# ATOMIC STRUCTURE

Atom (greek word)

A TOM

(not) (divisible) [according to John Dalton]

Atom : According to John Dalