore (\Delta H_{eg1} + \Delta H_{eg2}) > 0$$

Note : $\Delta H_{e.g.} \approx -EA$



Ionisation energy of element is equal to electron affinity of its cation.

FACTORS AFFECTING ELECTRON AFFINITY :

- (1) **Atomic size :** Varies inversely
- (2) **Nuclear charge :** Varies directly
- (3) For stable electronic configuration i.e. half filled and fully filled shells EA decreases.

General Trend : Along a period, electron affinity increases [with a few exceptions] as $Z_{eff} \uparrow$.

Along a group, electron affinity decreases after 3rd period. Between 2nd and 3rd period in p block electron affinity of 2nd period is lesser.

Exception :

- (1) A fully filled and half filled configuration have low values of EA or even sometimes energy is required rather than getting released.
- (2) 2nd period has lower value than 3rd owing to repulsion between electrons in small sized 2nd period elements.

Electron affinity of the main-group elements (in electron volts)

1							18
H							He
+0.754	2	13	14	15	16	17	-0.5
Li	Be	B	C	N	O	F	Ne
+0.618	≤ 0	$\leq +0.277$	+1.263	-0.07	+1.461	+3.399	-1.2
Na	Mg	Al	Si	P	S	Cl	Ar
+0.548	≤ 0	+0.441	+1.385	+0.747	+2.077	+3.617	-1.0
K	Ca	Ga	Ge	As	Se	Br	Kr
+0.502	-	+0.03	+1.2	+0.81	+2.021	+3.365	-1.0
Rb	Sr	In	Sn	Sb	Te	I	Xe
+0.486	-	+0.3	+1.2	+1.07	+1.971	+3.059	-0.8

ELECTRO NEGATIVITY :

Property of an atom in a molecule

F has highest electronegativity in the periodic table.

Decreasing order $\rightarrow \text{F} > \text{O} > \text{Cl} \approx \text{N} > \text{Br} > \text{S} \approx \text{C} > \text{I} > \text{H}.$

$$\text{Pauling Scale : } |X_A - X_B| = 0.208\sqrt{\Delta_{A-B}} \quad \Delta \text{ in kcal/mol}$$

$$|X_A - X_B| = 0.102 \sqrt{\Delta_{A-B}} \quad \Delta \text{ in kJ/mol}$$

$$\Delta_{A-B} = E_{A-B} - (E_{A-A} \times E_{B-B})^{1/2}$$

Where, E_{A-B} = Bond energy of A-B; E_{A-A} = Bond energy of A-A; E_{B-B} = Bond energy of B-B

$$\text{Mulliken's Scale : } X_M = \frac{IP + EA}{2} \quad (\text{IP \& EA are expressed in eV})$$

Mulliken's values of E_N are about 2.8 times higher than values on Pauling's scale.

$$\text{i.e. } X_p = \frac{X_M}{28}$$

$$\text{Allred-Rochow's Scale : } X_{AR} = \frac{0.359Z_{\text{eff}}}{r^2} \quad ; \quad X_P = X_{AR} + 0.744$$

r = covalent radius of atom (in Å)

 Z_{eff} = Effective nuclear charge on periphery

FACTORS AFFECTING ELECTRO NEGATIVITY :

- (1) **Nuclear attraction** : Varies directly
- (2) **Atomic radius** : Varies inversely
- (3) **Charge on ions** : More positive charge, more electronegativity and more –ve charge, less electronegativity.
- (4) **Hybridisation** : To be discussed later in chemical bonding chapter.

General Trends : Along a period, electronegativity increases

Along a group, electronegativity decreases

Exceptions : Not Noteworthy.



Note: Electronegativity of $F > Cl$ but Electron affinity of $Cl > F$

Electronegativity of Some Elements (on Paulling's Scale)

H 2.1						
Li 1.0	Be 1.5	B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2	Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.7	Ba 0.9	Tl 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2
Fr 0.7	Ra 0.9					

In **Pauling's Scale**, elements having almost same electronegativity are-

$$C \simeq S \simeq I \simeq 2.5$$

$$N = C1 = 3.0$$

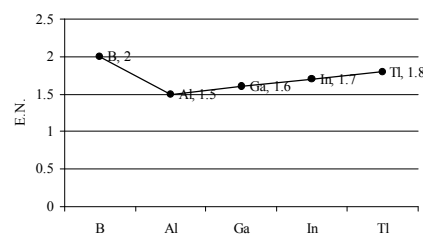
$$P = H = 2.1$$

$C_s = Fr = 0.7$

$$\text{Be} = \text{Al} = 1.5$$

(1) % ionic character	(2) Strength of bond
(3) Bond Length	(4) Nature of hydrides
(5) Nature of hydroxide.	

BORON FAMILY



Element	EN
N	3.0
P	2.1
As	2.0
Sb	1.9
Bi	1.9

Halogen	E.N.
F	4.0
Cl	3.0
Br	2.8
I	2.5

LATTICE ENERGY :

The amount of energy released during the formation of 1 mole crystal lattice from constituent gaseous ions.



OR

The lattice energy of an ionic compound is the energy required to separate 1 mole of solid ionic substance completely into gaseous ions.



Lattice energies are large and positive because of attraction between positive and negative ions. The potential energy of two interacting charged particles is given by:

$$E = K \frac{Q_1 Q_2}{r} \quad \text{where, } r = r^+ + r^- ; r^+ \rightarrow \text{radius of cation, } r^- \rightarrow \text{radius of anion}$$

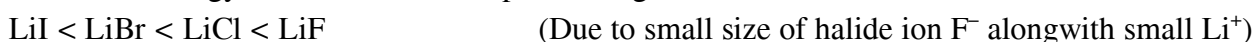
Where Q_1 and Q_2 are the charge on the particles in coulombs, and r is the distance between their centres in meters. The constant K has the value $9.0 \times 10^9 \text{ J - m/C}^2$.

Factors affecting lattice energy :

- The lattice energy increases as the charge on the ions increases and as their radii decreases.
- The magnitude of lattice energies however depends primarily on the ionic charges because ionic radii do not vary over a wide range.

For Example :

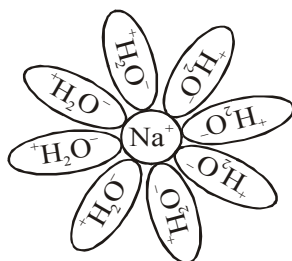
The lattice energy order for some compounds is given below.

**HYDRATION ENERGY :**

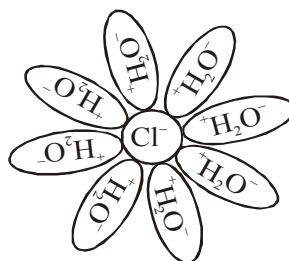
It is the energy released when 1 mol of gaseous ions are hydrated in water. It is directly proportional to nuclear charge and inversely proportional to size. It always decreases down the group.

- As the charge density of ion increases hydrated size (or aqueous radius) increases.

Size : $\text{Li}^+(\text{aq}) > \text{Na}^+(\text{aq}) > \text{K}^+(\text{aq}) > \text{Rb}^+(\text{aq}) > \text{Cs}^+(\text{aq})$



Hydration of Na^+



Hydration of Cl^-

- As the hydrated size of ion increases ionic mobility decreases, which thus, decreases conductivity of ions.

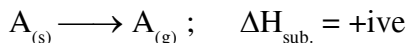
Mobility : $\text{Li}^+(\text{aq}) < \text{Na}^+(\text{aq}) < \text{K}^+(\text{aq}) < \text{Rb}^+(\text{aq}) < \text{Cs}^+(\text{aq})$

Conductivity : $\text{Li}^+(\text{aq}) < \text{Na}^+(\text{aq}) < \text{K}^+(\text{aq}) < \text{Rb}^+(\text{aq}) < \text{Cs}^+(\text{aq})$

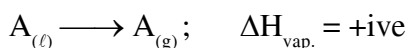
- Hydration energy also affects the solubility of ionic compounds. If hydration energy is greater than lattice energy then ionic compound will be soluble in water. More is the hydration energy, greater is the solubility, whereas, if lattice energy decreases, solubility of ionic compound increases.

The Born-Haber cycle is an approach to analyze reaction energies.

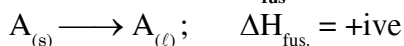
⇒ **Heat of sublimation ($\Delta H_{\text{sub.}}$)**: It is heat required to change one mole of a substance from solid state to gaseous state.



⇒ **Heat of vaporisation ($\Delta H_{\text{vap.}}$)** : It is heat required to change one mole of liquid substance into gas.

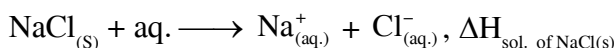


⇒ **Heat of fusion (ΔH_{fus})** : It is heat required to change one mole of solid substance into liquid.



⇒ **Heat of atomization (ΔH_{atm})** : It is change in enthalpy when one mole of a substance is converted into its constituent gaseous atoms.

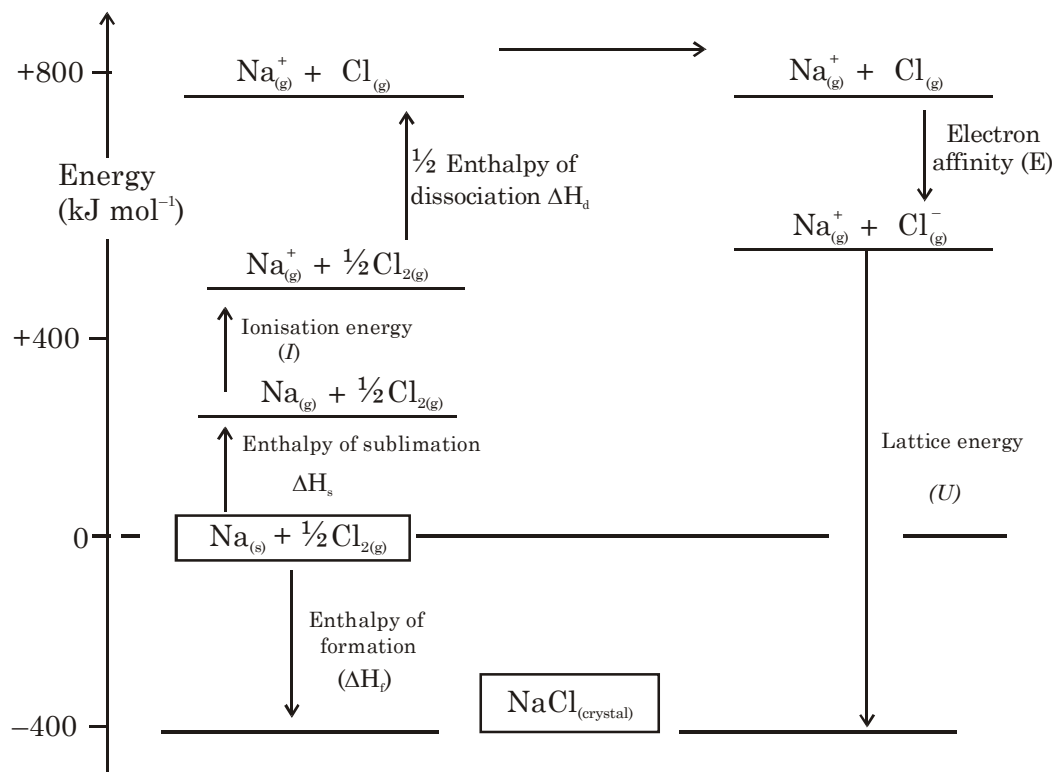
⇒ **Heat of solution (ΔH_{sol})**: It is the change in enthalpy when one mole of a solute is dissolved in excess amount of solvent.



⇒ **Bond dissociation energy (B.D.E.) and Bond Energy (B.E.) :** It is the amount of heat required to break one mole of bond between two atoms of a gaseous molecule into gaseous atoms.

⇒ **Heat of formation (ΔH_f)** : It is the change in enthalpy when one mole of substance is formed from it's element in standard state.

Born -Haber cycle for $\text{NaCl}_{(s)}$



$$\Delta H_f = \Delta H_s + I + \frac{1}{2}\Delta H_d + E + U$$

Examples : MgO , AlF_3

MISCELLANEOUS CHEMICAL PROPERTIES :

1. Periodicity of hydra acids :

- (a) Acidic character of hydra acid increases from left to right in a period.
- (b) Acidic character of hydra acid increases from top to bottom in a group.

2. Periodicity of oxy acids :

- (a) Acidic character of oxy acid increases from left to right in a period.
- (b) Acidic character of oxy acid decreases from top to bottom in a group.

3. Periodicity of nature of oxide :

- (a) On moving from left to right in a period acidic nature of oxide generally increases.
e.g. $\text{CO}_2 < \text{P}_2\text{O}_5 < \text{SO}_3 < \text{Cl}_2\text{O}_7$
- (b) On moving from top to bottom in a group acidic nature of oxide generally decreases.

4. General trends

- (a) **Hydration energy** decreases along a group.
- (b) **Lattice energy** decreases along a group.

:: Some points to Remember ::

(without considering radioactive elements)

1. Second most electronegative element is Oxygen
2. Hydrogen is the lightest element and Lithium is lightest metal.
3. Helium has the highest value of I.P.
4. In periodic table metalloids are only in p-block.
5. Total gaseous elements are 11 (He, Ne, Ar, Kr, Xe, Rn, H_2 , N_2 , O_2 , Cl_2 , F_2)
6. Liquid metal at room temperature is – Hg.
7. Diamond is hardest natural substance.
8. Halogens have highest electron affinity and amongst them, Cl has the highest amongst them.
9. The largest cation of the periodic table = Cs^+ .
10. The smallest cation of the periodic table = H^+ .
11. The smallest anion of the periodic table = F^- .
12. The biggest element of periodic table = Fr.
13. The smallest element of periodic table = H.
14. Br is liquid non-metal element at room temperature.
15. Osmium is the heaviest element known.
16. Fluorine is the most electronegative element.

EXERCISE # O-1

Periodic Table

- Which is not anomalous pair of elements in the Mendeleev's periodic table:-
(A) Ar and K (B) Co and Ni (C) Te and I (D) Al and Si
PT0001
- Representative elements belong to :
(A) s-and p-block (B) d-block (C) d- and f-block (D) f-block
PT0002
- True statement is :-
(A) All the transuranic elements are synthetic elements
(B) Elements of third period are called transition elements
(C) Element of $[\text{Ar}] 3d^{10}4s^2$ configuration is placed in IIA group
(D) Electronic configuration of elements of a group is same
PT0003
- Which of the following match is correct :-
(A) Last natural element – Uub
(B) General electronic configuration of IA group – ns^2
(C) Inert gas elements lies between 2nd – 6th period
(D) Typical elements – 3rd period elements
PT0004
- The electronic configuration of elements X and Z are $1s^2 2s^2 2p^6 3s^2 3p^5$ and $1s^2 2s^2 2p^5$ respectively. What is the position of element X with respect to position of Z in the periodic table -
(A) Just below element Z (B) Just above Z
(C) Left to the Z (D) right to the Z
PT0005
- Which of the following is not a Dobereiner triad :
(A) H, F, Cl (B) N, O, F (C) P, As, Sb (D) S, Se, Te
PT0006
- Select the incorrect statement for Lothar Meyer's curve :
(A) Curve is plotted between atomic weight and atomic volume
(B) Alkali metals occupy maxima of curve
(C) Halogens occupy descending portions of the curve
(D) Transition metals occupy bottom portions of the curve
PT0007

Atomic & Ionic Radii

8. The size of the following species increases in the order:
 (A) $\text{Mg}^{2+} < \text{Na}^+ < \text{F}^-$ (B) $\text{F}^- < \text{Na}^+ < \text{Mg}^{2+}$
 (C) $\text{Mg}^{2+} < \text{F}^- < \text{Na}^+$ (D) $\text{Na}^+ < \text{F}^- < \text{Mg}^{2+}$
PT0008
9. Highest size will be of
 (A) Br^- (B) I (C) I^- (D) I^+
PT0009
10. Element Cu has two oxidation states Cu^{+1} & Cu^{+2} . the right order of radii of these ions.
 (A) $\text{Cu}^{+1} > \text{Cu}^{+2}$ (B) $\text{Cu}^{+2} > \text{Cu}^{+1}$ (C) $\text{Cu}^{+1} = \text{Cu}^{+2}$ (D) $\text{Cu}^{+2} \geq \text{Cu}^{+1}$
PT0010
11. The correct order of increasing atomic size of element N, F, Si & P.
 (A) $\text{N} < \text{F} < \text{Si} < \text{P}$ (B) $\text{F} > \text{N} < \text{P} < \text{Si}$ (C) $\text{F} < \text{N} < \text{P} < \text{Si}$ (D) $\text{F} < \text{N} < \text{Si} < \text{P}$
PT0011
12. The correct order of atomic or ionic size
 (A) $\text{N} < \text{Li} < \text{B}$ (B) $\text{Cl} < \text{Mg} < \text{Ca}$ (C) $\text{Ca}^{+2} < \text{S}^{-2} < \text{Cl}^-$ (D) $\text{Na}^+ < \text{Mg}^{+2} < \text{Cl}^-$
PT0012
13. In isoelectronic series largest difference between size is observed in N^{3-} , O^{2-} , F^- , Na^+ , Mg^{2+} :
 (A) N^{3-} , Mg^{2+} (B) N^{3-} , O^{2-} (C) Mg^{2+} , Na^+ (D) F^- , Na^+
PT0013
14. Mg, Mg^{2+} , Al and Al^{3+} are arranged in decreasing order of size 1 > 2 > 3 > 4. Species which are present at 1 and 4 position respectively are :
 (A) Al, Mg^{2+} (B) Mg, Al^{3+} (C) Mg^{2+} , Al (D) Al^{3+} , Mg
PT0014

Ionization Energy or Potential

15. In which of the following electronic configuration, ionisation energy will be maximum in
 (A) $[\text{Ne}] 3s^2 3p^1$ (B) $[\text{Ne}] 3s^2 3p^2$ (C) $[\text{Ne}] 3s^2 3p^3$ (D) $[\text{Ar}] 3d^{10} 4s^2 4p^3$
PT0015
16. The correct order of second ionisation potential of C, N, O and F is:
 (A) $\text{C} > \text{N} > \text{O} > \text{F}$ (B) $\text{O} > \text{N} > \text{F} > \text{C}$ (C) $\text{O} > \text{F} > \text{N} > \text{C}$ (D) $\text{F} > \text{O} > \text{N} > \text{C}$
PT0016
17. The ionization energy will be maximum for which process?
 (A) $\text{Ba} \rightarrow \text{Ba}^+$ (B) $\text{Be} \rightarrow \text{Be}^+$ (C) $\text{Cs} \rightarrow \text{Cs}^+$ (D) $\text{Li} \rightarrow \text{Li}^+$
PT0017
18. Amongst the following, the incorrect statement is
 (A) $\text{IE}_1(\text{Al}) < \text{IE}_1(\text{Mg})$ (B) $\text{IE}_1(\text{Na}) < \text{IE}_1(\text{Mg})$
 (C) $\text{IE}_2(\text{Mg}) > \text{IE}_2(\text{Na})$ (D) $\text{IE}_3(\text{Mg}) > \text{IE}_3(\text{Al})$
PT0018

19. Decreasing ionization potential for K, Ca & Ba is

- (A) $Ba > K > Ca$ (B) $Ca > Ba > K$
(C) $K > Ba > Ca$ (D) $K > Ca > Ba$

PT0019

20. Alkaline earth metals always form dipositive ions due to

- (A) $IE_2 - IE_1 > 10 \text{ eV}$ (B) $IE_2 - IE_1 = 17 \text{ eV}$
(C) $IE_2 - IE_1 < 10 \text{ eV}$ (D) None of these

PT0020

21. The correct order of second I.P.

- (A) $Na < Mg > Al < Si$ (B) $Na > Mg < Al > Si$
(C) $Na > Mg > Al < Si$ (D) $Na > Mg > Al > Si$

PT0021

Electron affinity or Electron Gain Enthalpy

22. The process requires absorption of energy is

- (A) $F \rightarrow F^-$ (B) $Cl \rightarrow Cl^-$ (C) $O^- \rightarrow O^{2-}$ (D) $H \rightarrow H^-$

PT0022

23. Of the following elements, which possesses the highest electron affinity?

- (A) As (B) O (C) S (D) Se

PT0023

24. Electron affinities of O, F, S and Cl are in the order.

- (A) $O < S < Cl < F$ (B) $O < S < F < Cl$
(C) $S < O < Cl < F$ (D) $S < O < F < Cl$

PT0024

25. Increasing order of Electron affinity for following configuration.

- (a) $1s^2, 2s^2 2p^2$ (b) $1s^2, 2s^2 2p^4$
(c) $1s^2, 2s^2 2p^6 3s^2 3p^4$ (d) $1s^2, 2s^2 2p^6, 3s^2 3p^3$
(A) $d < a < b < c$ (B) $d < a < c < b$ (C) $a < b < c < d$ (D) $a < b < d < c$

PT0025

26. Highest electron affinity is shown by

- (A) F^- (B) Cl^- (C) Li^+ (D) Na^+

PT0026

27. Which of the following statements is not true?

- (A) F atom can hold additional electron more tightly than Cl atom
(B) Cl atom can hold additional electron more tightly than F atom
(C) The incoming electron encounters greater repulsion for F atom than for Cl atom
(D) It is easier to remove an electron from F^- than Cl^- .

PT0027

Electronegativity

28. The outermost electronic configuration of most electronegative element amongst the following is :
 (A) $ns^2 np^3$ (B) $ns^2 np^4$ (C) $ns^2 np^5$ (D) $ns^2 np^6$

PT0028

29. In the following, which is the correct representation ?



PT0029

30. On the Pauling's electronegativity scale, which element is next to F.



PT0030

31. Which one is not correct order of electronegativity.



PT0031

32. The increasing order of acidic nature of Li_2O , BeO , B_2O_3



PT0032

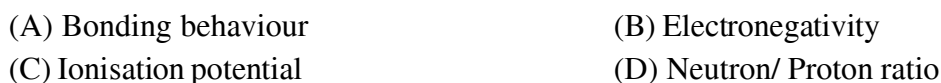
33. The lowest electronegativity of the element from the following atomic number is.



PT0033

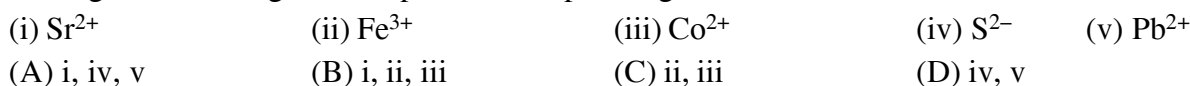
Miscellaneous

34. Which of the following does not reflect the periodicity of element



PT0034

35. Among the following, which species is/are paramagnetic ?



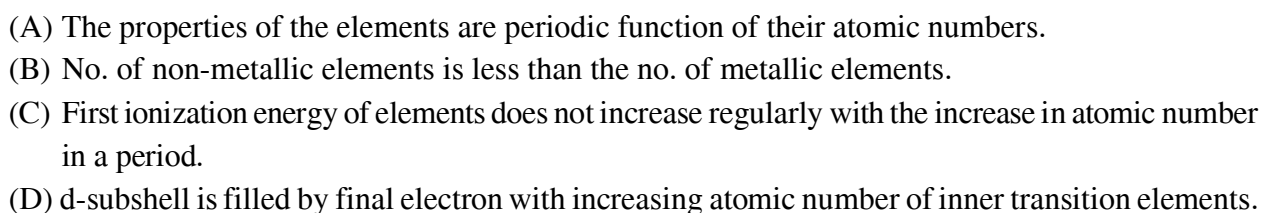
PT0035

36. Choose the s-block element from the following:



PT0036

37. False statement for periodic classification of elements is



PT0037

38. Which of the following order is incorrect against the property indicated :

- (A) $Mg < Ar < Na$ (2nd I.E.) (B) $Be < F < Cl$ ($|\Delta H_{eg}|$)
(C) $Rb < Na < K > Ca$ (atomic radius) (D) $P < S < N$ (electronegativity)

PT0038

39. If each orbital can hold a maximum of three electrons, the number of elements in 9th period of periodic table (long form) will be

- (A) 48 (B) 162 (C) 50 (D) 75

PT0039

40. Which of the following element has highest metallic character .

- | Element | IP |
|---------|-------|
| (A) P | 17 eV |
| (B) Q | 2 eV |
| (C) R | 10 eV |
| (D) S | 13 eV |

PT0040

41. The electronic configuration of an element is $1s^2 2s^2 2p^6 3s^2 3p^4$. The atomic number and the group number of the element 'X' which is just below the above element in the periodic table are respectively.

- (A) 24 & 6 (B) 24 & 15 (C) 34 & 16 (D) 34 & 8

PT0041

42. The number of d- electrons in Mn^{2+} is equal to that of

- (A) p-electrons in N (B) s-electrons in Na
(C) d-electrons in Fe^{+2} (D) p-electrons in O^{-2}

PT0042

43. Which of the following has the maximum number of unpaired electrons

- (A) Mg^{2+} (B) Ti^{3+} (C) V^{3+} (D) Fe^{2+}

PT0043

44. EN of the element (A) is E_1 and IP is E_2 . Hence EA will be according to mulliken

- (A) $2E_1 - E_2$ (B) $E_1 - E_2$ (C) $E_1 - 2E_2$ (D) $(E_1 + E_2)/2$

PT0044

45. Moving from right to left in a periodic table, the atomic size is:

- (A) Increased (B) Decreased (C) Remains constant (D) None of these

PT0045

46. One element has atomic weight 39. Its electronic configuration is $1s^2, 2s^2 2p^6, 3s^2 3p^6 4s^1$. The true statement for that element is:

- (A) High value of IE (B) Transition element (C) Isotone with ${}_{18}Ar^{38}$ (D) None

PT0046

47. The number of paired electrons in oxygen atom is:

- (A) 6 (B) 16 (C) 8 (D) 32

PT0047

48. The decreasing size of K^+, Ca^{+2}, Cl^- & S^{2-} follows the order:

- (A) $K^+ > Ca^{+2} > S^{2-} > Cl^-$ (B) $K^+ > Ca^{+2} > Cl^- > S^{2-}$
(C) $Ca^{+2} > K^+ > Cl^- > S^{2-}$ (D) $S^{2-} > Cl^- > K^+ > Ca^{+2}$

PT0048

EXERCISE : O-2*Atomic & Ionic Radius*

1. Select correct order of size :



PT0049

2. Which of the following orders of atomic / Ionic radius is correct ?



PT0050

Electron Affinity

3. Which of the following is correct order of EA.



PT0051

4. The electron affinity of the members of oxygen family of the periodic table, follows the sequence



PT0052

Ionisation Energy

5. Considering the following ionisation steps :

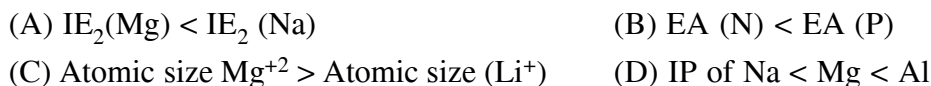


Select the correct statements :



PT0053

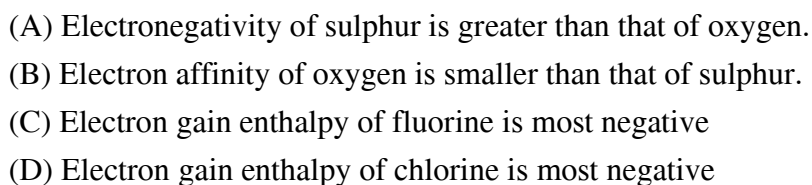
6. Which of the following are correct ?



PT0054

Electronegativity

7. Amongst the following statements, which is / are correct?



PT0055

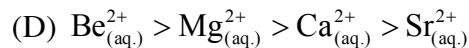
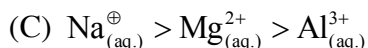
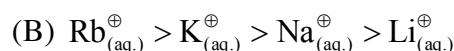
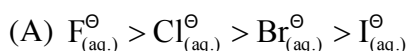
8. An element 'E' have
- $\text{IE} = x \text{ eV/atom}$
- and
- $\text{EA} = y \text{ eV / atom}$
- and EN on Pauling scale is 1.2. Find EN of 'E' on Mullikan scale :



PT0056

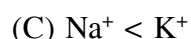
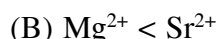
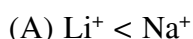
Hydration Energy

9. Choose the INCORRECT order of hydrated size of the ions -



PT0057

10. Find the correct ionic mobility order in aqueous solution from the following options-



PT0058

Miscellaneous

11. Select the correct statement(s).

(A) The value of electron gain enthalpy of an element can be -ve or +ve.

(B) In the periodic table, metallic character of the elements increases down the group and decreases across the period

(C) The Cl^- & S^{2-} are isoelectronic species but first one is not smaller in size than the second

(D) Ionization enthalpy of an atom is equal to electron gain enthalpy of cation

PT0059

12. In halogens, which of the following properties increase from iodine to fluoroine

(A) Ionisation energy

(B) Electronegativity

(C) Bond length

(D) Electron affinity

PT0060

13. In which of the following set of elements 1st element is more metallic than second.

(A) Ba, Ca

(B) Sb, Sn

(C) Ge, S

(D) Na, F

PT0061

14. Which of the following order(s) is / are **CORRECT** :

(A) $Li < Be < B < C$ (IE_1)

(B) $HF < HCl < HBr < HI$ (Bond length)

(C) $Na_2O < MgO < Al_2O_3 < SiO_2 < P_2O_5$ (Acidic)

(D) $Li^+(g) < Na^+(g) < K^+(g) < Cs^+(g)$ (Ionic radius)

PT0062

15. Which of the following order is correct :

(A) $P < Si < Be < Mg < Na$ (Metallic character)

(B) $Mg^{+2} < Na^+ < F^- < O^{2-}$ (Ionic radius)

(C) $Li < B < Be < C < N < O$ (2nd ionization energy)

(D) $Li^+ < Na^+ < K^+ < Rb^+ < Cs^+$ (Ionic mobility)

PT0063

16. The ionic compound $A^+ B^-$ is formed easily when the
- (A) electron affinity of B is high (B) ionization energy of A is low
(C) lattice energy of AB is high (D) lattice energy of AB is low

PT0064

17. Which of the following is/are correct?
- (A) For $A(g) + e^- \longrightarrow A^-(g)$ ΔH may be negative
(B) For $A^-(g) + e^- \longrightarrow A^{2-}(g)$ ΔH may be negative
(C) For $A^-(g) + e^- \longrightarrow A^{2-}(g)$ ΔH must be positive
(D) For $Ne(g) + e^- \longrightarrow Ne^-(g)$ ΔH may be zero

PT0065

9. Upto argon find the number of elements which have lower IE_1 as compared to He.

PT0074

10. The number of pairs, in which EA of the second element is more than that of the first element is :
[O, S], [C, N], [O, N], [N, P], $[Cl^+, F^+]$, $[K^+, Na^+]$

PT0075

11. For an element the successive ionisation energy values (in eV/atom), are given below.
14.534, 29.601, 47.448, 77.472, 97.888, 552.057, 667.029
Find the number of valence shell electrons in that element.

PT0076

Subjective :

12. Calculate E.N. of chlorine atom on Pauling scale if I.E. of Cl^- is 4eV & of E.A. of Cl^+ is + 13.0 eV.

PT0077

13. Increasing order of ionic size :
 N^{3-} , Na^+ , F^- , O^{2-} , Mg^{2+}

PT0078

EXERCISE # S-2

Paragraph for Questions 1 to 2

First electron gain enthalpy (in $\frac{\text{kJ}}{\text{mol}}$) of few elements are given below :

Elements	ΔH_{eg}
I	-60
II	-45
III	-328
IV	-295
V	+ 48

Answer the following questions on the basis of above data:

- Which element may be an inert gas
(A) I (B) III (C) IV (D) V
- Which element is most non-metallic among all the elements -
(A) I (B) II (C) III (D) IV

PT0079

PT0079

Paragraph for Questions 3 to 4

The IE_1 and the IE_2 in KJ/mol of a few elements designated by U, V, W, X are shown below.

Atom	IE_1	IE_2
U	2464	6110
V	610	7542
W	928	1810
X	1588	3410

Based on the above information answer the following question :-

- Which of the elements represent a noble gas.
(A) U (B) V (C) W (D) X
- Which of the following element belongs to group 1 (IA).
(A) U (B) V (C) W (D) X

PT0080

PT0080

Paragraph for Question 5 to 7

Nature of bond can be predicted on the basis of electronegativity of bonded atoms, greater difference in electronegativity (X), more will be the polarity of bond, and polar bond are easily broken in polar solvent like water. For hydroxy acids $\text{X}_\text{O} - \text{X}_\text{A}$ difference predict the nature of oxide formed by the element A.

$|\text{X}_\text{O} - \text{X}_\text{A}| > |\text{X}_\text{O} - \text{X}_\text{H}|$ then A-O-H show basic nature (NaOH)

$|\text{X}_\text{O} - \text{X}_\text{A}| < |\text{X}_\text{O} - \text{X}_\text{H}|$ then A-O-H show acidic nature (H-O-Cl)

With the help of EN values [$\text{EN}_\text{A} = 1.8$, $\text{EN}_\text{B} = 2.6$, $\text{EN}_\text{C} = 1.6$, $\text{EN}_\text{D} = 2.8$] answer the following questions for the compounds HAO, HBO, HCO, HDO.

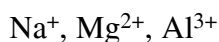
- Compounds whose aqueous solution is acidic and order of their acidic strength
(A) AOH, COH ; AOH < COH (B) HDO, HBO ; HDO > HBO
(C) AOH, COH ; AOH > COH (D) HDO, HBO ; HDO < HBO

PT0081

6. Compounds whose aqueous solution is basic and order of their basic strength
 (A) AOH, COH ; AOH < COH (B) HDO, HBO ; HDO > HBO
 (C) AOH, COH ; AOH > COH (D) HDO, HBO ; HDO < HBO
- PT0081
7. Percentage ionic character of compound AB is
 (A) 42.42% (B) 24.24% (C) 15.04% (D) None of these
- PT0081

Paragraph for Question 8 to 12

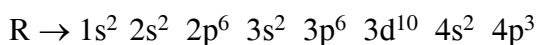
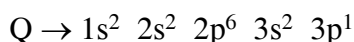
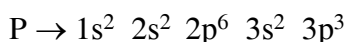
All the simple salt dissolve in water, producing ions and consequently the solution conduct electricity. In this process water molecule surround both the cations and anions & release energy. This process is called hydration & energy released is called hydration energy & it depends on size of gaseous ions. Answer the following questions with respect to given cations.



8. Order of extent of hydration
 (A) $\text{Na}^+ = \text{Mg}^{2+} = \text{Al}^{3+}$ (B) $\text{Na}^+ > \text{Mg}^{2+} > \text{Al}^{3+}$
 (C) $\text{Al}^{3+} > \text{Mg}^{2+} > \text{Na}^+$ (D) $\text{Al}^{3+} > \text{Mg}^{2+} < \text{Na}^+$
- PT0082
9. Order of hydration energy
 (A) $\text{Na}^+ = \text{Mg}^{2+} = \text{Al}^{3+}$ (B) $\text{Na}^+ > \text{Mg}^{2+} > \text{Al}^{3+}$
 (C) $\text{Al}^{3+} > \text{Mg}^{2+} > \text{Na}^+$ (D) $\text{Al}^{3+} > \text{Mg}^{2+} < \text{Na}^+$
- PT0082
10. Order of size of hydrated ion.
 (A) $\text{Na}^+ = \text{Mg}^{2+} = \text{Al}^{3+}$ (B) $\text{Na}^+ > \text{Mg}^{2+} > \text{Al}^{3+}$
 (C) $\text{Al}^{3+} > \text{Mg}^{2+} > \text{Na}^+$ (D) $\text{Al}^{3+} > \text{Mg}^{2+} < \text{Na}^+$
- PT0082
11. Order of ionic mobility
 (A) $\text{Na}^+ = \text{Mg}^{2+} = \text{Al}^{3+}$ (B) $\text{Na}^+ > \text{Mg}^{2+} > \text{Al}^{3+}$
 (C) $\text{Al}^{3+} > \text{Mg}^{2+} > \text{Na}^+$ (D) $\text{Al}^{3+} > \text{Mg}^{2+} < \text{Na}^+$
- PT0082
12. Order of size of gaseous ions.
 (A) $\text{Na}^+ = \text{Mg}^{2+} = \text{Al}^{3+}$ (B) $\text{Na}^+ > \text{Mg}^{2+} > \text{Al}^{3+}$
 (C) $\text{Al}^{3+} > \text{Mg}^{2+} > \text{Na}^+$ (D) $\text{Al}^{3+} > \text{Mg}^{2+} < \text{Na}^+$
- PT0082

Paragraph for Question 13 to 14 are based on the following information.

Four elements P, Q, R & S have ground state electronic configuration as:



13. Comment which of the following option represent the correct order of true (T) & false (F) statement.

I size of P < size of Q

II size of R < size of S

III size of P < size of R (appreciable difference) IV size of Q < size of S (appreciable difference)

(A) TTTT

(B) TTTF

(C) FFTT

(D) TTFF

PT0083

14. Order of IE_1 values among the following is

(A) $P > R > S > Q$

(B) $P < R < S < Q$

(C) $R > S > P > Q$

(D) $P > S > R > Q$

PT0083

Matching List

15. Column-I

Element

(P) Si

(Q) Sc

(R) Ga

(S) Tl

Column-II

Period and group number respectively

(1) 4, 3

(2) 3, 14

(3) 6, 13

(4) 4, 13

Code :

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

PT0084

Match the column

16. Match the column :

Column I

(A) Highest density

(B) Metallic character

(C) Lightest Metal

(D) Liquid at room temperature

Column II

(P) Lithium

(Q) Osmium

(R) Mercury

(S) Bromine

PT0085

17. If electrons are filled in the sub shells of an atom in the following order 1s, 2s, 2p, 3s, 3p, 3d, 4s, 4p, 4d, 4f..... then match the following element in List I with block in List II.

List-I

- (A) K(19)
(B) Fe(26)
(C) Ga(31)
(D) Sn(50)

List-II

- (P) s-Block
(Q) p-Block
(R) d-Block
(S) f-block

PT0086

18. Match the characteristics mentioned in List II with the process in List I.

List I

- (A) $O(g) + e^- \rightarrow O^-(g)$
(B) $O^-(g) + e^- \rightarrow O^{2-}(g)$
(C) $Na^+(g) \rightarrow Na(g) + e^-$
(D) $Mg^+(g) + e^- \rightarrow Mg(g)$

List II

- (P) Positive electron gain enthalpy
(Q) Negative electron gain enthalpy
(R) Exothermic
(S) Endothermic

PT0087

19. Match the column :

Column I

- (A) Cl
(B) F
(C) Cu
(D) He

Column II

- (P) Metal
(Q) Highest negative electron gain enthalpy
(R) Most Electronegative element
(S) Highest ionisation energy.

PT0088

EXERCISE # JEE-MAIN

1. The correct order of electron gain enthalpy with negative sign of F, Cl, Br and I, having atomic number 9, 17, 35 and 53 respectively, is :- [AIEEE-2011]

- (1) $I > Br > Cl > F$ (2) $F > Cl > Br > I$
(3) $Cl > F > Br > I$ (4) $Br > Cl > I > F$

PT0089

2. The increasing order of the ionic radii of the given isoelectronic species is :- [AIEEE-2012]

- (1) $K^+, S^{2-}, Ca^{2+}, Cl^-$ (2) $Cl^-, Ca^{2+}, K^+, S^{2-}$
(3) $S^{2-}, Cl^-, Ca^{2+}, K^+$ (4) $Ca^{2+}, K^+, Cl^-, S^{2-}$

PT0090

3. Which of the following represents the correct order of increasing first ionization enthalpy for Ca, Ba, S, Se and Ar ? [JEE-MAIN-2013]

- (1) $Ca < S < Ba < Se < Ar$ (2) $S < Se < Ca < Ba < Ar$
(3) $Ba < Ca < Se < S < Ar$ (4) $Ca < Ba < S < Se < Ar$

PT0091

4. The first ionisation potential of Na is 5.1 eV. The value of electron gain enthalpy of Na^+ will be :- [JEE-MAIN-2013]

- (1) -2.55 eV (2) -5.1 eV (3) -10.2 eV (4) $+2.55$ eV

PT0092

5. Electron gain enthalpy with negative sign of fluorine is less than that of chlorine due to :

[JEE-MAIN 2013 (On-Line)]

- (1) Smaller size of chlorine atom (2) Bigger size of 2p orbital of fluorine
(3) High ionization enthalpy of fluorine (4) Smaller size of fluorine atom

PT0093

6. Given [JEE-MAIN 2013 (On-Line)]

Reaction	Energy Change (in kJ)
$Li(s) \longrightarrow Li(g)$	161
$Li(g) \longrightarrow Li^+(g)$	520
$\frac{1}{2} F_2(g) \longrightarrow F(g)$	77
$F(g) + e^- \longrightarrow F^-(g)$	(Electron gain enthalpy)
$Li^+(g) + F^-(g) \longrightarrow LiF(s)$	-1047
$Li(s) + \frac{1}{2} F_2(g) \longrightarrow LiF(s)$	-617

Based on data provided, the value of electron gain enthalpy of fluorine would be :

- (1) -300 kJ mol⁻¹ (2) -328 kJ mol⁻¹ (3) -350 kJ mol⁻¹ (4) -228 kJ mol⁻¹

PT0094

7. The order of increasing sizes of atomic radii among the elements O, S, Se and As is :
[JEE-MAIN 2013 (On-Line)]

(1) $\text{As} < \text{S} < \text{O} < \text{Se}$ (2) $\text{O} < \text{S} < \text{As} < \text{Se}$
(3) $\text{Se} < \text{S} < \text{As} < \text{O}$ (4) $\text{O} < \text{S} < \text{Se} < \text{As}$

PT0095

8. Which is the correct order of second ionization potential of C, N, O and F in the following ?
[JEE-MAIN 2013 (On-Line)]

(1) $\text{O} > \text{F} > \text{N} > \text{C}$ (2) $\text{O} > \text{N} > \text{F} > \text{C}$
(3) $\text{C} > \text{N} > \text{O} > \text{F}$ (4) $\text{F} > \text{O} > \text{N} > \text{C}$

PT0096

9. Which of the following series correctly represents relations between the elements from X to Y ?
[JEE-MAIN 2014 (On-Line)]

$\text{X} \longrightarrow \text{Y}$

(1) ${}_{18}\text{Ar} \rightarrow {}_{54}\text{Xe}$ Noble character increases
(2) ${}_3\text{Li} \rightarrow {}_{19}\text{K}$ Ionization enthalpy increases
(3) ${}_6\text{C} \rightarrow {}_{32}\text{Ge}$ Atomic radii increases
(4) ${}_9\text{F} \rightarrow {}_{35}\text{Br}$ Electron gain enthalpy with negative sign increases

PT0097

10. The ionic radii (in Å) of N^{3-} , O^{2-} and F^{-} are respectively :- [JEE-MAIN 2015 (Off-Line)]
(1) 1.71, 1.40 and 1.36 (2) 1.71, 1.36 and 1.40
(3) 1.36, 1.40 and 1.71 (4) 1.36, 1.71 and 1.40

PT0098

11. In the long form of the periodic table, the valence shell electronic configuration of $5s^2 5p^4$ corresponds to the element present in:
[JEE-MAIN 2015 (On-Line)]
(1) Group 16 and period 5 (2) Group 17 and period 6
(3) Group 17 and period 5 (4) Group 16 and period 6

PT0099

12. Which of the following atoms has the highest first ionization energy ?
[JEE-MAIN 2016 (Off-Line)]
(1) Sc (2) Rb (3) Na (4) K

PT0100

13. The non-metal that does not exhibit positive oxidation state is :
[JEE-MAIN 2016 (On-Line)]
(1) Oxygen (2) Fluorine (3) Iodine (4) Chlorine

PT0101

14. The electronic configuration with the highest ionization enthalpy is:- [JEE-MAIN 2017]
(1) $[\text{Ar}] 3d^{10} 4s^2 4p^3$ (2) $[\text{Ne}] 3s^2 3p^1$
(3) $[\text{Ne}] 3s^2 3p^2$ (4) $[\text{Ne}] 3s^2 3p^3$

PT0102

15. Consider the following ionization enthalpies of two elements 'A' and 'B' :

Element	Ionization enthalpy (kJ/mol)		
	1 st	2 nd	3 rd
A	899	1757	14847
B	737	1450	7731

[JEE-MAIN 2017]

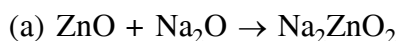
Which of the following statements is correct ?

- (1) Both A and B belong to group-2 where A comes below B
- (2) Both A and B belong to group-1 where A comes below B
- (3) Both A and B belong to group-1 where B comes below A
- (4) Both A and B belong to group-2 where B comes below A

PT0103

16. In the following reactions, ZnO is respectively acting as a/an :

[JEE-MAIN 2017]

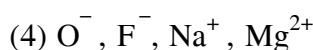
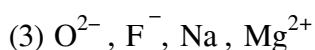
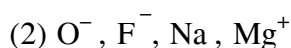
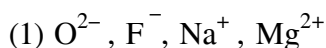


- (1) base and acid (2) base and base (3) acid and acid (4) acid and base

PT0104

17. The group having isoelectronic species is :-

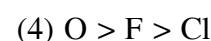
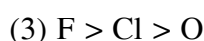
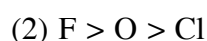
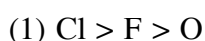
[JEE-MAIN 2017]



PT0105

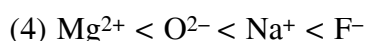
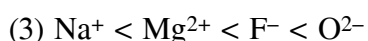
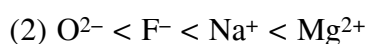
18. The correct order of electron affinity is :-

[JEE-MAIN 2018]



PT0106

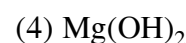
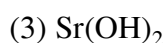
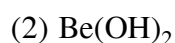
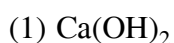
19. For Na^+ , Mg^{2+} , F^- and O^{2-} ; the correct order of increasing ionic radii is : [JEE-MAIN 2018]



PT0107

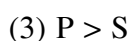
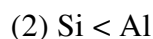
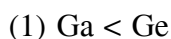
20. The amphoteric hydroxide is :

[JEE-MAIN ONLINE 2019]



PT0108

21. The correct option with respect to the Pauling electronegativity values of the elements is :-



[JEE-MAIN ONLINE 2019]

PT0109

22. The effect of lanthanoid contraction in the lanthanoid series of elements by and large means :
 (1) decrease in both atomic and ionic radii [JEE-MAIN ONLINE 2019]
 (2) increase in atomic radii and decrease in ionic radii
 (3) increase in both atomic and ionic radii
 (4) decrease in atomic radii and increase in ionic radii
PT0110
23. When the first electron gain enthalpy ($\Delta_{eg}H$) of oxygen is -141 kJ/mol , its second electron gain enthalpy is :
 (1) almost the same as that of the first [JEE-MAIN ONLINE 2019]
 (2) negative , but less negative than the first
 (3) a positive value
 (4) a more negative value than the first
PT0111
24. The correct order of hydration enthalpies of alkali metal ions is - [JEE-MAIN ONLINE 2019]
 (1) $\text{Li}^+ > \text{Na}^+ > \text{K}^+ > \text{Rb}^+ > \text{Cs}^+$
 (2) $\text{Li}^+ > \text{Na}^+ > \text{K}^+ > \text{Cs}^+ > \text{Rb}^+$
 (3) $\text{Na}^+ > \text{Li}^+ > \text{K}^+ > \text{Rb}^+ > \text{Cs}^+$
 (4) $\text{Na}^+ > \text{Li}^+ > \text{K}^+ > \text{Cs}^+ > \text{Rb}^+$
PT0112
25. The IUPAC symbol for the element with atomic number 119 would be : [JEE-MAIN ONLINE 2019]
 (1) unh (2) uun (3) une (4) uue
PT0113
26. The element having greatest difference between its first and second ionization energies, is :
 (1) Ca (2) K (3) Ba (4) Sc [JEE-MAIN ONLINE 2019]
PT0114
27. The correct statements among I to III regarding group 13 element oxides are,
 (I) Boron trioxide is acidic. [JEE-MAIN ONLINE 2019]
 (II) Oxides of aluminium and gallium are amphoteric.
 (III) Oxides of indium and thallium are basic.
 (1) (I), (II) and (III) (2) (II) and (III) only (3) (I) and (III) only (4) (I) and (II) only
PT0115
28. Consider the hydrated ions of Ti^{2+} , V^{2+} , Ti^{3+} and Sc^{3+} . The correct order of their spin-only magnetic moments is :
 (1) $\text{Sc}^{3+} < \text{Ti}^{3+} < \text{Ti}^{2+} < \text{V}^{2+}$ [JEE-MAIN ONLINE 2019]
 (2) $\text{Ti}^{3+} < \text{Ti}^{2+} < \text{Sc}^{3+} < \text{V}^{2+}$
 (3) $\text{Sc}^{3+} < \text{Ti}^{3+} < \text{V}^{2+} < \text{Ti}^{2+}$
 (4) $\text{V}^{2+} < \text{Ti}^{2+} < \text{Ti}^{3+} < \text{Sc}^{3+}$
PT0116

29. The pair that has similar atomic radii is :

[JEE-MAIN ONLINE 2019]

- (1) Sc and Ni (2) Ti and Hf (3) Mo and W (4) Mn and Re

PT0117

30. Within each pair of elements of F & Cl, S & Se, and Li & Na, respectively, the elements that release more energy upon an electron gain are-
[JEE-MAIN ONLINE 2020]

- (1) F, Se and Na
(2) F, S and Li
(3) Cl, S and Li
(4) Cl, Se and Na

PT0118

31. The atomic radius of Ag is closest to :

[JEE-MAIN ONLINE 2020]

- (1) Cu (2) Hg (3) Au (4) Ni

PT0119

32. The third ionization enthalpy is minimum for :

[JEE-MAIN ONLINE 2020]

- (1) Fe (2) Ni (3) Co (4) Mn

PT0120

33. B has a smaller first ionization enthalpy than Be. Consider the following statements :

- (I) It is easier to remove 2p electron than 2s electron
(II) 2p electron of B is more shielded from the nucleus by the inner core of electrons than the 2s electrons of Be.
(III) 2s electron has more penetration power than 2p electron.
(IV) atomic radius of B is more than Be
(Atomic number B = 5, Be = 4)

The correct statements are :

[JEE-MAIN ONLINE 2020]

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

PT0121

EXERCISE # JEE-ADVANCED

1. **Statement-1** : F atom has a less negative electron gain enthalpy than Cl atom. [JEE 2000]
Statement-2 : Additional electron is repelled more efficiently by 3p electron in Cl atom than by 2p electron in F atom.
 (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
 (B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
 (C) Statement-1 is true, statement-2 is false.
 (D) Statement-1 is false, statement-2 is true.
- PT0122
2. The correct order of radii is: [JEE 2000]
 (A) $N < Be < B$ (B) $F^- < O^{2-} < N^{3-}$ (C) $Na < Li < K$ (D) $Fe^{3+} < Fe^{2+} < Fe^{4+}$
- PT0123
3. The IE_1 of Be is greater than that of B. [T/F] [JEE 2001]
 PT0124
4. The set representing correct order of IP_1 is [JEE 2001]
 (A) $K > Na > Li$ (B) $Be > Mg > Ca$ (C) $B > C > N$ (D) $Fe > Si > C$
- PT0125
5. Identify the least stable ion amongst the following: [JEE 2002]
 (A) Li^- (B) Be^- (C) B^- (D) C^-
- PT0126
6. The increasing order of atomic radii of the following group 13 elements is [JEE 2016]
 (A) $Al < Ga < In < Tl$ (B) $Ga < Al < In < Tl$
 (C) $Al < In < Ga < Tl$ (D) $Al < Ga < Tl < In$
- PT0127
7. The option(s) with only amphoteric oxides is (are): [JEE 2017]
 (A) Cr_2O_3 , CrO , SnO , PbO
 (B) NO , B_2O_3 , PbO , SnO_2
 (C) Cr_2O_3 , BeO , SnO , SnO_2
 (D) ZnO , Al_2O_3 , PbO , PbO_2
- PT0128

ANSWERS KEY

EXERCISE # O-1

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

EXERCISE # O-2

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	A,B,C,D	A, B, D	A, C	B, C	A, B, C	A, B	B, D	A, B	B, C	A,B,C,D
Que.	11	12	13	14	15	16	17			
Ans.	A, B, D	A, B	A, C, D	B, C, D	A, B, D	A, B, C	A, C			

EXERCISE # S-1

Que.	1	2	3	4	5	6	7	8	9	10
Ans.	6	4	3	3	4	0	3	3	17	4
Que.	11	12	13							
Ans.	5	3.03 (Pauling)	$Mg^{2+} < Na^{+} < F^{-} < O^{2-} < N^{3-}$							

EXERCISE # S-2

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

EXERCISE # JEE-MAIN

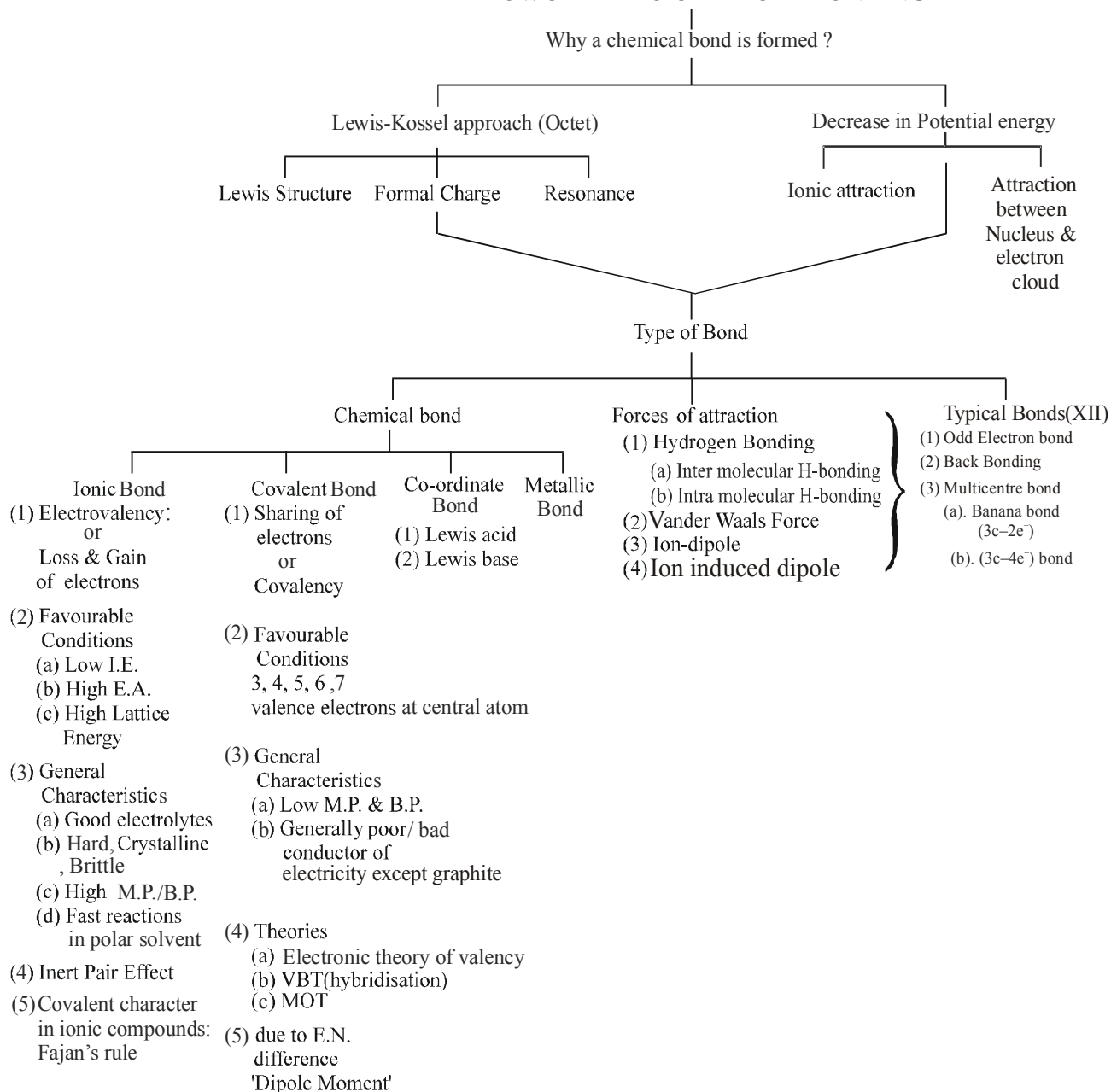
Que.	1	2	3	4	5	6	7	8	9	10
Ans.	3	4	3	2	4	2	4	1	3	1
Que.	11	12	13	14	15	16	17	18	19	20
Ans.	1	1	2	4	4	4	1	1	1	2
Que.	21	22	23	24	25	26	27	28	29	30
Ans.	1	1	3	1	4	2	1	1	3	3
Que.	31	32	33							
Ans.	3	1	1							

EXERCISE # JEE-ADVANCED

Que.	1	2	3	4	5	6	7			
Ans.	C	B	T	B	B	B	C, D			

CHEMICAL BONDING

FLOWCHART TO CHEMICAL BONDING



KEY CONCEPT

CHEMICAL BOND

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

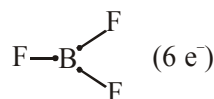
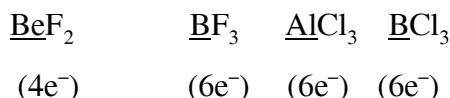
CAUSE OF CHEMICAL COMBINATION

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

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

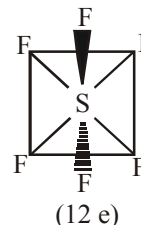
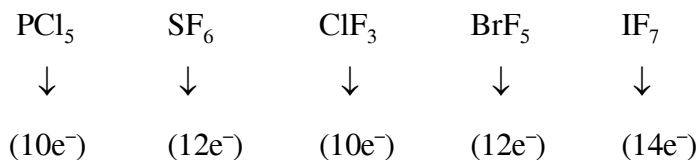
LIMITATION OF OCTET RULE

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



These compounds are hypovalent.

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



These compounds are hypervalent.

3. **Odd electron species**

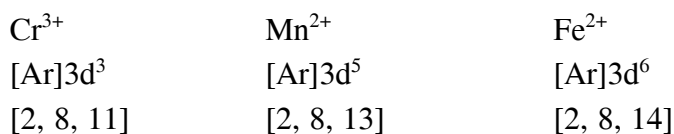
Ex. NO, NO₂, ClO₂ etc.

OTHER EXCEPTIONS OF OCTET RULE

1. **Compounds of Noble gases**

Noble gases which have already completed their octets (or duplet in case of He.) should not form compounds. However, their compounds like XeF₂, XeF₆ & KrF₂ etc., have been actually prepared.

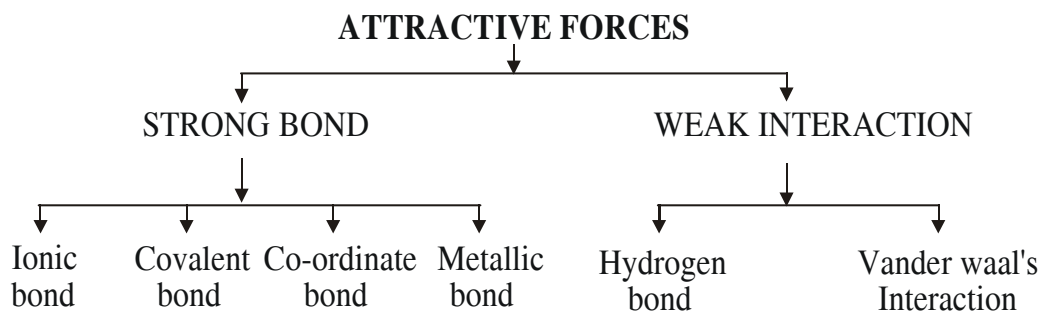
2. **Transition metal ions**



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



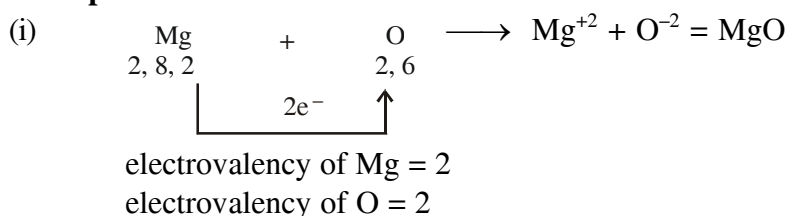
CLASSIFICATION OF BONDS



ELECTROVALENT OR IONIC BOND

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

Example



Note : Ionic bond is non-directional.

FACTORS FAVOURING IONIC BONDING

- Less Ionization energy of atom forming cation
- Higher electron affinity of atom forming anion
- Greater Lattice energy of formed product.
- Greater Electronegativity difference between atoms forming cation & anion.

COVALENT BOND

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

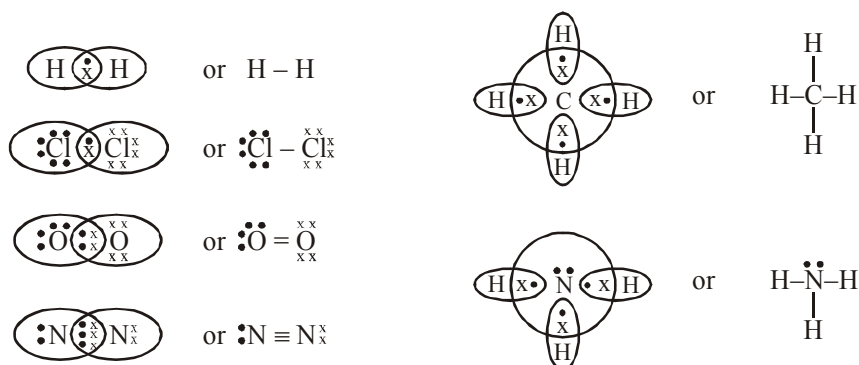


(b) The shared pair of electrons must have opposite spins, and are localised between two atoms concerned.

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

Covalency : Capacity to form covalent bond is known as covalency

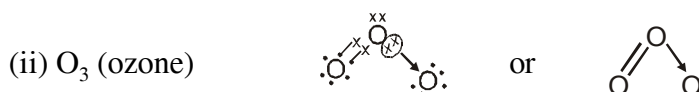
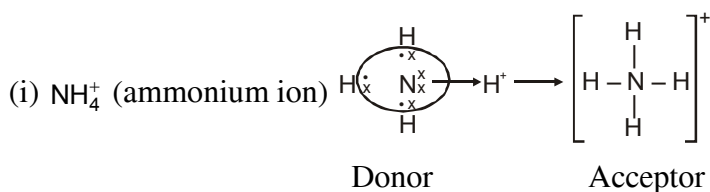
It is represented by (–) small line. – means single bond ; = means double bond ; ≡ means triple bond.



★ Covalent bonds are directional in nature

COORDINATE BOND (DATIVE BOND)

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

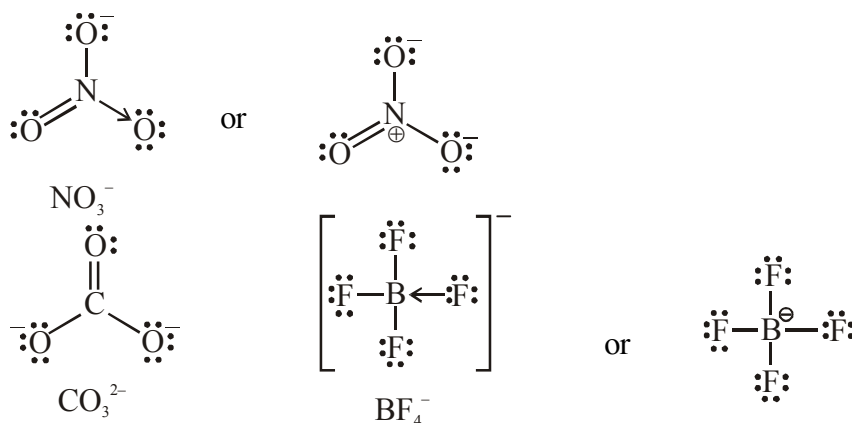


Lewis Dot structures:

- ✦ Arrangement of various atoms in a molecule & types of bonding present in it but no idea of geometry of the molecule.
- ✦ In most cases we can construct a Lewis structure in three steps :
 - (1) Decide on the number of electrons that are included in the structure by adding together the number of all the valence electrons provided by the atoms.
 - (2) Write the chemical symbols of the atoms in the arrangement that shows which atoms are bonded together.
 - (3) Distribute the electrons in pairs so that there is one pair of electrons forming a single bond between each pair of atom bonded together and then supply electron pairs (to form lone pairs or multiple bonds) until each atom has an octet.
- ✦ In oxy acids all 'H' atoms are attached to oxygen as $-\text{OH}$ groups except in H_3PO_3 (dibasic), H_3PO_2 (monobasic) & $\text{H}_4\text{P}_2\text{O}_5$ (dibasic). Which are directly bonded to central atom.

Applications :

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



FORMAL CHARGE

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

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

Where :

N_A = Total number of valence electron in the free atom

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

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

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

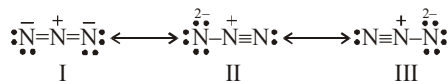
RESONANCE*

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

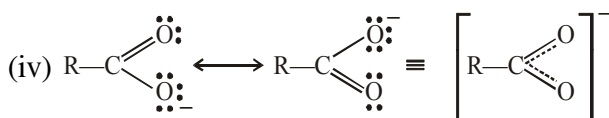
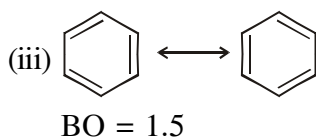
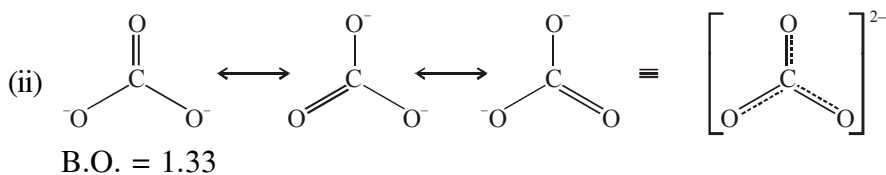
- ❖ Resonance stabilizes the molecule as the energy of the resonance hybrid is less than the energy of any single canonical structure.
- ❖ Resonance averages the bond characteristics as a whole.
- ❖ The canonical forms have no real existence.

Resonance Structure of Some Molecules/Ions :**(i) Azide ion, N_3^- :**

The azide ion may be represented as -



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



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

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

VALENCE BOND THEORY

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

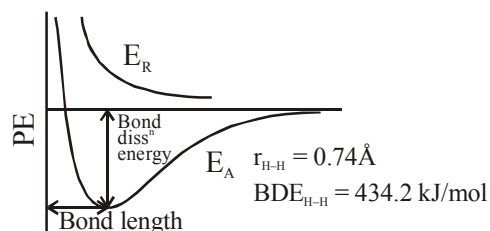
Formation of H_2 molecule :

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

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

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

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

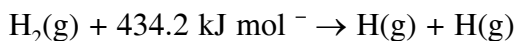


Internuclear separation
The potential energy curve for the formation of H_2 molecule as a function of internuclear distance of the H atoms. The minimum in the curve corresponds to the most stable state of H_2 .

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

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

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



ORBITAL OVERLAP CONCEPT

In the formation of hydrogen molecule, there is a minimum energy state when two hydrogen atoms are so near that their atomic orbitals undergo partial interpenetration. This partial merging of atomic orbitals is called overlapping of atomic orbitals which results in the pairing of electrons. The extent of overlap decides the strength of a covalent bond. In general, greater the overlap the stronger is the bond formed between two atoms. Therefore, according to orbital overlap concept, the formation of a covalent bond between two atoms results by pairing of electrons, present in the valence shell having opposite spins.

Directional Properties of Bonds :

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

Types of Overlapping and Nature of Covalent Bonds

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

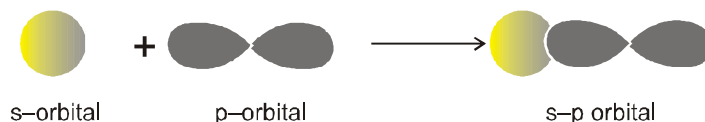
(i) sigma(σ) bond (ii) pi (π) bond (iii) delta(δ) bond

- (i) **Sigma (σ) bond :** This type of covalent bond is formed by the end to end (head on or axial) overlap of bonding orbitals along the internuclear axis. This can be formed by any one of the following types of combinations of atomic orbitals.

- s-s overlapping : In this case, there is overlap of two half filled s-orbitals along the internuclear axis as shown below :



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

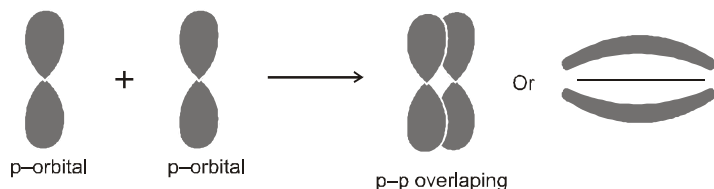


- p-p overlapping : This type of overlap takes place between half filled similar p-orbitals of the two approaching atoms.

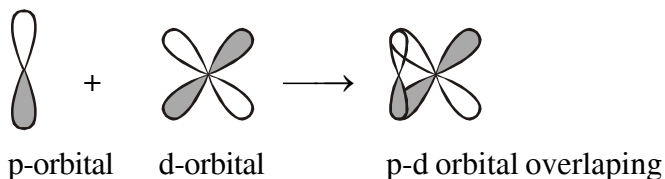


- (ii) **π bond** : In the formation of π bond the atomic orbitals overlap in such a way that their axis remain parallel to each other and perpendicular to the internuclear axis. The orbitals formed due to sidewise overlapping consists of two saucer type charged clouds above and below the plane of the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

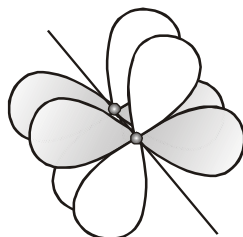
(a) **$p_\pi-p_\pi$**



(b) **$p_\pi-d_\pi$**



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



Strength of sigma and pi Bonds :

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

Advantages of VBT :

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

Disadvantages of VBT :

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

HYBRIDISATION

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

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

1. The number of hybrid orbitals is equal to the number of the atomic orbitals that get hybridised.
2. The hybridised orbitals are always equivalent in energy and shape.
3. The hybrid orbitals are more effective in forming stable bonds than the pure atomic orbitals.
4. These hybrid orbitals are directed in space in some preferred direction to have minimum repulsion between electron pairs and thus a stable arrangement. Therefore, the type of hybridisation indicates the geometry of the molecules.

Important conditions for hybridisation

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

Types of Hybridisation

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

- (i) sp hybridisation
- (ii) sp^2 hybridisation
- (iii) sp^3 hybridisation
- (iv) sp^3d hybridisation:
- (v) sp^3d^2 hybridisation:
- (vi) sp^3d^3 hybridisation:

Determination of hybridisation state –

To predict hybridisation following formula may be used :

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

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

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

Hybridisation in Ionic solid species :

Species	Cationic part	Anionic part
PCl_5	$\text{PCl}_4^+ (\text{sp}^3)$	$\text{PCl}_6^- (\text{sp}^3\text{d}^2)$
PBr_5	$\text{PBr}_4^+ (\text{sp}^3)$	Br^-
XeF_6	$\text{XeF}_5^+ (\text{sp}^3\text{d}^2)$	F^-
N_2O_5	$\text{NO}_2^+ (\text{sp})$	$\text{NO}_3^- (\text{sp}^2)$
$\text{N}_2\text{O}_3(\text{s})$	NO^+	$\text{NO}_2^- (\text{sp}^2)$
$\text{N}_2\text{O}_4(\text{s})$	NO^+	$\text{NO}_3^- (\text{sp}^2)$
$\text{I}_2\text{Cl}_6 (\text{liquid})$	$\text{ICl}_2^+ (\text{sp}^3)$	$\text{ICl}_4^- (\text{sp}^3\text{d}^2)$
$\text{I}_2(\text{liquid})$	$\text{I}_3^+ (\text{sp}^3)$	$\text{I}_3^- (\text{sp}^3\text{d})$
Cl_2O_6	$\text{ClO}_2^+ (\text{sp}^2)$	$\text{ClO}_4^- (\text{sp}^3)$

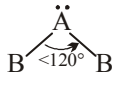
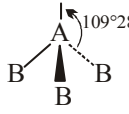
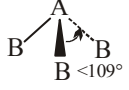
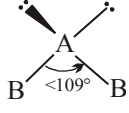
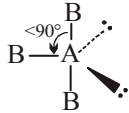
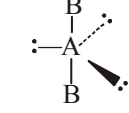
$\text{PF}_5(\text{s})$ exist in form of trigonal bipyramidal geometry.

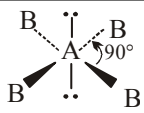
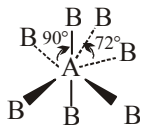
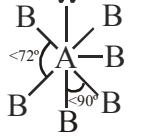
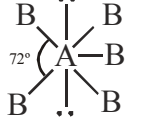
VALENCE SHELL ELECTRON PAIR REPULSION THEORY (VSEPR)

- (a) Molecules having covalent bond have definite geometry as covalent bonding has directional characteristics. A simple theory was given for the molecular shape of the covalent molecules by Gillespie and Nyholm in 1957.
- (b) This theory predicts the shape of the molecule by considering the most stable configuration of the bond angles in the molecule. This theory states
 - (i) Electron pairs in the valence shell of the central atom of a molecule, whether bonding or lone pairs are regarded as occupying localised orbitals. These orbitals arrange themselves in so as to minimize the mutual electronic repulsions.
 - (ii) The magnitude of the different types of electronic repulsions follows the order given below:

lone pair-lone pair > lone pair - bonded pair > bonded pair - bonded pair
 - (iii) The electronic repulsion between two pairs of electrons will be minimum if they are as far apart as possible.
 - (iv) The actual shape of the molecules containing lone pairs is a little distorted from the basic shape as in the NH_3 and H_2O molecules, the bond angles are not $109^\circ 28'$ but 107° and 104.5° respectively due to presence of one lone pair in NH_3 and two lone pairs in H_2O .

SHAPES OF MOLECULES BASED ON VSEPR THEORY

Total no. of hybrid orbitals	No. of b.p. (bond pairs)	No. of unshared pair i.e. l_p	General formula	Type of hybridisation	Stereo chemical formula/str.	Shape	Exam.
2	2	0	AB_2	sp		linear	$BeCl_2$
3	3	0	AB_3	sp^2		Trigonal planar	BCl_3 , NO_3^- , GaF_3 , CO_3^{2-}
3	2	1	AB_2	sp^2		V or Bent or angular	$SnCl_2$, O_3 , SO_2
4	4	0	AB_4	sp^3		Tetrahedron	CH_4 , SiF_4 , NH_4^+
4	3	1	AB_3	sp^3		Trigonal pyramidal	NH_3 , CH_3^-
4	2	2	AB_2	sp^3		V or Bent or angular	H_2O , SF_2
4	1	3	AB	sp^3		linear	ClO^-
5	5	0	AB_5	sp^3d		Trigonal bipyramidal	PF_5 , SF_5^+ , $SbBr_5$, XeO_3F_2
5	4	1	AB_4	sp^3d		Seesaw	SF_4
5	3	2	AB_3	sp^3d		T-shaped	ClF_3 , BrF_3
5	2	3	AB_2	sp^3d		Linear	ICl_2^- , XeF_2 , I_3^-
6	6	0	AB_6	sp^3d^2		Octahedral or Square bipyramidal	SF_6 , IF_6^+
6	5	1	AB_5	sp^3d^2		Square pyramidal	IF_5 , $XeOF_4$, BrF_5

6	4	2	AB_4	sp^3d^2		Square planar	IF_4^- , XeF_4 , ICl_4
7	7	0	AB_7	sp^3d^3		Pentagonal bipyramidal	IF_7
7	6	1	AB_6	sp^3d^3		Distorted octahedral	XeF_6 , IF_6^-
7	5	2	AB_5	sp^3d^3		Pentagonal planar	XeF_5^-

BOND PARAMETERS

(I) Bond order

(III) Bond Angle

(I) Bond order :

The Bond Order is given by the number of bonds between the two atoms in a molecule.

The bond order, for example in H_2 (with a single shared electron pair), in O_2 (with two shared electron pairs) and in N_2 (with three shared electron pairs) is 1,2,3 respectively.

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

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

(II) Bond Length :-

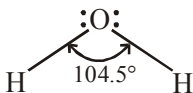
Bond length is defined as the equilibrium distance between the nuclei of two bonded atoms in a molecule. Bond lengths are measured by spectroscopic, X-ray diffraction and electron-diffraction techniques about which you will learn in higher classes.

Factors affecting bond length

- | | |
|-----------------------------|---|
| (a) Size of atoms | (b) Effect of bond order or number of bonds |
| (c) Effect of Resonance | (d) Effect of Electronegativity difference |
| (e) Effect of Hybridisation | |

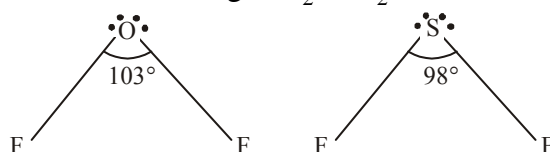
(III) Bond angle :

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



Comparison of bond angles.

- If central atoms are in different hybridisations then it can be compared.
- If same hybridisation but different central atoms then bond angle would be more of the molecule in which central atom is more E.N. eg. OF_2 , SF_2



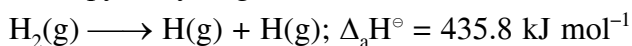
- Molecules having same C.A. but different substituent then bond angle increases as the size of attached atom increases except in symmetrical molecules and H_2O / F_2O , NH_3 / NF_3

Factors affecting bond angle

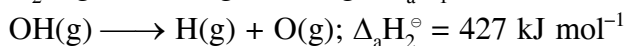
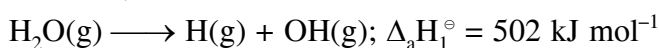
- State of Hybridisation
- Presence of lone pair
- Electronegativity of central atom
- Electronegativity of surrounding atom
- Size of surrounding atom
- Lone pairs may sometimes be transferred from a filled shell of one atom to an unfilled shell of another bonded atom, causing less repulsion.
- Multiple bond orbital repel other orbitals more strongly than single bond orbitals.

(IV) Bond Enthalpy

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

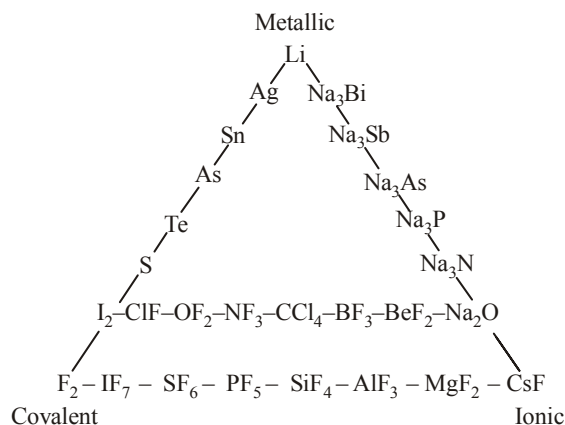


⇒ In polyatomic molecules the **term mean or average bond enthalpy** is used. It is obtained by dividing total bond dissociation enthalpy by the number of bonds broken as explained below in case of water molecule,



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

SUMMARY OF THE THREE MAIN TYPES OF BONDS

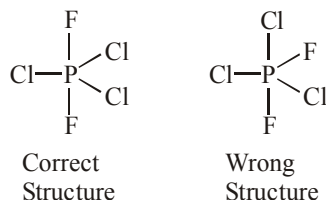


BENT'S RULE

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

Ex. Draw the geometry of PCl_3F_2

Sol.



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

DRAGO'S RULE

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

- (i) Central atom belongs to third or lower period in periodic table
- (ii) Central atom must contain atleast one lone pair of electron, and
- (iii) Electronegativity of surrounding atom is ≤ 2.5

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

In such molecules bond angle is approximately 90° .

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

- Right order of bond angle.

(a) $\text{H}_2\text{O} > \text{H}_2\text{S} > \text{H}_2\text{Se} > \text{H}_2\text{Te}$

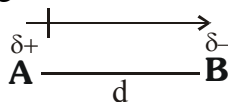
(b) $\text{NH}_3 > \text{PH}_3 > \text{AsH}_3 > \text{SbH}_3$

MOLECULES THAT DO NOT EXIST

- (1) SF_4 , SF_6 & PF_5 exist while. OF_4 , OF_6 , NF_5 do not exist
- (2) (a) $\text{PI}_5(\text{vap})$ & SCl_6 do not exist
(b) SCl_6 does not exist while TeCl_6 exist
(c) PI_5 (Solid) exist
- (3) SF_6 , PF_5 , XeF_6 , XeF_4 & XeF_2 exist while SH_6 , PH_5 , XeH_6 , XeH_4 , XeH_2 do not exist

DIPOLE MOMENT

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



Electronegativity of A < Electronegativity of B

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

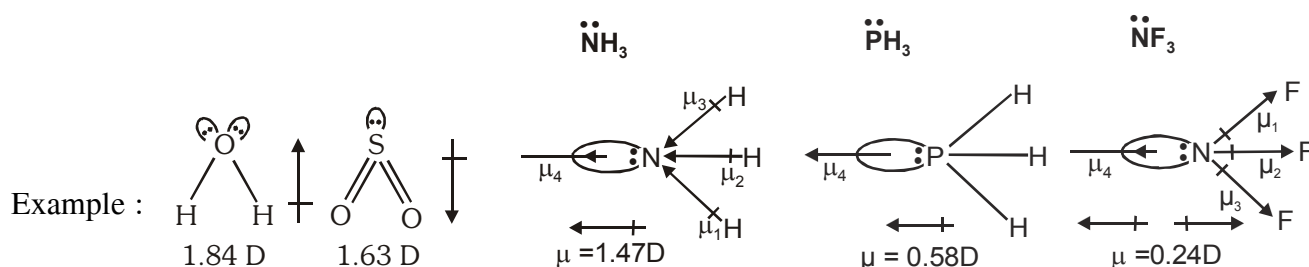
- Dipole moment is a vector quantity.
The direction of dipole moment is represented by $\text{---} \rightarrow$
- Units = Cm (S.I.) or esu cm (CGS) or Debye (common unit)
- 1 D = 10^{-18} esu cm = 3.33×10^{-30} coulomb m

Dipole moment depends on

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

Application of dipole moment

- To determine the polarity and geometry of molecules



- To calculate the percentage of ionic character

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

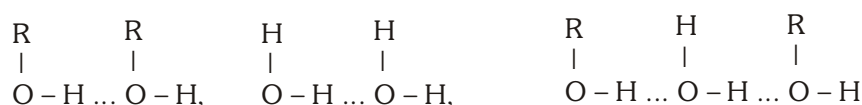
HYDROGEN BONDING

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

Types of H-bonding:

- Intermolecular H-bond

- This type of H-bonding takes place between two molecules. **Ex.** ROH, H_2O , R - OH & H_2O

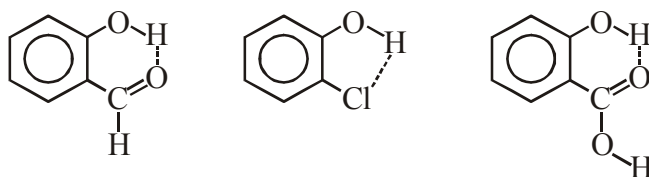


- In such compounds molecular wt., M.P. & B.P. are high.

- Extent of Inter molecular H-bonding \uparrow viscosity & density \uparrow .

★ Intramolecular H-bond

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



Properties influenced by hydrogen bonding

- Abnormal behaviour of water.
- Association of molecules eg. dimerisation of CH_3COOH , HCOOH
- Dissociation of a polar species.
- Abnormal melting point & boiling point.
- Enhanced solubility in water.

★ **Metallic bonds :**

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

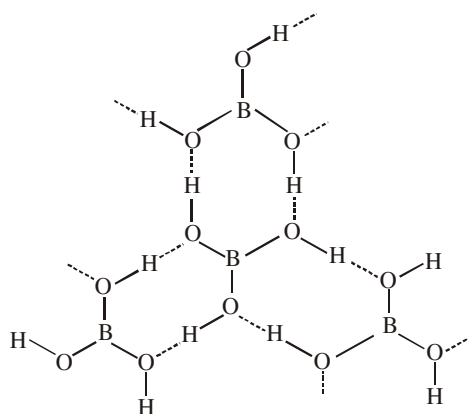
QUESTION OF HYDROGEN BONDING

- Q.1 Explain the structure of Boric acid in solid state.
- Q.2 Boiling point of o-Nitrophenol is less than meta and para nitrophenol. Why?
- Q.3 Maleic acid is more acidic than fumaric acid. Why?
- Q.4 H-F is only liquid among halogen acid. Why?
- Q.5 Ammonia is more easily liquefied than HCl , explain.
- Q.6 Why ice floats on water?
- Q.7 Water shows maximum density at 4°C . Why?
- Q.8 HI is the strongest halogen acid, whereas H-F is the weakest. Why?
- Q.9 Wood pieces are used to hold ice-cream. Why?
- Q.10 KHF_2 is possible but not KBr_2 or KI_2 . Why?
- Q.11 o-Nitrophenol is less soluble in H_2O than p-Nitrophenol. Why?
- Q.12 o-Hydroxy benzaldehyde is a liquid at room temperature while p-hydroxy benzaldehyde is a high melting solid.
- Q.13 Glycerol is more viscous than ethanol. Explain.
- Q.14 CH_4 and H_2O have nearly same molecular weight. Yet CH_4 has a boiling point 112 K and water 373 K. Explain.

- Q.15 The experimental molecular weight of acetic acid is just double than theoretical molecular weight of acetic acid. Why?
- Q.16 Although chlorine has same electronegativity as nitrogen but the former does not form effective H-bonding. Explain.
- Q.17 Molar entropy change of vapourization of acetic acid is less than that of water. Explain
- Q.18 Heat of vapourization of water is higher than HF, however strength of H-bond in HF is higher than water. Explain

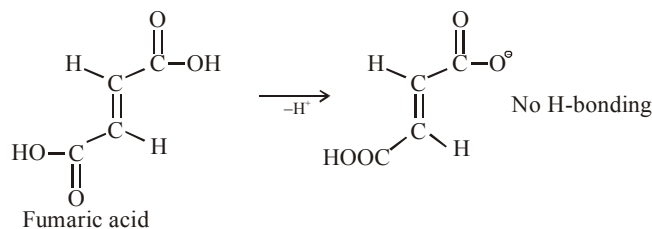
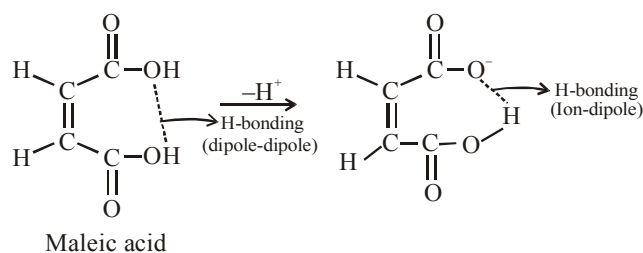
ANSWER OF HYDROGEN BONDING

1.

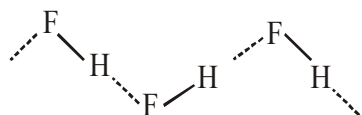


Structure of boric acid; the dotted lines represent hydrogen bonds

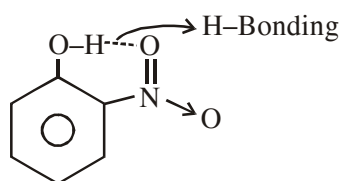
2. Inter molecular H-Bonding in case of para nitro phenol is strong enough to increase boiling point which is not favoured in o-Nitro phenol.
3. Maleic acid anion gets stabilize due to intra molecular H-bonding which is not possible in anion of Fumaric acid. So H^+ releasing tendency is more in case of maleic acid



4. Due to strong H-Bonding in H-F

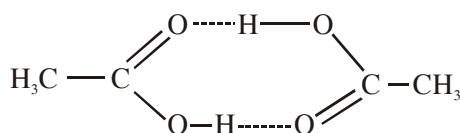


5. Due to H-Bonding in NH_3 .
6. Density of ice is higher than that of water due to cage like structure of ice volume of ice increases and density decreases.
7. On heating ice in temperature range $0-4^\circ\text{C}$ H-bonds of ice break down, which decreases volume, hence density of H_2O increases. On heating ice after 4°C thermal vibrations of H_2O molecules increases which increases effective volume of ice, so density of ice again decreases.
8. H-I bond is weak as compare to H-F so it can be dissociated easily and can give H^+ easily.
9. The organic matter in wood participate in H-bonding with water molecules in ice-cream.
10. $\text{K}^+[\text{F}-\text{H}\cdots\text{F}]$ But KHBr_2 & KHI_2 can't form H-Bond.
 \downarrow
 H-bonding
11. In o-Nitrophenol intra molecular H-bond is present which decreases it's solubility in water.



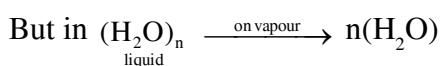
Ortho Nitro-phenol

12. In o-hydroxy benzaldehyde intramolecular H-bond is present which is less stronger than intermolecular H-bond in p-hydroxy benzaldehyde.
13. Extent of H-bonding in glycerol is more as compare to ethanol so it is more viscous.
14. Due to H-bonding in H_2O
15. Due to H-bonding in acetic acid it forms dimer so overall molecular weight is just double of original

Dimer of CH_3COOH

16. Due to bigger size of 'Cl' atom it's interaction is not enough to evolve the amount of energy which lies in the range of H-bond.
17. $(\text{AcOH})_n \xrightarrow[\text{liquid}]{\text{on vapour}} \frac{n}{2} (\text{AcOH})_2$

} Not completely converted



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

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

VANDER WAAL'S FORCES

- ⇒ These are the weakest type of inter molecular forces that exist among the chemical species which bring about significant change in physical properties.
- ⇒ These are non-directional, non-valence cohesive forces. These attractive forces being played between the two molecules are independent of the presence of other molecules.
- ⇒ Solid, liquid or gaseous states of many molecules are explained on the basis of inter molecular forces other than covalent, ionic or metallic bonds. Although inert gases do not form any type of bond but may exist in liquid and solid states. This shows that the atoms of inert gases are attracted by each other through some type of inter molecular forces. These intermolecular forces are called Vander Waals forces.

Types of Vander Waal's Forces

- (1) **Dipole-dipole interaction (Keesom forces)** : The force of attraction between the oppositely charged poles of two polar molecules (for example : H_2S , HCl , PH_3 etc.) is called dipole-dipole attraction.
- (2) **Dipole-induced dipole interaction (Debye forces)** : This type of cohesive forces occurs in a mixture of polar and non polar molecules. The former induce polarity in non polar molecules by disturbing their electron system. for example force of attraction between Cl_2 and H_2O .
- (3) **Instantaneous dipole-Induced dipole interaction (Dispersion forces/London forces)** : The weak intermolecular forces operating in similar non polar gaseous molecules are called London forces. These forces are very weak in nature and exist only at low temperature. For example weak intermolecular forces in F_2 , Cl_2 , N_2 , molecules and in noble gases.

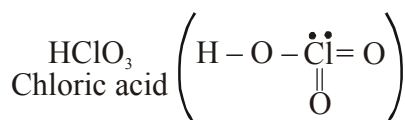
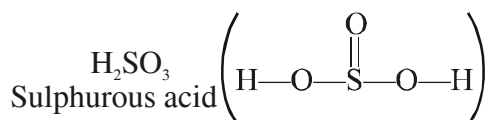
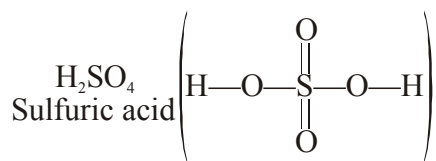
(Note :- London forces present in both polar and non polar species)

Other Weak Interactions

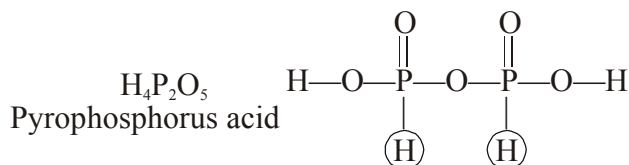
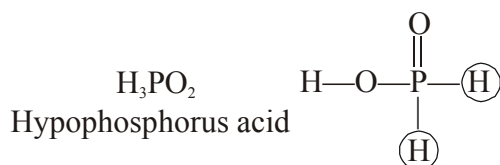
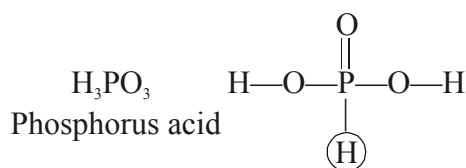
- (1) **Ion-dipole interaction** : Polar molecules are attracted by ions. The negative pole is attracted by cation and positive pole attracted by the anion. This type of attraction is called ion dipole attraction, ion-dipole attraction is observed generally in the process of solvation when sodium chloride ($\text{Na}^+ \text{Cl}^-$) is dissolved in water because negative poles of water aggregate around Na^+ ions and positive poles around Cl^- ions.
- (2) **Ion-induced dipole interaction** : When non polar molecules come in contact with ions, its electron cloud gets polarised and the oppositely charged end of it is attracted by the ion. For example attraction between I^- and I_2 molecule.

□ OXY-ACIDS

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

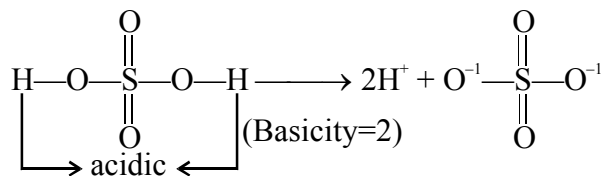


In oxy acids, all the hydrogens are attached with oxygen. Although there are a very few exceptions (as given below), in which all hydrogens are not attached with oxygen.

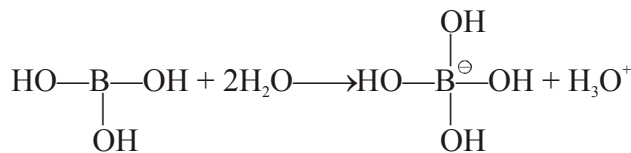


In these three oxyacids circled hydrogens are not attached with oxygen.

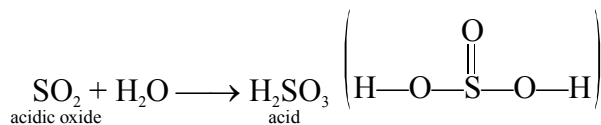
In oxyacids, those hydrogens which are attached with oxygen are acidic in nature, i.e., they ionise in solution.

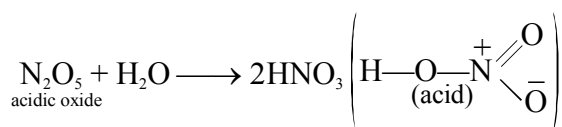
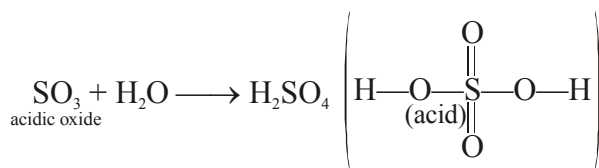


No. of hydrogens attached with oxygen is known as basicity of the acid. One notable exception is H_3BO_3 in which all the three hydrogens are attached with oxygen yet, they do not ionise in solution. In fact, H_3BO_3 when dissolved in water, it behaves as a monobasic acid.



Oxyacids are actually aqueous solutions of acidic oxides.



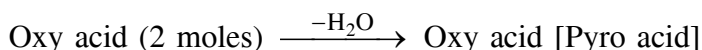


- Some acids have suffix-ic acid and some has-ous acid. Usually, when the central atom in oxy acid is in higher oxidation state the name of the acid ends with -ic acid and when the central atom is in lower oxidation state, it's name ends with -ous acid.

Oxyacids can be classified as

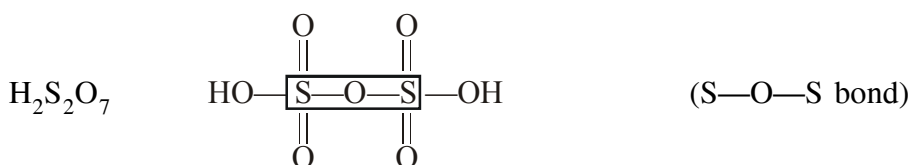
❑ PYRO ACIDS :

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

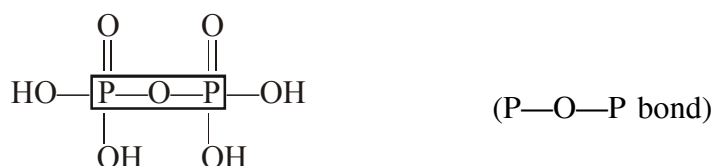


- H_2SO_4 (2 moles) = $\text{H}_4\text{S}_2\text{O}_8 \xrightarrow{-\text{H}_2\text{O}} \text{H}_2\text{S}_2\text{O}_7$ [Pyrosulphuric acid]
[Sulphuric acid]

In general Pyro acids contain X—O—X bond.



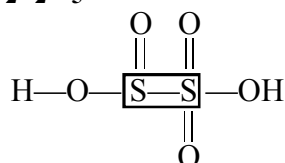
- H_3PO_4 (2 moles) = $\text{H}_6\text{P}_2\text{O}_8 \xrightarrow{-\text{H}_2\text{O}} \text{H}_4\text{P}_2\text{O}_7$ [Pyrophosphoric acid]
[Orthophosphoric acid]



- $2\text{H}_3\text{PO}_3$ (phosphorus acid) $\xrightarrow{-\text{H}_2\text{O}} \text{H}_4\text{P}_2\text{O}_5$ (pyrophosphorus acid) $\text{HO}-\begin{array}{c} \text{O} \quad \text{O} \\ \parallel \quad \parallel \\ \boxed{\text{P}-\text{O}-\text{P}}-\text{OH} \\ \parallel \quad \parallel \\ \text{H} \quad \text{H} \end{array}$

- $2\text{H}_2\text{SO}_3 \xrightarrow{-\text{H}_2\text{O}} \text{H}_2\text{S}_2\text{O}_5$ (Pyrosulfurous acid)

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

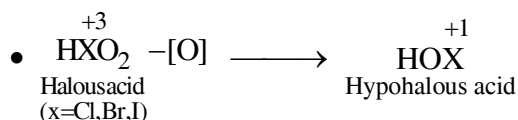
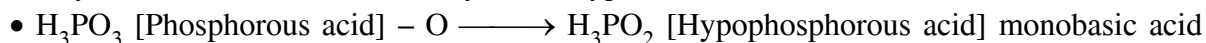


Pyrosulfurous acid

HYPO ACID :

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

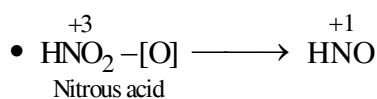
Oxy acid(-ous form) $\xrightarrow{-O}$ Oxy acid (Hypo -ous acid)



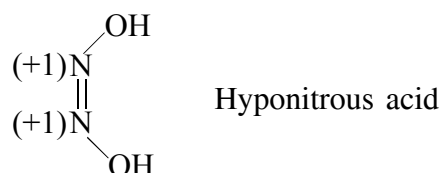
HOCl - Hypochlorous acid

HOBr - Hypobromous acid

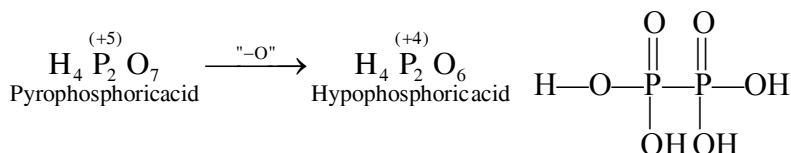
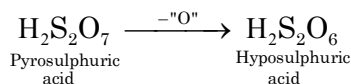
HOI - Hypoiodous acid



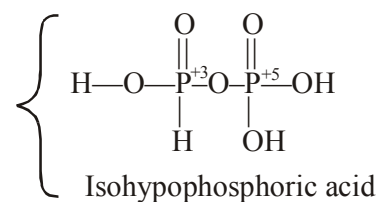
HNO exist in dimeric form i.e. as $(\text{HNO})_2 = \text{H}_2\text{N}_2\text{O}_2$



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

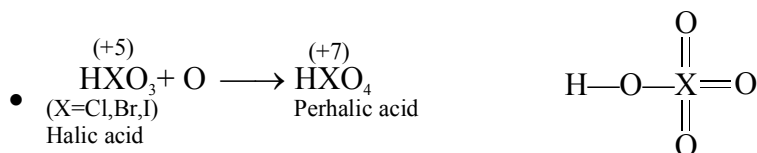


Exception : (It may be exist as isohypophosphoric acid)



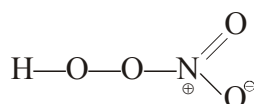
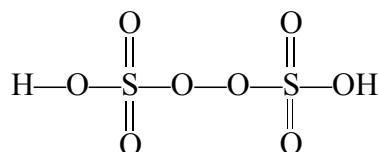
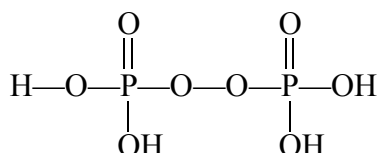
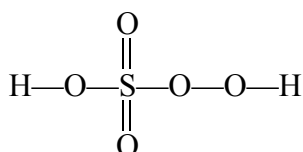
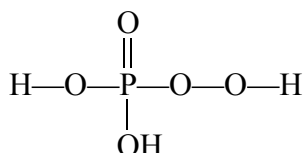
PER ACID AND PEROXY ACID :

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

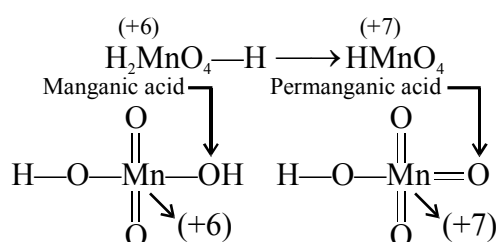


HClO_4 perchloric acid HBrO_4 - Perbromic acid.

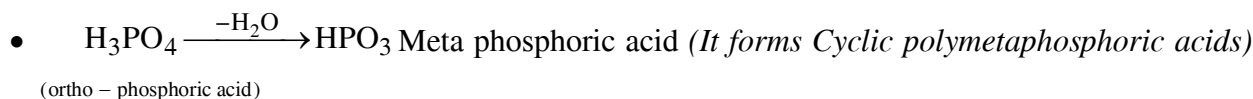
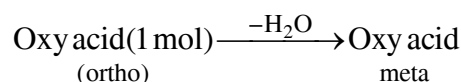
Peroxy prefix is added to those oxy acids which are obtained when one oxygen is added to -ic form of acid and the oxidation number of central atom remains the same. Peroxy acids contain peroxy linkage ($-\text{O}-\text{O}-$).



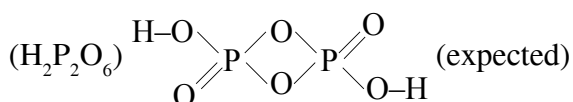
Exception : $\text{H}_2\overset{+6}{\text{MnO}_4}$ is manganic acid when one hydrogen is removed from H_2MnO_4 , HMnO_4 is formed which is named as permanganic acid.

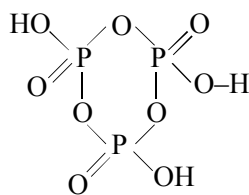


When one mole of H_2O is removed from one mole of an oxy acid, the resulting compound, if an oxy acid (i.e. it contains at least one $\text{X}-\text{OH}$ bond) then the oxy acid from which H_2O is removed is named as ortho acid and the product oxyacid is known as META ACID.

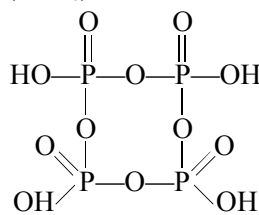


- ◆ **Cyclic polymetaphosphoric acids :**
(HPO₃)_n - Dimetaphosphoric acid

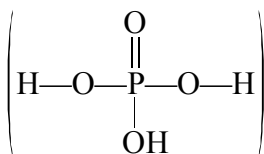




Trimetaphosphoric acid

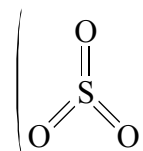
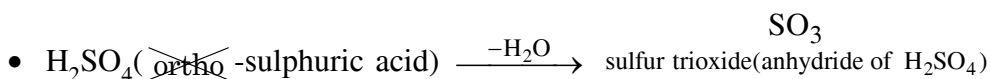
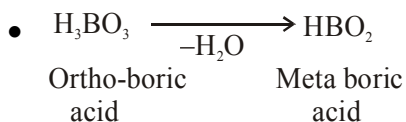


Tetrametaphosphoric acid



Orthophosphoric acid

An ortho acid must contain at least three hydrogens.

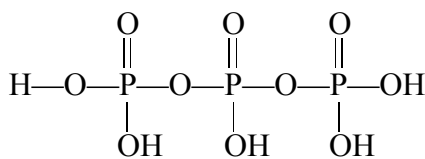


As SO_3 does not contain any hydrogen (i.e., X-OH/S-OH bond), so SO_3 is not an oxy acid rather it is anhydride of sulphuric acid (H_2SO_4) so, H_2SO_4 can't be prefixed with ortho, and its name does not contain any prefix and it is named as sulphuric acid.

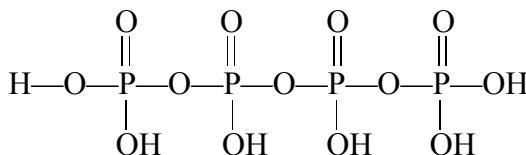
☐ POLYPHOSPHORIC ACID :

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

$\text{H}_5\text{P}_3\text{O}_{10}$ - Tripolyphosphoric acid

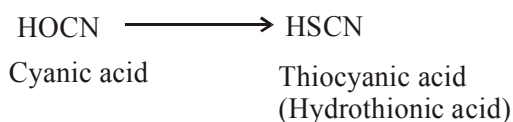
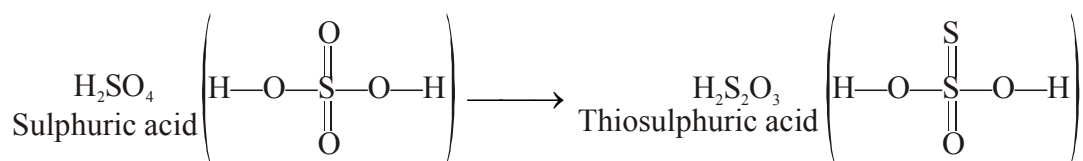


$\text{H}_6\text{P}_4\text{O}_{13}$ - Tetrapolyphosphoric acid

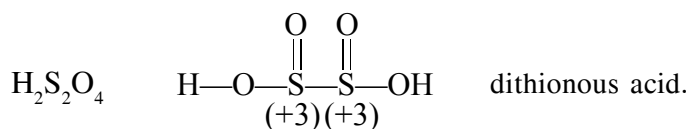


❑ **THIO ACID :**

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



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



Thionic acids : Oxy acids of sulphur containing S—S bond and having general formula $\text{H}_2\text{S}_{(n+2)}\text{O}_6$ are known as thionic acids

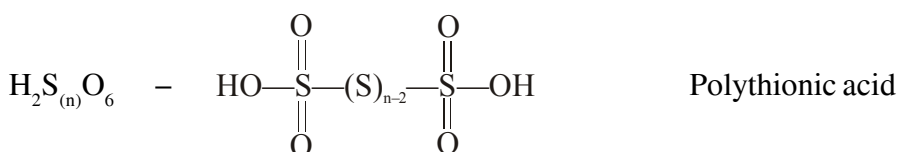
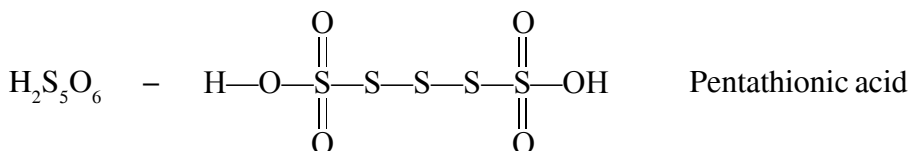
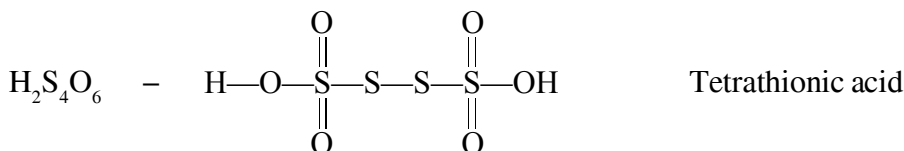
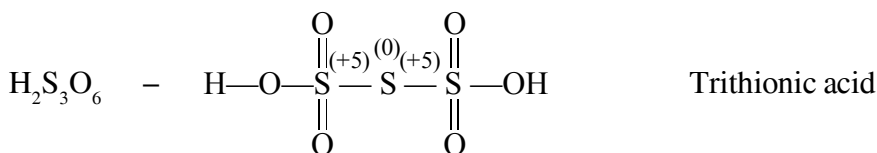


TABLE OF OXIDATION STATE OF OXY-ACIDS :

Element	-Ous acid	-ic acid
P	<p>(+3, H_3PO_3, $\text{H}_4\text{P}_2\text{O}_5$)</p> <p>(+2, H_3PO_2)</p>	<p>(+4) $\text{H}_4\text{P}_2\text{O}_6$ (Hypophosphoric acid)</p> <p>+5 $\begin{cases} \rightarrow \text{H}_{n+2}\text{P}_n\text{O}_{3n+1} - \text{polyphosphoric acid} \\ \rightarrow \text{H}_3\text{PO}_4, \text{H}_4\text{P}_2\text{O}_7, \text{H}_4\text{P}_2\text{O}_8 \\ \rightarrow \text{H}_3\text{PO}_5 - \text{peroxymonophosphoric acid} \end{cases}$</p>
S	<p>(+4) H_2SO_3 Sulfurous acid</p> $\begin{array}{c} \text{O} \quad \text{O} \\ \parallel \quad \parallel \\ \text{H}-\text{O}-\text{S}-\text{S}-\text{OH} \\ \text{(+3)} \quad \text{(+5)} \\ \parallel \quad \parallel \\ \text{O} \quad \text{O} \end{array}$ <p>Pyrosulfurous acid</p>	<p>(+6) Sulphuric acid (H_2SO_4)</p> <p>$\text{H}_2\text{S}_2\text{O}_7$ - Pyrosulphuric acid</p> <p>$\text{H}_2\text{S}_{(n+2)}\text{O}_6$ - Thionic acids</p> $\begin{array}{c} \text{O} \quad \text{O} \quad \text{(+5)} \\ \parallel \quad \parallel \quad \parallel \\ \text{H}-\text{O}-\text{S}-\text{S}-\text{S}-\text{OH} \\ \parallel \quad \parallel \quad \parallel \\ \text{O} \quad \text{O} \quad \text{O} \end{array}$ <p>e.g : Dithionic acid</p>
	$\begin{array}{c} \text{O} \quad \text{O} \\ \parallel \quad \parallel \\ \text{H}_2\text{S}_2\text{O}_4 \quad \text{H}-\text{O}-\text{S}-\text{S}-\text{OH} \\ \text{(+3)} \quad \text{(+3)} \\ \parallel \quad \parallel \\ \text{O} \quad \text{O} \end{array}$ <p>dithionous acid</p>	$\begin{array}{c} \text{O} \quad \text{(+5)} \quad \text{O} \quad \text{(+5)} \\ \parallel \quad \parallel \quad \parallel \quad \parallel \\ \text{H}-\text{O}-\text{S}-\text{S}-\text{S}-\text{S}-\text{OH} \\ \parallel \quad \parallel \quad \parallel \quad \parallel \\ \text{O} \quad \text{(0)} \quad \text{(0)} \quad \text{O} \end{array}$ <p>Tetrathionic acid</p> <p>(+6) H_2SO_5 - Peroxymonosulfuric acid</p> <p>(+6) $\text{H}_2\text{S}_2\text{O}_8$ - Peroxydisulfuric acid</p>
X (X=Cl, Br, I)	<p>(+1) $\text{H}-\text{O}-\text{X}$ Hypohalous acid</p> <p>e.g. $\text{H}-\text{O}-\text{Cl}$ - Hypochlorous acid</p> <p>$\text{H}-\text{O}-\text{I}$ - Hypoiodous acid (+3) HXO_2; $\text{H}-\text{O}-\text{X}=\text{O}$ Halous acid $\text{H}-\text{O}-\text{I}=\text{O}$ - Iodous acid</p>	<p>(+5) Halic acid (HXO_3)</p> $\begin{array}{c} \text{O} \\ \parallel \\ \text{H}-\text{O}-\text{X}=\text{O} \\ \text{(+5)} \end{array}$ <p>$\begin{array}{c} \text{O} \\ \parallel \\ \text{H}-\text{O}-\text{Cl}=\text{O} \end{array}$ [Chloric acid]</p> <p>(+7) Perhalic acid (HXO_4)</p> $\begin{array}{c} \text{O} \\ \parallel \\ \text{H}-\text{O}-\text{Br}=\text{O} \\ \parallel \\ \text{O} \end{array}$ <p>e.g. [Perbromic acid]</p>
Others		<p>(+3) H_3BO_3 Orthoboric acid</p> <p>(+3) HBO_2 - Metaboric acid</p> <p>(+4) Orthosilicic acid H_4SiO_4</p> <p>H_2SiO_3 - Metasilicic acid</p> <p>$\text{H}_6\text{Si}_2\text{O}_7$ - Pyrosilicic acid</p>

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

H_2SO_4
Sulphuric acid

H_3PO_4
Orthophosphoric acid

HPO_3
meta phosphoric acid

$HClO_3$
chloric acid

$HClO_4$
Perchloric acid

H_3PO_4
Orthophosphoric acid
 $(HPO_3)_6 = H_6P_6O_{18}$
Hexametaphosphoric acid

HBO_2
metaboric acid

H_2SO_5
Peroxysulphuric acid

$H_4P_2O_7$
Pyrophosphoric acid

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

$HClO_2$
chlorous acid

H_3PO_3
Phosphorous acid
(dibasic acid)

H_2SO_3
sulfurous acid

HNO_2
Nitrous acid

$HOCl$

Na_2SO_4 - Sodium sulfate

K_2SO_4 - Potassium sulfate

$BaSO_4$ - Barium sulfate

$FeSO_4$ - Ferrous sulfate

$Al_2(SO_4)_3$ - Aluminium sulfate

Na_3PO_4 - Sodium orthophosphate

K_3PO_4 - Potassium orthophosphate

$Ca_3(PO_4)_2$ - Calcium Orthophosphate

$AlPO_4$ - Aluminium orthophosphate

$NaPO_3$ - Sodium metaphosphate

KPO_3 - Potassium metaphosphate

$Ca(PO_3)_2$ - Calcium metaphosphate

$Al(PO_3)_3$ - Aluminium metaphosphate

$KClO_3$ - Potassium chlorate

$NaClO_3$ - Sodium chlorate

$Ca(ClO_3)_2$ - Calcium chlorate

$NaClO_4$ - Sodium perchlorate

$KClO_4$ - Potassium perchlorate

NH_4ClO_4 - Ammonium perchlorate

$Ca(ClO_4)_2$ - Calcium perchlorate

KH_2PO_4 potassium dihydrogen orthophosphate

$Ca(H_2PO_4)_2$ calcium dihydrogen orthophosphate

$Na_6P_6O_{18}$

Sodium hexametaphosphate

$NaBO_2$ sodium metaborate

Na_2SO_5 - Sodium peroxysulfate

$Na_4P_2O_7$ - Sodium pyrophosphate

$NaClO_2$ sodium chlorite

$KClO_2$ potassium chlorite

$Ca(ClO_2)_2$ calcium chlorite

Na_2HPO_3 sodium phosphite

K_2HPO_3 Potassium phosphite

$CaHPO_3$ calcium phosphite

Na_2SO_3 sodium sulfite

K_2SO_3 potassium sulfite

$NaNO_2$ sodium nitrite

KNO_2 potassium nitrite

$NaOCl$ sodium hypochlorite

Hypochlorous acid

KOBr potassium hypobromite



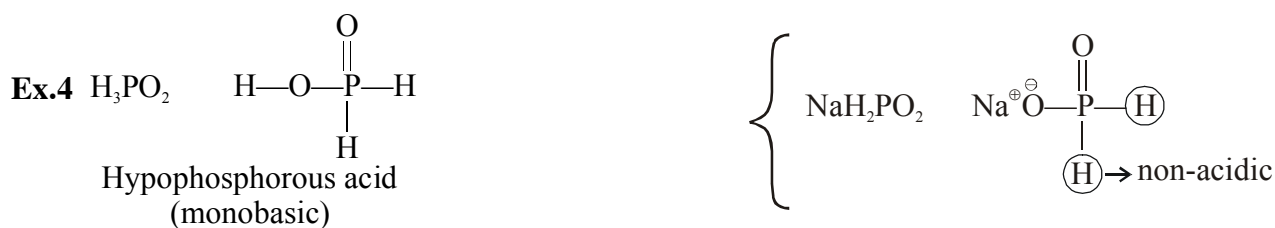
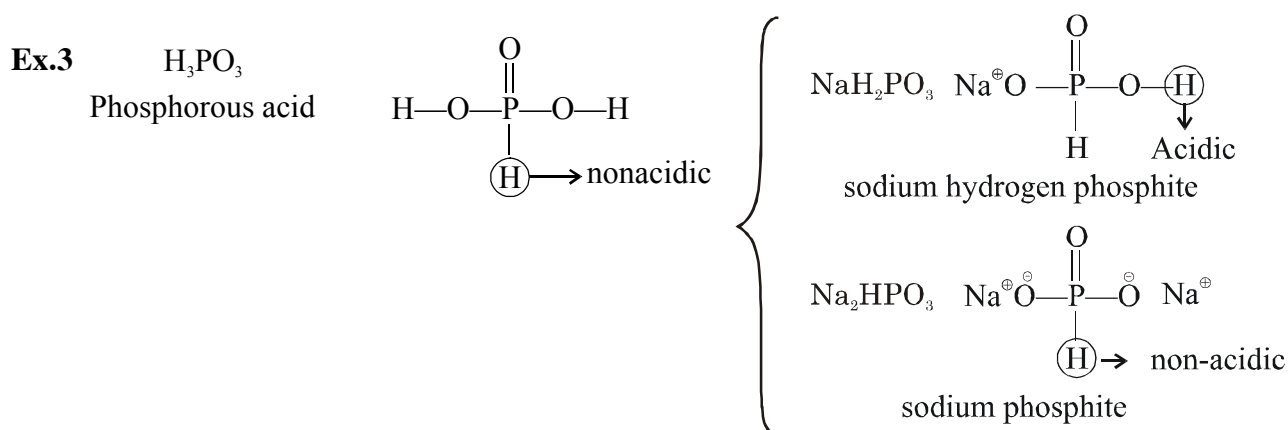
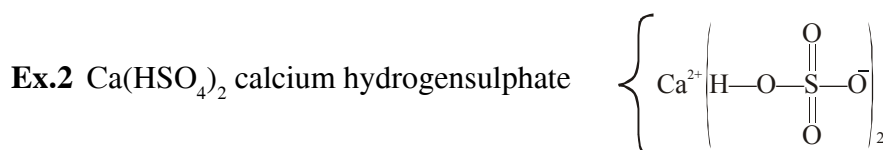
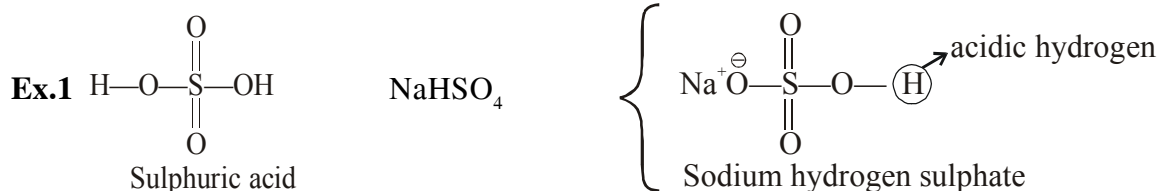
NaOI sodium hypoiodite

Hypophosphorous acid
(monobasic acid)

NaH_2PO_2 sodium hypophosphite

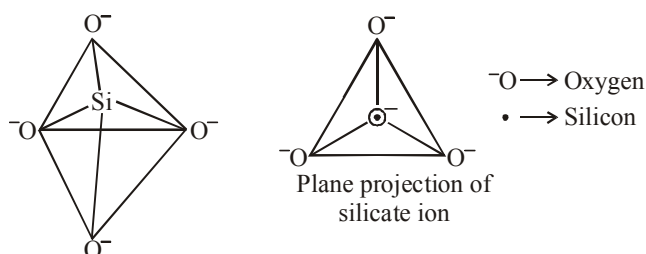
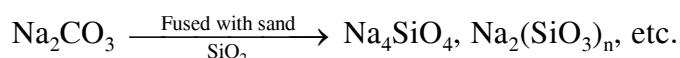
$\text{Ba}(\text{H}_2\text{PO}_2)_2$ Barium hypophosphite

If all the ionisable hydrogens are not removed from the acid to form salt, then the hydrogen word is added to the name of the salt containing acidic hydrogens (H attached with oxygen)



SILICATES

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



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

Silicates	Sharing of O-atom / Basic Tetrahedral unit	Contribution of O-atom/Basic Tetrahedral unit	General formula
Ortho	0	4	SiO_4^{4-}
Pyro	1	3.5	$\text{Si}_2\text{O}_7^{6-}$
Cyclic	2	3	$(\text{SiO}_3)_n^{2n-}$
Simple chain (pyroxene)	2	3	$(\text{SiO}_3)_n^{2n-}$
Double chain (Amphibole)	(3, 2) av = 2.5	$\frac{11}{4} = \left(\frac{5.5}{2}\right)$	$(\text{Si}_4\text{O}_{11})_n^{6n-}$
2D or (Sheet)	3	2.5	$(\text{Si}_2\text{O}_5)_n^{2n-}$
3D	4	2	$(\text{SiO}_2)_n$

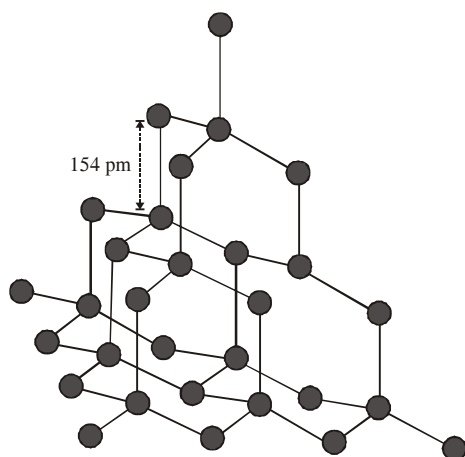
ALLOTROPE OF CARBON FAMILY

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

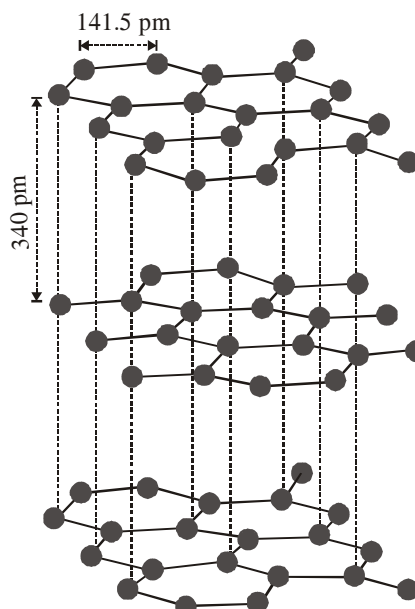
- It has a **crystalline lattice**. A rigid three dimensional network of carbon atoms.
- Each carbon atom undergoes **sp^3 hybridisation** and linked to four other carbon atoms by using hybridised orbitals in tetrahedral fashion.
- **C—C bond length is 154 pm.**
- It is very difficult to break **extended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

Uses :-

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



The structure of diamond



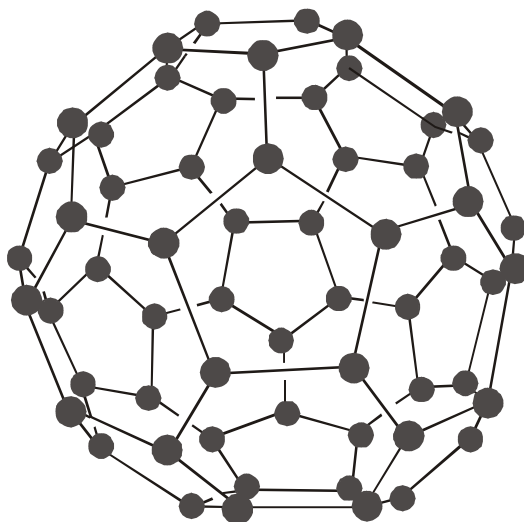
The structure of graphite

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

- Layered structure. **Layers are held by van der Waals forces** and distance between two **layers is 340 pm.**
- Each layer is composed of **planar hexagonal rings** of carbon atoms. **C—C bond length within the layer is 141.5 pm.**
- Each carbon atom in hexagonal ring **undergoes sp^2 hybridisation** and makes three sigma bonds with three neighbouring carbon atoms. **Fourth electron forms a π bond.** The electrons are delocalised over the whole sheet. Thus, graphite is lustrous.
- Electrons are mobile and, therefore, graphite conducts electricity along the sheet.
- Graphite cleaves easily between the layers and, therefore, it is very soft and slippery.
- **Uses :-** Due to slippery nature graphite is used as a **dry lubricant** in machines running at high temperature, where oil cannot be used as a lubricant.
- **Being good conductor, graphite is used for electrodes in batteries and industrial electrolysis.**

Fullerenes

- Fullerenes are made by the heating of graphite in an electric arc in the presence of inert gases such as helium or argon.
- The sooty material formed by condensation of vapourised C_n small molecules consists of mainly C_{60} with smaller quantity of C_{70} and traces of fullerenes consisting of even number of carbon atoms up to 350 or above.
- **Fullerenes are the only pure form of carbon because they have smooth structure without having 'dangling' bonds. Fullerenes are cage like molecules.**
- **Fullerene C_{60} :- molecule has a shape like soccer ball and called Buckminsterfullerene. It contains 20, six- membered rings and 12, five membered rings.**
- This ball shaped molecule has **60 vertices** and each one is occupied by one carbon atom and it also **contains both single and double bonds** with C–C distances of 143.5 pm and 138.3 pm respectively. **Spherical fullerenes are also called *bucky balls* in short.**
- A six membered ring is fused with six or five membered rings but a five membered ring can only fuse with six membered rings.
- All the carbon atoms are equal and they undergo sp^2 hybridisation. Each carbon atom forms three sigma bonds with other three carbon atoms.
- The remaining electron at each carbon is delocalised in molecular orbitals, which in turn give aromatic character to molecule. However, because of non-planar nature of fullerenes, their aromatic character gets diminished and reactivity increases.



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

IMPORTANT POINTS FOR CARBON

- **Thermodynamic stability order** : Graphite > Diamond > Fullerene C_{60}
- It is very important to know that **graphite is thermodynamically most stable allotrope of carbon** and, therefore, ΔH_f of graphite is taken as zero. ΔH_f values of diamond and fullerene, C_{60} are 1.90 and 38.1 kJ mol⁻¹, respectively.
- Other forms of elemental carbon like carbon black, coke, and charcoal are all impure forms of graphite or fullerenes.
 \Rightarrow **Carbon black** is obtained by burning hydrocarbons in a limited supply of air.
 \Rightarrow **Charcoal and coke** are obtained by heating wood or coal respectively at high temperatures in the absence of air.

Uses of Carbon

- **Graphite fibres** embedded in plastic material form high strength, lightweight composites. The composites are used in products such as tennis rackets, fishing rods, aircrafts and canoes.
- **Crucibles** made from graphite are inert to dilute acids and alkalies.
- Being **highly porous, activated charcoal** is used in adsorbing poisonous gases; also used in water filters to remove organic contaminants and in airconditioning system to control odour.
- **Carbon black** is used as black pigment in black ink and as filler in automobile tyres.
- **Coke** is used as a fuel and largely as a reducing agent in metallurgy.

ALLOTROPE OF OXYGEN FAMILY

Oxygen

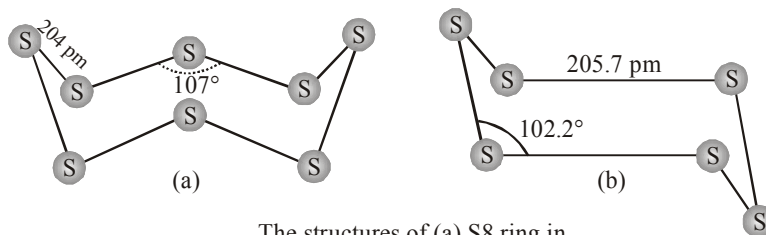
Two non-metallic forms, dioxygen O_2 and ozone O_3 . Dioxygen O_2 is stable as a diatomic molecule. O_3 molecule is diamagnetic while O_2 is paramagnetic.

- Six allotropes of **selenium** are known.
- **Tellurium** has only one crystalline form, which is silvery white and semimetallic.
- This is similar to grey Se, but has stronger metallic interaction.

Sulphur Allotropic forms :

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

- ⇒ **Rhombic sulphur (α -sulphur)** (*Most stable sulphur allotrope at room temperature*)
- This allotrope is **yellow in colour, m.p. 385.8 K and specific gravity 2.06**. Rhombic sulphur crystals are formed on evaporating the solution of roll sulphur in CS_2 .
 - It is **insoluble in water** but dissolves to some extent in benzene, alcohol and ether. It is **readily soluble** in CS_2 .
- ⇒ **Monoclinic sulphur (β -sulphur)**
- Its m.p. is 393 K and specific gravity 1.98. It is **soluble in CS_2 while water insoluble**.
 - This form of sulphur is prepared by melting rhombic sulphur in a dish and cooling, till crust is formed. Two holes are made in the crust and the remaining liquid poured out. On removing the crust, **colourless needle shaped crystals of β -sulphur are formed**.
 - It is stable above 369 K and transforms into α -sulphur below it**. Conversely, α -sulphur is stable below 369 K and transforms into β -sulphur above this. At 369 K, both the forms are stable. This temperature is called **transition temperature**.
 - Both rhombic and monoclinic sulphur have S_8 molecules**. These S_8 molecules are packed to give different crystal structures. **The S_8 ring in both the forms is puckered and has a crown shape**. The molecular dimensions are given in the figure.



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

EXTRA POINTS

- Several other modifications of sulphur containing 6-20 sulphur atoms per ring have been synthesised in the last two decades.
- In cyclo- S_6 , the ring adopts the chair form and the molecular dimensions are as shown in figure.
- At elevated temperatures (~ 1000 K), S_2 is the dominant species and is paramagnetic just like O_2 .
- Engel's sulphur (ϵ -sulphur)** is unstable and contains S_6 rings arranged in the chair conformation. It is made by pouring $\text{Na}_2\text{S}_2\text{O}_3$ solution into concentrated HCl and extracting the S with toluene.
- Plastic sulphur- (χ) is obtained by pouring liquid sulphur into water.

Allotropes of Nitrogen Family :

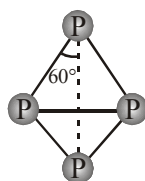
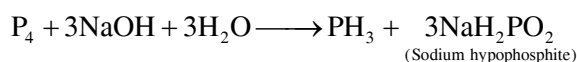
Solid As, Sb and Bi each exist in several allotropic forms. Arsenic vapour contains tetrahedral As_4 molecules. A reactive yellow form of the solid resembles white phosphorus and is thought to contain tetrahedral As_4 units. Sb also has a yellow form. All three elements have much less reactive metallic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

PHOSPHORUS ALLOTROPIC FORMS

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

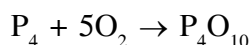
⇒ White phosphorus

- Translucent, white, waxy solid.
- It is poisonous, **insoluble in water** but **soluble in carbon disulphide** and glows in dark (chemiluminescence).
- It dissolves in boiling NaOH solution in an inert atmosphere giving PH_3 .



Discrete tetrahedral P_4 unit of White Phosphorus

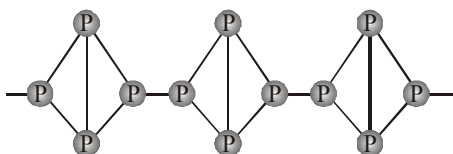
- White phosphorus is **less stable** and therefore, **more reactive** than the other solid phases under normal conditions **because of angular strain** in the P_4 molecule where the angles are only 60° . It readily catches fire in air to give dense white fumes of P_4O_{10} .



⇒ Red phosphorus

- Obtained by heating white phosphorus at 573K in an inert atmosphere for several days.
- When red phosphorus is heated under high pressure, a series of phases of black phosphorus is formed.
- Red phosphorus possesses **iron grey lustre**. It is **odourless, nonpoisonous and insoluble** in water as **well as in carbon disulphide**.
- Chemically, red phosphorus is **much less reactive than white phosphorus**. **It does not glow in the dark**.

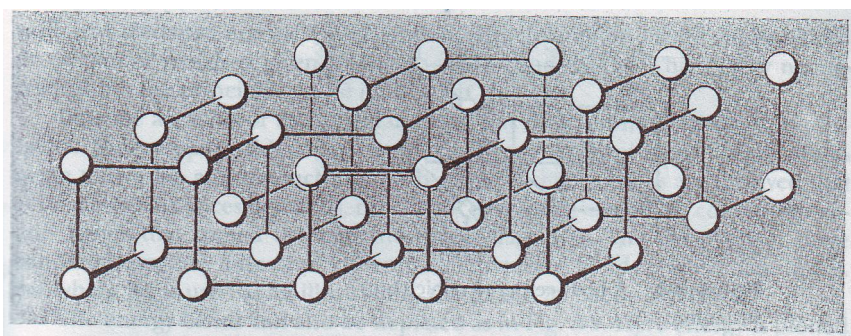
It is polymeric, consisting of chains of P_4 tetrahedra linked together in the manner as shown in Fig.



Red Phosphorus

⇒ **Black phosphorus**

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

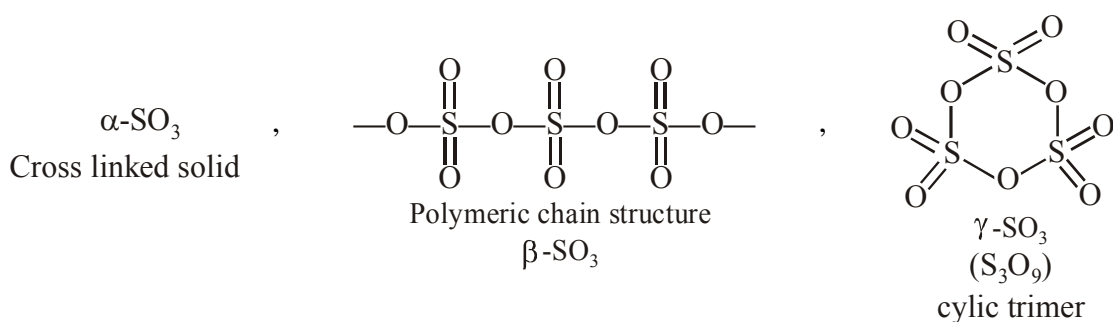


Thermodynamic stability order : Black phosphorus > Red phosphorus > White phosphorus

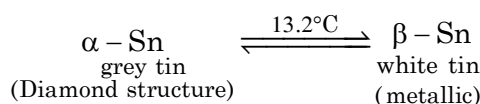
Reactivity order : Black phosphorus < Red phosphorus < White phosphorus

ALLOTROPIC FORM OF SO_3

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



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



EXERCISE # O-1

IONIC BOND

(Only one option is correct)

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

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

CBO0001

2. A bond formed between two like atoms cannot be

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

CBO0002

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

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

CBO0003

COVALENT BOND, CO-ORDINATE BOND & LEWIS STRUCTURE

4. Which of the following species are hypervalent?

(1) PCl_5 , (2) BF_3 , (3) XeF_2 , (4) CO_3^{2-}
 (A) 1, 2, 3 (B) 1, 3 (C) 3, 4 (D) 1, 2

CBO0004

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

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

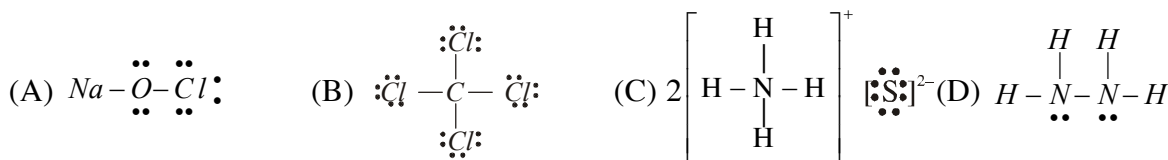
CBO0005

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

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

CBO0006

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



CBO0007

V.B.T., HYBRIDISATION & VSEPR THEORY

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

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

CBO0008

9. Maximum bond energy is in :

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

CBO0009

10. The hybridisation and shape of BrF_3 molecule are :
 (A) sp^3d and bent T shape (B) sp^2d^2 and tetragonal
 (C) sp^3d and bent (D) none of these
 CBO0010
11. The shape of methyl cation (CH_3^+) is likely to be:
 (A) linear (B) pyramidal (C) planar (D) spherical
 CBO0011
12. The structure of XeF_2 involves hybridization of the type :
 (A) sp^3 (B) sp^2 (C) sp^3d (D) sp^3d^2
 CBO0012
13. Which of the following has been arranged in increasing order of length of the hybrid orbitals ?
 (A) $\text{sp} < \text{sp}^2 < \text{sp}^3$ (B) $\text{sp}^3 < \text{sp}^2 < \text{sp}$ (C) $\text{sp}^2 < \text{sp}^3 < \text{sp}$ (D) $\text{sp}^2 < \text{sp} < \text{sp}^3$
 CBO0013
14. In the context of carbon, which of the following is arranged in the correct order of electronegativity :
 (A) $\text{sp} > \text{sp}^2 > \text{sp}^3$ (B) $\text{sp}^3 > \text{sp}^2 > \text{sp}$ (C) $\text{sp}^2 > \text{sp} > \text{sp}^3$ (D) $\text{sp}^3 < \text{sp} < \text{sp}^2$
 CBO0014
15. When $2s-2s$, $2p-2p$ and $2p-2s$ orbitals overlap, the bond strength decreases in the order :
 (A) $p-p > s-s > p-s$ (B) $p-p > p-s > s-s$
 (C) $s-s > p-p > p-s$ (D) $s-s > p-s > p-p$
 CBO0015
16. Carbon atoms in $\text{C}_2(\text{CN})_4$ are :
 (A) sp -hybridized (B) sp^2 -hybridized
 (C) sp - and sp^2 hybridized (D) sp , sp^2 and sp^3 - hybridized
 CBO0016
17. The structure of XeF_6 in vapour phase is
 (A) pentagonal bipyramidal (B) trigonal bipyramidal
 (C) capped octahedron (D) square bipyramidal
 CBO0017

BENT'S RULE AND DRAGO'S RULE

18. C-H bond distance is the longest in:
 (A) C_2H_2 (B) C_2H_4 (C) C_2H_6 (D) $\text{C}_2\text{H}_2\text{Br}_2$
 CBO0018
19. The bond angle and hybridization in ether (CH_3OCH_3) is :
 (A) $106^\circ 51'$, sp^3 (B) $104^\circ 31'$, sp^3 (C) 110° , sp^3 (D) $109^\circ 28'$, sp^3
 CBO0019
20. Which of the following has been arranged in order of decreasing bond length ?
 (A) $\text{P-O} > \text{Cl-O} > \text{S-O}$ (B) $\text{P-O} > \text{S-O} > \text{Cl-O}$
 (C) $\text{S-O} > \text{Cl-O} > \text{P-O}$ (D) $\text{Cl-O} > \text{S-O} > \text{P-O}$
 CBO0020

21. Select the **CORRECT** set of statements :

As the s-character of a hybrid orbital decreases

- (I) The bond angle decreases (II) The bond strength increases
(III) The bond length increases (IV) Size of orbital increases

(A) (I), (III) and (IV) (B) (II), (III) and (IV) (C) (I) and (II) (D) All are **CORRECT**
CBO0021

22. Among the following, the **CORRECT** statement is :

- (A) Between NH_3 and PH_3 , NH_3 is a better electron donor because the lone pair of electrons occupies spherical 's' orbital and is less directional
(B) Between NH_3 and PH_3 , PH_3 is a better electron donor because the lone pair of electrons occupies sp^3 orbital and is more directional
(C) Between NH_3 and PH_3 , NH_3 is a better electron donor because the lone pair of electrons occupies sp^3 orbital and is more directional
(D) Between NH_3 and PH_3 , PH_3 is a better electron donor because the lone pair of electrons occupies spherical 's' orbital and is less directional

CBO0022

23. In which of the following molecule C—C bond length will be highest ?

- (A) $\text{CF}_3 - \text{CF}_3$ (B) $\text{F}_2\text{CH} - \text{CHF}_2$ (C) $\text{FCH}_2 - \text{CH}_2\text{F}$ (D) $\text{CH}_3 - \text{CF}_3$

CBO0023

24. In BClBrI molecule the maximum % s-character provided from the central atom is in bond :

- (A) B – I (B) B – Cl (C) B – Br (D) Can not predict

CBO0024

25. Which of the following order is **CORRECT** for increasing p-character in orbital used for bonding by central atom

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

CBO0025

MOLECULE DOES NOT EXIST

26. PCl_5 exists but NCl_5 does not because :

- (A) Nitrogen has no vacant 2d-orbitals (B) NCl_5 is unstable
(C) Nitrogen atom is much smaller than P (D) Nitrogen is highly inert

CBO0026

27. Which of the following molecules do not exist.

- (A) BF_6^{3-} (B) NCl_3 (C) NOF_3 (D) XeF_5^-

CBO0027

28. Select non existing species

- (A) PH_3 (B) PH_4^+ (C) $[\text{PF}_6]^-$ (D) None of these

CBO0028

29. Among the fluorides below, the one which does not exist is -

- (A) XeF_4 (B) BeF_4 (C) SF_4 (D) CF_4

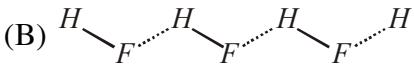
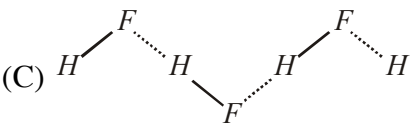
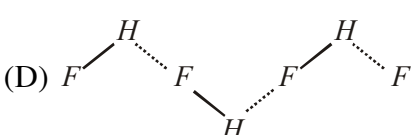
CBO0029

30. Which of the following compound exist -

- (A) XeH_2 (B) ClF_7 (C) PH_5 (D) ICl_3

CBO0030

DIPOLE MOMENT & HYDROGEN BONDING

31. Which of the following has been arranged in order of decreasing dipole moment ?
 (A) $\text{CH}_3\text{Cl} > \text{CH}_3\text{F} > \text{CH}_3\text{Br} > \text{CH}_3\text{I}$ (B) $\text{CH}_3\text{F} > \text{CH}_3\text{Cl} > \text{CH}_3\text{Br} > \text{CH}_3\text{I}$
 (C) $\text{CH}_3\text{Cl} > \text{CH}_3\text{Br} > \text{CH}_3\text{I} > \text{CH}_3\text{F}$ (D) $\text{CH}_3\text{F} > \text{CH}_3\text{Cl} > \text{CH}_3\text{I} > \text{CH}_3\text{Br}$
CBO0031
32. The experimental value of the dipole moment of HCl is 1.03 D . The length of the $\text{H}-\text{Cl}$ bond is 1.275 \AA . The percentage of ionic character in HCl is nearly :
 (A) 43 (B) 21 (C) 17 (D) 7
CBO0032
33. Ethanol has a higher boiling point than dimethyl ether though they have the same molecular weight. This is due to :
 (A) resonance (B) coordinate bonding
 (C) hydrogen bonding (D) ionic bonding
CBO0033
34. Which of the following compounds would have significant intermolecular hydrogen bonding ?
 HF , CH_3OH , N_2O_4 , CH_4
 (A) HF , N_2O_4 (B) HF , CH_4 , CH_3OH (C) HF , CH_3OH (D) CH_3OH , CH_4
CBO0034
35. For H_2O_2 , H_2S , H_2O and HF , the correct order of decreasing strength of hydrogen bonding is :
 (A) $\text{H}_2\text{O} > \text{HF} > \text{H}_2\text{O}_2 > \text{H}_2\text{S}$ (B) $\text{HF} > \text{H}_2\text{O}_2 > \text{H}_2\text{O} > \text{H}_2\text{S}$
 (C) $\text{HF} > \text{H}_2\text{O} > \text{H}_2\text{O}_2 > \text{H}_2\text{S}$ (D) $\text{H}_2\text{O}_2 > \text{H}_2\text{O} > \text{HF} > \text{H}_2\text{S}$
CBO0035
36. Which one of the following does not have intermolecular H-bonding?
 (A) H_2O (B) *o*-nitro phenol (C) HF (D) CH_3COOH
CBO0036
37. The order of strength of hydrogen bonds is:
 (A) $\text{NH}\cdots\text{N} > \text{OH}\cdots\text{O} > \text{FH}\cdots\text{F}$ (B) $\text{NH}\cdots\text{N} < \text{OH}\cdots\text{O} < \text{FH}\cdots\text{F}$
 (C) $\text{NH}\cdots\text{N} > \text{OH}\cdots\text{O} < \text{FH}\cdots\text{F}$ (D) $\text{NH}\cdots\text{N} < \text{OH}\cdots\text{O} > \text{FH}\cdots\text{F}$
CBO0037
38. The H bond in solid HF can be best represented as:
 (A) $\text{H}-\text{F}\cdots\text{H}-\text{F}\cdots\text{H}-\text{F}$ (B) 
 (C) 
 (D) 
CBO0038

VANDERWAAL FORCES

39. **Statement-1 :** The melting point of noble gases increases as its atomic mass increases.
Statement-2 : Instantaneous dipole induced dipole attraction increases with increase in atomic mass of noble gases.
- (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
 (B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1
 (C) Statement-1 is true, statement-2 is false.
 (D) Statement-1 is false, statement-2 is true.

CBO0039

40. The critical temperature of water is higher than that of O_2 because the H_2O molecule has :
- (A) fewer electrons than O_2 (B) two ionic bonds
 (C) V-shape (D) dipole moment

CBO0040

41. Which of the following boiling point order is correct -
- (A) $He > T_2 > D_2$ (B) $He < T_2 < D_2$ (C) $T_2 > He > D_2$ (D) $He < D_2 < T_2$

CBO0041

42. Which is the incorrect match for the energy distance function for following interaction -
- (A) Debye force : r^{-6} (B) Ion-induced dipole interaction : r^{-2}
 (C) London force : r^{-6} (D) Keesom force : r^{-3}

CBO0042

43. Identify the incorrect order of boiling point in the following pair.
- (A) $B(OH)_3 < B(OCH_3)_3$ (B) $NF_3 < N(CH_3)_3$
 (C) $BF_3 < B(CH_3)_3$ (D) $C_2H_6 < C_2F_6$

CBO0043

SILICATE

44. The number of corners or O-atoms shared per tetrahedron for pyroxene chain silicate is -
- (A) 3 (B) 2 (C) 2.5 (D) 1

CBO0044

45. The mineral $Na_2Fe^{II}Fe^{III}_2[Si_8O_{22}](OH)_2$ (chrocidolite) is a :
- (A) Pyroxene chain silicate (B) Sheet silicate
 (C) Amphiboles chain silicate (D) 3D-silicate

CBO0045

46. The silicate anion in the mineral kinoite is a chain of three SiO_4 tetrahedra that share corners with adjacent tetrahedra. The mineral also contains Ca^{2+} ions, Cu^{2+} ions, and water molecules in a 1:1:1 ratio mineral is represented as :
- (A) $CaCuSi_3O_{10} \cdot H_2O$ (B) $CaCuSi_3O_{10} \cdot 2H_2O$
 (C) $Ca_2Cu_2Si_3O_{10} \cdot 2H_2O$ (D) none of these

CBO0046

47. Silicate thortveitite ($\text{Sc}_2\text{Si}_2\text{O}_7$) is an example of -
 (A) Ortho silicate (B) Pyro silicate (C) Cyclic silicate (D) Chain silicate

CBO0047

48. Name of the structure of silicates in which three oxygen atoms of SiO_4^{4-} are shared is -
 (A) Pyro silicate (B) Sheet silicate
 (C) Linear chain silicate (D) Three dimensional silicate

CBO0048

MISCELLEANEOUS

49. The formal charges on the three O-atoms in O_3 molecule are
 (A) 0, 0, 0 (B) 0, 0, -1 (C) 0, 0, +1 (D) 0, +1, -1

CBO0049

50. The types of bonds present in $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ are
 (A) electrovalent and covalent
 (B) electrovalent, coordinate covalent & H-bond
 (C) covalent, coordinate covalent & H-bonds
 (D) electrovalent, covalent, coordinate covalent & H-bond

CBO0050

51. If ethylene molecule lies in X-Y plane then nodal planes of the π -bond will lie in
 (A) XZ plane (B) YZ plane
 (C) In a plane that bisects C-C axis (D) XY plane

CBO0051

52. Two ice cubes are pressed over each other and unite to form one cube. Which force is responsible for holding them together :
 (A) van der Waal's forces (B) Covalent attraction
 (C) Hydrogen bond formation (D) Dipole-dipole attraction

CBO0052

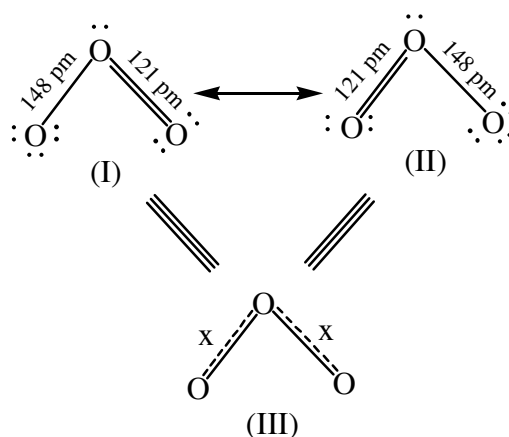
EXERCISE # O-2

IONIC BOND, COVALENT BOND & COORDINATE BOND

1. Which of the following compounds contain ionic, covalent and co-ordinate bonds?
 (A) NH_4Cl (B) KCN (C) NaBF_4 (D) NaOH CBO0053
2. Which of the following statements is/are true?
 (A) Covalent bonds are directional
 (B) Ionic bonds are nondirectional
 (C) A polar bond is formed between two atoms which have the same electronegativity value.
 (D) The presence of polar bonds in a polyatomic molecule suggests that it has zero dipole moment CBO0054
3. To which of the following species octet rule is not applicable :
 (A) BrF_5 (B) SF_6 (C) IF_7 (D) CO CBO0055

LEWIS STRUCTURE & BOND LENGTH

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



which of the following values of x are not correct

- (A) 148 pm (B) 121 pm (C) less than 121 pm (D) more than 148 pm CBO0056
5. Select the correct statement -
 (A) C–O bond length of CO molecule is higher than the C–O bond length of CO_2
 (B) C–O bond length of CO molecule is lower than the C–O bond length of CO_2
 (C) N–O bond length of NO_3^- ion is higher than the N–O bond length of NO_2^-
 (D) N–O bond length of NO_3^- ion is lower than the N–O bond length of NO_2^- CBO0057

VBT, HYBRIDISATION & VSEPR THEORY

6. Which of the following statement(s) is / are not correct?
 (A) Hybridization is the mixing of atomic orbitals of large energy difference.
 (B) sp^2 -hybrid orbitals are formed from two p - atomic orbitals and one s - atomic orbital
 (C) sp^3d^2 -hybrid orbitals are all at 90° to one another
 (D) sp^3 -hybrid orbitals are directed towards the corners of a regular tetrahedron
CBO0058
7. Which of the following species are linear ?
 (A) ICl_2^- (B) I_3^- (C) N_3^- (D) ClO_2^+
CBO0059
8. Which of the following molecules have bent shape.
 Where A is central atom, B is surrounding atom and E is lone pair -
 (A) AB_2E_2 (B) AB_2E (C) AB_3E (D) AB_2
CBO0060
9. In which of the following process(s) hybridisation of underlined atom does not change -
 (A) $\underline{N}H_3 + BF_3 \rightarrow H_3N.BF_3$ (B) $\underline{Si}F_4 + 2F^\ominus \rightarrow [SiF_6]^{2-}$
 (C) $BH_3 + \text{cyclopropane} \rightarrow H_3B \leftarrow \text{cyclopropane}$ (D) $H_3\underline{B}O_3 \xrightarrow{OH^-} [B(OH)_4]^-$
CBO0061
10. Which of the following 'd' orbital(s) participate in the hybridisation for Xe in the cationic part of $XeF_6(s)$:-
 (A) d_{xy} (B) $d_{x^2-y^2}$ (C) d_{z^2} (D) d_{y^2}
CBO0062
11. Select the **CORRECT** statement if internuclear axis is y-axis :-
 (A) d_{xy} and d_{xy} orbital of two atoms form π -bond
 (B) p_z and p_z orbital of two atoms form σ -bond
 (C) $d_{x^2-y^2}$ and $d_{x^2-y^2}$ orbital of two atoms form π -bond
 (D) p_y and d_{zx} orbital of two atoms form π -bond
CBO0063
12. What is the hybridisation state of Cl in cationic part of solid Cl_2O_6 ?
 (A) sp^3 (B) sp (C) sp^2 (D) sp^3d
CBO0064

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

- (A) $\text{OCl}_2 > \text{SF}_2$ (B) $\text{H}_2\text{O} > \text{OF}_2$ (C) $\text{SO}_4^{2-} > \text{CF}_4$ (D) $\text{NF}_3 > \text{NH}_3$

CBO0065

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

- (A) Bond angle order : $\text{CH}_4 > \text{CF}_4$ (B) Bond length order : $d_{\text{N-O}}(\text{NO}_2^-) < d_{\text{N-O}}(\text{NO}_3^-)$
 (C) Bond order of S-O : $\text{SO}_4^{2-} > \text{SO}_3^{2-}$ (D) Bond angle order : $\text{NH}_3 < \text{PH}_3$

CBO0066

MOLECULE DOES NOT EXIST

15. Which of the following molecules do not exist ?

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

CBO0067

16. Which of the following do not exists ?

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

CBO0068

17. Which of the following molecule exist-

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

CBO0069

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

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

CBO0070

DIPOLE MOMENT & HYDROGEN BOND

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

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

CBO0071

20. Which of the following statements are correct?

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

CBO0072

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

- (A) $\text{Na}_2\text{HPO}_3(\text{s})$ (B) $\text{K}_2\text{HPO}_4(\text{s})$ (C) $\text{KHCO}_3(\text{s})$ (D) $\text{NaHCO}_3(\text{s})$

CBO0073

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

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

CBO0074

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

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

CBO0075

VANDERWAAL FORCES

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

(A) Instantaneous dipole-induced dipole interaction
(B) Dipole-induced dipole interaction
(C) Dipole-dipole interaction
(D) Size of molecule

CBO0076

25. Which of the following are true ?

(A) Vander Waals forces are responsible for the formation of molecular crystals
(B) Branching lowers the boiling points of isomeric organic compounds due to decrease in Vander Waals forces of attraction
(C) In graphite, vander Waals forces act between the carbon layers
(D) In diamond, vander Waals forces act between the carbon layers

CBO0077

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

(A) London forces (B) Dipole-dipole attraction
(C) Covalent bonds (D) Coulombic force

CBO0078

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

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

CBO0079

SILICATE

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

(A) Pyroxene chain silicate (B) Amphibole chain silicate
(C) 5-membered cyclic silicate (D) None of these

CBO0080

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

(A) $CaMg[(SiO_3)_2]$ (B) $BaTi[Si_3O_9]$
(C) $Ca_2Mg_5[(Si_4O_{11})_2](OH)_2$ (D) $Al_2(OH)_4[Si_2O_5]$

CBO0081

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

(A) Two oxygen atoms (B) Four oxygen atoms
(C) One silicon and two oxygen atoms (D) One silicon and four oxygen atoms

CBO0082

31. The ratio of 'Si' atom to monovalent 'O' atom in amphibole silicate is -
(A) 2 : 3 (B) 4 : 5 (C) 4 : 11 (D) 1 : 3

CBO0083

32. In which of the following silicate/s, 'Si' atoms are sp^3 hybrid -
(A) Pyro silicate (B) Sheet silicate (C) Pyroxene (D) Amphiboles

CBO0084

MISCELLENEOUS & STRUCTURE

33. Which of the following oxyacids of sulphur contain $S-S$ bonds ?
(A) $H_2S_2O_8$ (B) $H_2S_2O_6$ (C) $H_2S_2O_4$ (D) $H_2S_2O_5$

CBO0085

34. Molecule(s) having both polar and non polar bonds is / are
(A) O_2F_2 (B) S_2Cl_2 (C) N_2H_4 (D) S_2F_{10}

CBO0086

35. Which of the following molecule is/are planar -
(A) CH_2Cl_2 (B) XeF_4 (C) SO_3 (D) NF_3

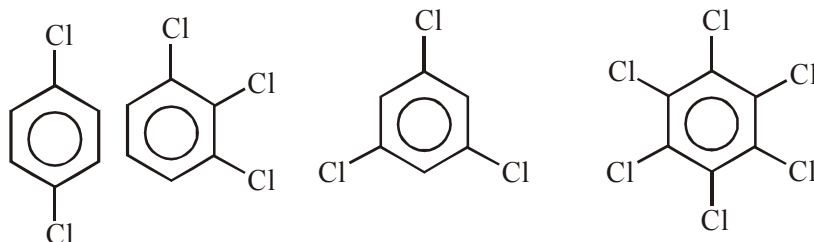
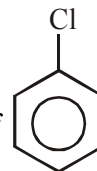
CBO0087

EXERCISE # S-1

Integer Type Answer :

1. In solid NaCl^+ one Na^+ is surrounded by six Cl^- ions find out total number of directional bonds formed by each Na^+ with Cl^- ions. CBO0088
2. Find out total number of $p\pi-d\pi$ bonds present in SO_2 molecule CBO0089
3. Find out total number of $p\pi-p\pi$ bonds present in SO_4^{2-} CBO0090
4. How many number of atomic orbitals are required, so that their mixing produces hybrid orbitals each having % of s-character nearly equal to 17%. CBO0091
5. Calculate the maximum number of atoms lying in one plane of PCl_3F_2 . CBO0092
6. Find the total number of following molecule(s) which have all bond lengths are same.
 XeF_4 , SF_4 , SH_2 , NO_3^- , SiF_4 , ClF_3 , PF_2Cl_3 , XeO_3F_2 CBO0093
7. A diatomic molecule has a dipole moment of 1.2 D. If bond length is 1.0 \AA , what percentage of an electronic charge exists on each atom.
[Add the digits untill you are getting single digit. e.g. If the answer is 537, then $5 + 3 + 7 = 15$] again $1 + 5 = 6$ and 6 is to be written as answer. CBO0094
8. Total number of sp^3 hybridised atom(s) in given hydrocarbon.
 $\text{CH}_3-\text{CH}=\text{CH}-\underset{\text{CH}_3}{\text{CH}}-\text{C}\equiv\text{CH}$ CBO0095
9. Find the number of lone pair on central atom of ICl_4^- CBO0096
10. Find the number of acid(s) which are having hypo prefix in it's name from the following.
 H_3PO_4 , H_3BO_3 , H_3PO_3 , H_3PO_2 , HClO_3 , HClO , $(\text{HNO})_2$, $\text{H}_4\text{P}_2\text{O}_6$ CBO0097
11. Find the number of planar molecules/ions which are cyclic –
 $\text{B}_3\text{N}_3\text{H}_6$, $\text{C}_3\text{N}_3\text{Cl}_3$, $(\text{BO}_2)_3$, $\text{S}_2\text{O}_8^{2-}$ CBO0098

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



CBO0099

13. Find the number of molecules having intramolecular hydrogen bonding in the following :
ice, o-boric acid, o-nitrophenol, o-chlorophenol, chloral hydrate, o-salicylaldehyde
CBO0100
14. Calculate the value of "n" in $\text{Zn}_n\text{Ca}_2(\text{Si}_3\text{O}_{10}) \cdot 2\text{H}_2\text{O}$
CBO0101
15. In which of the following silicates structure, the number of corner/oxygen atoms shared per tetrahedron is '2'.
Pyrosilicate , pyroxene chain silicate ,
2D-silicate , 3D-silicate , 4-membered cyclic silicate
CBO0102

EXERCISE # S-2

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

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

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



CBO0103

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

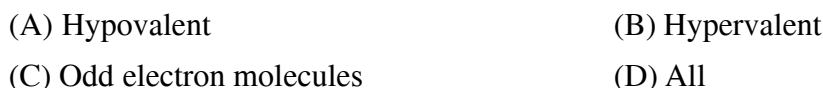


CBO0103

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

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

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



CBO0104

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



CBO0104

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

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

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



CBO0105

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



CBO0105

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



CBO0105

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

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

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

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

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

CBO0106

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

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

CBO0106

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

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

CBO0106

Match the Column :**11. Match the column****Column-I (molecules)**

- (A) PCl_5 ($\theta = 120^\circ$), ($\theta' = 90^\circ$)
 (B) NH_3 ($\theta = 107^\circ$)
 (C) SiH_4 ($\theta = 109^\circ 28'$)
 (D) SO_2 ($\theta = 116^\circ$)

Column-II (correct about molecule)

- (P) Number of the given bond angle (θ or θ') is = One
 (Q) Number of the given bond angle (θ or θ') is = Three
 (R) Number of the given bond angle (θ or θ') is = Six
 (S) d-orbital(s) is/are involved in hybridisation of central atom
 (T) Lone pair at underlined atom is present

CBO0107

12. Column I

- (A) BrF_3
 (B) TeF_5^-
 (C) IF_7
 (D) XeF_4

Column II

- (P) Atleast one angle $\leq 90^\circ$
 (Q) Central atom is sp^3d^2 hybridised
 (R) Non planar
 (S) Polar

CBO0108

13. Column I

- (A) $I(CN)_2^-$
 (B) CO_3^{2-}
 (C) XeO_2F_2
 (D) SOF_4

Column II

- (P) Having $p\pi-p\pi$ bond & $\mu_D = 0$
 (Q) Having $p\pi-d\pi$ bond & $\mu_D \neq 0$
 (R) Planar
 (S) Central atom is sp^3d

CBO0109

14. Column I

- (A) $\text{H}_2\text{S}_2\text{O}_5$
 (B) $\text{H}_6\text{B}_2\text{O}_7^{2-}$
 (C) $\text{H}_4\text{P}_2\text{O}_6$ (tetrabasic)
 (D) $\text{H}_6\text{Si}_2\text{O}_7$

Column II

- (P) Central atom is sp^3 hybridised
 (Q) $\text{M}-\text{O}-\text{M}$ i.e. oxo linkage is present
 (R) $\text{M}-\text{M}$ linkage is present
 (S) Non planar

CBO0110

15. Column-I

- (P) XeF_4
 (Q) BrF_5
 (R) ClF_3
 (S) SO_3^{2-}

Column-II

- (1) sp^3d hybridised with 2 lone pair on central atom
 (2) sp^3d^2 hybridised with 2 lone pair on central atom
 (3) sp^3 hybridised with 1 lone pair on central atom
 (4) sp^3d^2 hybridised with 1 lone pair on central atom

Code :

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

CBO0111

16. Column-I

- (P) NH_4Cl
 (Q) $\text{K}[\text{HF}_2]$
 (R) $\text{B}_3\text{N}_3\text{H}_6$
 (S) SiC

Column-II

- (1) diamond like structure
 (2) Benzene like structure
 (3) Both hydrogen bond and ionic bond exist
 (4) Both covalent bond and ionic bond exist

Code :

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

CBO0112

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

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

17. Which of the following combination results in π -bond formation if internuclear axis is z-axis
 (A) (P), (1), (ii) (B) (P), (4), (i) (C) (R), (4), (iv) (D) (R), (3), (ii)

CBO0113

18. Which of the following combination results in σ -bond formation if internuclear axis is z-axis
 (A) (P), (1), (ii) (B) (Q), (3), (ii) (C) (Q), (4), (i) (D) (R), (2), (ii)

CBO0113

19. Which of the following combination results in δ -bond formation if internuclear axis is x-axis
 (A) (P), (1), (i) (B) (P), (3), (iii) (C) (R), (3), (iv) (D) (P), (2), (ii)

CBO0113

20. Match the column

Column-I
(Molecules)

- (A) CH_4
 (B) CH_2F_2
 (C) CHF_3
 (D) CF_4

Column-I
(Characteristics)

- (P) Molecule is having perfect tetrahedral shape
 (Q) C-F bond has maximum p-character
 (R) C-H bond has maximum s-character
 (S) Molecule is having maximum number of equal angles
 (T) Molecule has lowest bond angle

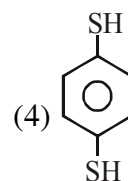
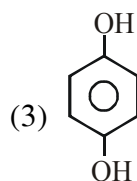
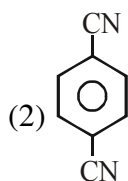
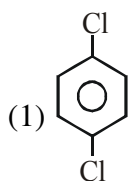
CBO0114

EXERCISE # JEE-MAIN

- The hybridisation of orbitals of N atom in NO_3^- , NO_2^+ and NH_4^+ are respectively:- [AIEEE-2011]
 (1) sp , sp^3 , sp^2 (2) sp^2 , sp^3 , sp (3) sp , sp^2 , sp^3 (4) sp^2 , sp , sp^3
CBO0115
- The structure of IF_7 is :- [AIEEE-2011]
 (1) octahedral (2) pentagonal bipyramid
 (3) square pyramid (4) trigonal bipyramid
CBO0116
- Which of the following has maximum number of lone pairs associated with Xe [AIEEE-2011]
 (1) XeO_3 (2) XeF_4 (3) XeF_6 (4) XeF_2
CBO0117
- The molecule having smallest bond angle is :- [AIEEE-2012]
 (1) PCl_3 (2) NCl_3 (3) AsCl_3 (4) SbCl_3
CBO0118
- In which of the following pairs the two species are not isostructural ? [AIEEE-2012]
 (1) AlF_6^{3-} and SF_6 (2) CO_3^{2-} and NO_3^- (3) PCl_4^+ and SiCl_4 (4) PF_5 and BrF_5
CBO0119
- The number of S-S bonds in SO_3 , $\text{S}_2\text{O}_3^{2-}$, $\text{S}_2\text{O}_6^{2-}$ and $\text{S}_2\text{O}_8^{2-}$ respectively are :- [JEE-MAINS-2012]
 (1) 1, 0, 1, 0 (2) 0, 1, 1, 0 (3) 1, 0, 0, 1 (4) 0, 1, 0, 1 (On line)
CBO0120
- Among the following species which two have trigonal bipyramidal shape ? [JEE-MAINS-2012]
 (I) NI_3 (II) I_3^- (III) SO_3^{2-} (IV) NO_3^- (On line)
 (1) II and III (2) III and IV (3) I and IV (4) I and III
CBO0121
- Which of the following has the square planar structure :- [JEE-MAINS-2012]
 (1) NH_4^+ (2) CCl_4 (3) XeF_4 (4) BF_4^- (On line)
CBO0122
- The compound of Xenon with zero dipole moment is :- [JEE-MAINS-2012]
 (1) XeO_3 (2) XeO_2 (3) XeF_4 (4) XeOF_4 (On line)
CBO0123
- Among the following the molecule with the lowest dipole moment is :- [JEE-MAINS-2012]
 (1) CHCl_3 (2) CH_2Cl_2 (3) CCl_4 (4) CH_3Cl (On line)
CBO0124

11. The formation of molecular complex $\text{BF}_3 - \text{NH}_3$ results in a change in hybridisation of boron :-
[JEE-MAINS-2012]
(1) from sp^3 to sp^3d (2) from sp^2 to dsp^2 (On line)
(3) from sp^3 to sp^2 (4) from sp^2 to sp^3
CBO0125
12. Trigonal bipyramidal geometry is shown by:
[JEE-MAINS-2013]
(1) XeO_3F_2 (2) XeOF_2 (3) XeO_3 (4) FXeOSO_2F (On line)
CBO0126
13. Which one of the following molecules is polar?
[JEE-MAINS-2013]
(1) CF_4 (2) SbF_5 (3) IF_5 (4) XeF_4 (On line)
CBO0127
14. Oxidation state of sulphur in anions SO_3^{2-} , $\text{S}_2\text{O}_4^{2-}$ and $\text{S}_2\text{O}_6^{2-}$ increases in the orders :
[JEE-MAINS-2013]
(1) $\text{S}_2\text{O}_6^{2-} < \text{S}_2\text{O}_4^{2-} < \text{SO}_3^{2-}$ (2) $\text{SO}_3^{2-} < \text{S}_2\text{O}_4^{2-} < \text{S}_2\text{O}_6^{2-}$ (On line)
(3) $\text{S}_2\text{O}_4^{2-} < \text{SO}_3^{2-} < \text{S}_2\text{O}_6^{2-}$ (4) $\text{S}_2\text{O}_4^{2-} < \text{S}_2\text{O}_6^{2-} < \text{SO}_3^{2-}$
CBO0128
15. XeO_4 molecule is tetrahedral having :
[JEE-MAINS-2013]
(1) Two $\text{p}\pi\text{-d}\pi$ bonds (2) Four $\text{p}\pi\text{-d}\pi$ bonds (On line)
(3) One $\text{p}\pi\text{-d}\pi$ bond (4) Three $\text{p}\pi\text{-d}\pi$ bonds
CBO0129
16. Bond distance in HF is 9.17×10^{-11} m. Dipole moment of HF is 6.104×10^{-30} Cm. The percent ionic character in HF will be : (electron charge = 1.60×10^{-19} C) [JEE-MAINS-2013]
(1) 61.0% (2) 38.0% (On line)
(3) 35.5% (4) 41.5%
CBO0130
17. The shape of IF_6^- is :
[JEE-MAINS-2013]
(1) distorted octahedron (2) Pyramidal (On line)
(3) Octahedral (4) Square antiprism
CBO0131
18. Which has trigonal bipyramidal shape ?
[JEE-MAINS-2013]
(1) XeOF_4 (2) XeO_3 (3) XeO_3F_2 (4) XeOF_2 (On line)
CBO0132
19. The catenation tendency of C, Si and Ge is in the order $\text{Ge} < \text{Si} < \text{C}$. The bond energies (in kJ mol^{-1}) of C—C, Si—Si and Ge—Ge bonds are respectively : [JEE-MAINS-2013 (On line)]
(1) 348, 260, 297 (2) 348, 297, 260 (3) 297, 348, 260 (4) 260, 297, 348
CBO0133
20. In which of the following sets, all the given species are isostructural ? [JEE-MAINS-2013 (On line)]
(1) BF_3 , NF_3 , PF_3 , AlF_3 (2) PCl_3 , AlCl_3 , BCl_3 , SbCl_3
(3) BF_4^- , CCl_4 , NH_4^+ , PCl_4^+ (4) CO_2 , NO_2 , ClO_2 , SiO_2
CBO0134

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



(1) Only (3)

(2) (3) and (4)

(3) Only (1)

(4) (1) and (2)

CBO0135

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

(1) $\text{HClO}_4 > \text{HClO}_3 > \text{HClO}_2 > \text{HOCl}$

(2) $\text{HClO}_2 > \text{HClO}_4 > \text{HClO}_3 > \text{HOCl}$

(3) $\text{HOCl} > \text{HClO}_2 > \text{HClO}_3 > \text{HClO}_4$

(4) $\text{HClO}_4 > \text{HOCl} > \text{HClO}_2 > \text{HClO}_3$

CBO0136

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

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

(1) Two σ bonds and one π - bond

(2) Two σ bonds and two π - bonds

(3) One σ bond and two π - bonds

(4) One σ bond and one π - bond

CBO0137

24. For the compounds

[JEE-MAINS-2014]

CH_3Cl , CH_3Br , CH_3I and CH_3F ,

(On line)

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

(1) $\text{CH}_3\text{F} < \text{CH}_3\text{Br} < \text{CH}_3\text{Cl} < \text{CH}_3\text{I}$

(2) $\text{CH}_3\text{F} < \text{CH}_3\text{Cl} < \text{CH}_3\text{Br} < \text{CH}_3\text{I}$

(3) $\text{CH}_3\text{Cl} < \text{CH}_3\text{Br} < \text{CH}_3\text{F} < \text{CH}_3\text{I}$

(4) $\text{CH}_3\text{F} < \text{CH}_3\text{I} < \text{CH}_3\text{Br} < \text{CH}_3\text{Cl}$

CBO0138

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

[JEE-MAINS-2014]

(1) IF_7 : Pentagonal bipyramid

(2) BrF_5 : Trigonal bipyramid

(On line)

(3) ICl_3 : Planar dimeric

(4) BrF_3 : Planar T-shaped

CBO0139

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

(1) HCN

(2) $\text{C}_2\text{H}_2\text{Cl}_2$

(3) N_2F_2

(4) C_2H_4

(On line)

CBO0140

27. Example of a three-dimensional silicate is : [JEE-MAINS-2014]
 (1) Beryls (2) Zeolites (3) Feldspars (4) Ultramarines (On-line)
 CBO0141
28. The intermolecular interaction that is dependent on the inverse cube of distance between the molecules is :- [JEE-M-2015]
 (1) London force (2) Hydrogen bond
 (3) ion-ion interaction (4) ion-dipole interaction
 CBO0142
29. Which one has the highest boiling point ? [JEE-M-2015]
 (1) Kr (2) Xe (3) He (4) Ne
 CBO0143
30. Which intermolecular force is most responsible in allowing xenon gas to liquefy?
 (1) Ionic [JEE (MAIN) ONLINE 2016]
 (2) Instantaneous dipole- induced dipole
 (3) Dipole - dipole
 (4) Ion - dipole
 CBO0144
31. The pair in which phosphorous atoms have a formal oxidation state of + 3 is :-
 (1) Pyrophosphorous and pyrophosphoric acids [JEE-MAINS(offline)-2016]
 (2) Orthophosphorous and pyrophosphorous acids
 (3) Pyrophosphorous and hypophosphoric acids
 (4) Orthophosphorous and hypophosphoric acids
 CBO0145
32. The group of molecules having identical shape is : [JEE-MAINS(online)-2016]
 (1) SF_4 , XeF_4 , CCl_4 (2) ClF_3 , XeOF_2 , XeF_3^+
 (3) PCl_5 , IF_5 , XeO_2F_2 (4) BF_3 , PCl_3 , XeO_3
 CBO0146
33. **Assertion :** Among the carbon allotropes, diamond is an insulator, whereas, graphite is a good conductor of electricity. [JEE-MAINS(online)-2016]
Reason : Hybridization of carbon in diamond and graphite are sp^3 and sp^2 , respectively.
 (1) Assertion is incorrect statement, but the reason is correct.
 (2) Both assertion and reason are correct, and the reason is the correct explanation for the assertion.
 (3) Both assertion and reason are incorrect.
 (4) Both assertion and reason are correct, but the reason is not the correct explanation for the assertion.
 CBO0147

34. Aqueous solution of which salt will not contain ions with the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6$? [JEE-MAINS(online)-2016]
 (1) NaCl (2) CaI_2 (3) KBr (4) NaF **CBO0148**
35. The correct sequence of decreasing number of π -bonds in the structures of H_2SO_3 , H_2SO_4 and $\text{H}_2\text{S}_2\text{O}_7$ is:- [JEE-MAINS(online)-2017]
 (1) $\text{H}_2\text{S}_2\text{O}_7 > \text{H}_2\text{SO}_4 > \text{H}_2\text{SO}_3$ (2) $\text{H}_2\text{SO}_3 > \text{H}_2\text{SO}_4 > \text{H}_2\text{S}_2\text{O}_7$
 (3) $\text{H}_2\text{S}_2\text{O}_7 > \text{H}_2\text{SO}_3 > \text{H}_2\text{SO}_4$ (4) $\text{H}_2\text{SO}_4 > \text{H}_2\text{S}_2\text{O}_7 > \text{H}_2\text{SO}_3$ **CBO0149**
36. The increasing order of the boiling points for the following compounds is :- [JEE-MAINS(online)-2017]
 (I) $\text{C}_2\text{H}_5\text{OH}$ (II) $\text{C}_2\text{H}_5\text{Cl}$ (III) $\text{C}_2\text{H}_5\text{CH}_3$ (IV) $\text{C}_2\text{H}_5\text{OCH}_3$
 (1) (III) < (II) < (I) < (IV) (2) (II) < (III) < (IV) < (I)
 (3) (IV) < (III) < (I) < (II) (4) (III) < (IV) < (II) < (I) **CBO0150**
37. The number of P–OH bonds and the oxidation state of phosphorus atom in pyrophosphoric acid ($\text{H}_4\text{P}_2\text{O}_7$) respectively are:- [JEE-MAINS(online)-2017]
 (1) five and four (2) five and five (3) four and five (4) four and four **CBO0151**
38. The group having triangular planar structures is :- [JEE-MAINS(online)-2017]
 (1) CO_3^{2-} , NO_3^- , SO_3 (2) NCl_3 , BCl_3 , SO_3 (3) NH_3 , SO_3 , CO_3^{2-} (4) BF_3 , NF_3 , CO_3^{2-} **CBO0152**
39. The number of S=O and S–OH bonds present in peroxodisulphuric acid and pyrosulphuric acid respectively are : [JEE-MAINS(online)-2017]
 (1) (2 and 4) and (2 and 4) (2) (4 and 2) and (2 and 4)
 (3) (2 and 2) and (2 and 2) (4) (4 and 2) and (4 and 2) **CBO0153**
40. The number of P–O bonds in P_4O_6 is :- [JEE-MAINS(online)-2018]
 (1) 18 (2) 12 (3) 9 (4) 6 **CBO0154**
41. In XeO_3F_2 , the number of bond pair(s), π -bond(s) and lone pair(s) on Xe atom respectively are :- [JEE-MAINS(online)-2018]
 (1) 4, 2, 2 (2) 4, 4, 0 (3) 5, 2, 0 (4) 5, 3, 0 **CBO0155**
42. The decreasing order of bond angles in BF_3 , NH_3 , PF_3 and I_3^- is :- [JEE-MAINS(online)-2018]
 (1) $\text{I}_3^- > \text{BF}_3 > \text{NH}_3 > \text{PF}_3$ (2) $\text{BF}_3 > \text{NH}_3 > \text{PF}_3 > \text{I}_3^-$
 (3) $\text{I}_3^- > \text{NH}_3 > \text{PF}_3 > \text{BF}_3$ (4) $\text{BF}_3 > \text{I}_3^- > \text{PF}_3 > \text{NH}_3$ **CBO0156**
43. Identify the pair in which the geometry of the species is T-shape and square-pyramidal, respectively :- [JEE-MAINS(online)-2018]
 (1) IO_3^- and IO_2F_2^- (2) XeOF_2 and XeOF_4 (3) ICl_2^- and ICl_5 (4) ClF_3 and IO_4^- **CBO0157**

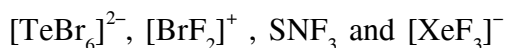
44. Which of the following is a lewis acid ? [JEE-MAINS(online)-2018]
 (1) NaH (2) NF_3 (3) PH_3 (4) $\text{B}(\text{CH}_3)_3$ CBO0158
45. Among the oxides of nitrogen : N_2O_3 , N_2O_4 and N_2O_5 ; the molecule(s) having nitrogen-nitrogen bond is/are :- [JEE-MAINS(online)-2018]
 (1) N_2O_3 and N_2O_5 (2) N_2O_4 and N_2O_5 (3) N_2O_3 and N_2O_4 (4) Only N_2O_5 CBO0159
46. The incorrect geometry is represented by :- [JEE-MAINS(online)-2018]
 (1) BF_3 - trigonal planar (2) NF_3 - trigonal planar
 (3) AsF_5 - trigonal bipyramidal (4) H_2O - bent CBO0160
47. Which of the following conversions involves change in both shape and hybridisation ? [JEE-MAINS(online)-2018]
 (1) $\text{BF}_3 \rightarrow \text{BF}_4^-$ (2) $\text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+$ (3) $\text{CH}_4 \rightarrow \text{C}_2\text{H}_6$ (4) $\text{NH}_3 \rightarrow \text{NH}_4^+$ CBO0161
48. Which of the following are Lewis acids ? [JEE-MAINS(offline)-2018]
 (1) AlCl_3 and SiCl_4 (2) PH_3 and SiCl_4 (3) BCl_3 and AlCl_3 (4) PH_3 and BCl_3 CBO0162
49. Total number of lone pair of electrons in I_3^- ion is [JEE-MAINS(offline)-2018]
 (1) 6 (2) 9 (3) 12 (4) 3 CBO0163
50. The element that shows greater ability to form $p\pi$ - $p\pi$ multiple bonds, is : [JEE-MAINS(online)-2019]
 (1) Si (2) Ge (3) Sn (4) C CBO0164
51. The type of hybridisation and number of lone pair(s) of electrons of Xe in XeOF_4 , respectively, are : [JEE-MAINS(online)-2019]
 (1) sp^3d and 1 (2) sp^3d and 2 (3) sp^3d^2 and 1 (4) sp^3d^2 and 2 CBO0165
52. The pair that contains two P-H bonds in each of the oxoacids is : [JEE-MAINS(online)-2019]
 (1) H_3PO_2 and $\text{H}_4\text{P}_2\text{O}_5$ (2) $\text{H}_4\text{P}_2\text{O}_5$ and $\text{H}_4\text{P}_2\text{O}_6$
 (3) H_3PO_3 and H_3PO_2 (4) $\text{H}_4\text{P}_2\text{O}_5$ and H_3PO_3 CBO0166
53. The ion that has sp^3d^2 hybridization for the central atom, is : [JEE-MAINS(online)-2019]
 (1) $[\text{ICl}_2]^-$ (2) $[\text{IF}_6]^-$ (3) $[\text{ICl}_4]^-$ (4) $[\text{BrF}_2]^-$ CBO0167
54. C_{60} , an allotrope of carbon contains : [JEE-MAINS(online)-2019]
 (1) 20 hexagons and 12 pentagons. (2) 12 hexagons and 20 pentagons.
 (3) 18 hexagons and 14 pentagons. (4) 16 hexagons and 16 pentagons. CBO0168
55. The oxoacid of sulphur that does not contain bond between sulphur atoms is : [JEE-MAINS(online)-2019]
 (1) $\text{H}_2\text{S}_4\text{O}_6$ (2) $\text{H}_2\text{S}_2\text{O}_7$
 (3) $\text{H}_2\text{S}_2\text{O}_3$ (4) $\text{H}_2\text{S}_2\text{O}_4$ CBO0169

56. The number of pentagons in C_{60} and trigons (triangles) in white phosphorus, respectively, are:
 (1) 12 and 3 (2) 20 and 4 [JEE-MAINS(online)-2019]
 (3) 12 and 4 (4) 20 and 3
 CBO0170
57. The C–C bond length is maximum in [JEE-MAINS(online)-2019]
 (1) graphite (2) C_{70} (3) diamond (4) C_{60}
 CBO0171
58. The dipole moments of CCl_4 , $CHCl_3$ and CH_4 are in the order : [JEE-MAINS(online)-2020]
 (1) $CH_4 = CCl_4 < CHCl_3$ (2) $CH_4 < CCl_4 < CHCl_3$
 (3) $CCl_4 < CH_4 < CHCl_3$ (4) $CHCl_3 < CH_4 = CCl_4$
 CBO0172
59. The relative strength of interionic/intermolecular forces in decreasing order is :
 (1) ion-dipole > ion-ion > dipole-dipole [JEE-MAINS(online)-2020]
 (2) dipole-dipole > ion-dipole > ion-ion
 (3) ion-dipole > dipole-dipole > ion-ion
 (4) ion-ion > ion-dipole > dipole-dipole
 CBO0173
60. Arrange the following bonds according to their average bond energies in descending order :
 C–Cl, C–Br, C–F, C–I [JEE-MAINS(online)-2020]
 (1) C–I > C–Br > C–Cl > C–F (2) C–Br > C–I > C–Cl > C–F
 (3) C–F > C–Cl > C–Br > C–I (4) C–Cl > C–Br > C–I > C–F
 CBO0174
61. The predominant intermolecular forces present in ethyl acetate, a liquid, are :
 (1) hydrogen bonding and London dispersion [JEE-MAINS(online)-2020]
 (2) Dipole-dipole and hydrogen bonding
 (3) London dispersion and dipole-dipole
 (4) London dispersion, dipole-dipole and hydrogen bonding
 CBO0175
62. The number of bonds between sulphur and oxygen atoms in $S_2O_8^{2-}$ and the number of bonds between sulphur and sulphur atoms in rhombic sulphur, respectively, are :
 (1) 4 and 8 (2) 4 and 6 [JEE-MAINS(online)-2020]
 (3) 8 and 8 (4) 8 and 6
 CBO0176
63. The number of sp^2 hybrid orbitals in a molecule of benzene is : [JEE-MAINS(online)-2020]
 (1) 24 (2) 6 (3) 12 (4) 18
 CBO0177

EXERCISE # JEE-ADVANCED

Integer Type

- The number of water molecule(s) directly bonded to the metal centre in $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is
[JEE 2009]
CBO0178
- Based on VSEPR theory, the number of 90 degree F–Br–F angles in BrF_5 is
[JEE 2010]
CBO0179
- The difference in the oxidation numbers of the two types of sulphur atoms in $\text{Na}_2\text{S}_4\text{O}_6$ is.
[JEE 2011]
CBO0180
- The total number of lone-pairs of electrons in melamine is
[JEE Adv. 2013]
CBO0181
- The sum of the number of lone pairs of electrons on each central atom in the following species is.
[JEE 2017]

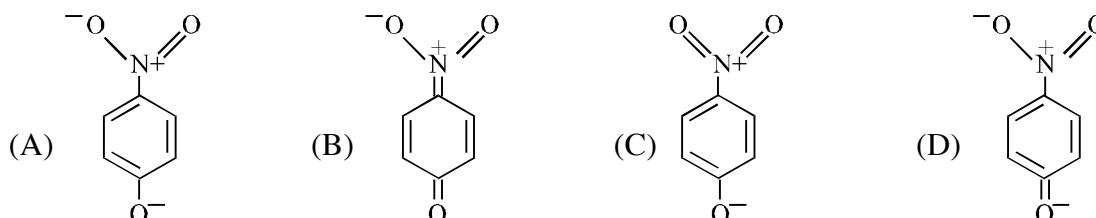


[Atomic number : N = 7, F = 9, S = 16, Br = 35, Te = 52, Xe = 54]

CBO0182

One or more than one correct

- The most likely representation of resonance structure of p-nitrophenoxide is:



CBO0183

- Specify hybridization of N and B atoms in a 1 : 1 complex of BF_3 and NH_3
[JEE 2002]
(A) N : tetrahedral, sp^3 ; B : tetrahedral, sp^3 (B) N : pyramidal, sp^3 ; B : pyramidal, sp^3
(C) N : pyramidal, sp^3 ; B : planar, sp^2 (D) N : pyramidal, sp^3 ; B : tetrahedral, sp^3

CBO0184

- The nodal plane in the π -bond of ethene is located in
[JEE 2002]
(A) the molecular plane
(B) a plane parallel to the molecular plane
(C) a plane perpendicular to the molecular plane which bisects, the carbon-carbon σ bond at right angle
(D) a plane perpendicular to the molecular plane which contains, the carbon-carbon bond.

CBO0185

9. **Statement-1** : p-Hydroxybenzoic acid has a lower boiling point than o-hydroxybenzoic acid.

because

Statement-2 : o-Hydroxybenzoic acid has intramolecular hydrogen bonding. [JEE 2007]

- (A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
 (B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.
 (C) Statement-1 is True, Statement-2 is False.
 (D) Statement-1 is False, Statement-2 is True.

CBO0186

10. **Statement-1** : In water, orthoboric acid behaves as a weak monobasic acid.

because

Statement-2 : In water, orthoboric acid acts as a proton donor. [JEE 2007]

- (A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
 (B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.
 (C) Statement-1 is True, Statement-2 is False.
 (D) Statement-1 is False, Statement-2 is True.

CBO0187

11. The nitrogen oxide(s) that contain(s) N–N bond(s) is/are

[JEE 2009]

- (A) N_2O (B) N_2O_3 (C) N_2O_4 (D) N_2O_5

CBO0188

12. The value of n in the molecular formula $Be_nAl_2Si_6O_{18}$ is

[JEE 2010]

CBO0189

13. The species having pyramidal shape is/are :

[JEE 2010]

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

CBO0190

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

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

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

CBO0191

15. The shape of XeO_2F_2 molecule is :

[JEE 2012]

- (A) Trigonal bipyramidal (B) Square planar
 (C) tetrahedral (D) see-saw

CBO0192

16. The compound(s) with TWO lone pairs of electrons on the central atom is(are)

[JEE 2016]

- (A) BrF_5 (B) ClF_3 (C) XeF_4 (D) SF_4

CBO0193

17. The crystalline form of borax has [JEE 2016]
(A) Tetranuclear $[B_4O_5(OH)_4]^{2-}$ unit
(B) All boron atoms in the same plane
(C) Equal number of sp^2 and sp^3 hybridized boron atoms
(D) One terminal hydroxide per boron atom
CBO0194
18. The order of the oxidation state of the phosphorus atom in H_3PO_2 , H_3PO_4 , H_3PO_3 and $H_4P_2O_6$ is [JEE 2017]
(A) $H_3PO_4 > H_4P_2O_6 > H_3PO_3 > H_3PO_2$
(B) $H_3PO_3 > H_3PO_2 > H_3PO_4 > H_4P_2O_6$
(C) $H_3PO_2 > H_3PO_3 > H_4P_2O_6 > H_3PO_4$
(D) $H_3PO_4 > H_3PO_2 > H_3PO_3 > H_4P_2O_6$
CBO0195
19. Based on the compounds of group 15 elements, the correct statement(s) is (are) [JEE 2018]
(A) Bi_2O_5 is more basic than N_2O_5
(B) NF_3 is more covalent than BiF_3
(C) PH_3 boils at lower temperature than NH_3
(D) The N–N single bond is stronger than the P–P single bond
CBO0196
20. The total number of compounds having at least one bridging oxo group among the molecules given below is _____. [JEE 2018]
 N_2O_3 , N_2O_5 , P_4O_6 , P_4O_7 , $H_4P_2O_5$, $H_5P_3O_{10}$, $H_2S_2O_3$, $H_2S_2O_5$
CBO0197

ANSWERS KEY

EXERCISE # O-1

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

EXERCISE # O-2

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

EXERCISE # S-1

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

EXERCISE # S-2

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

EXERCISE # JEE-MAIN

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

EXERCISE # JEE-ADVANCED

- Ans. 4
- Ans. 0
- Ans. 5
- Ans. 6
- Ans. 6

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

Important Notes

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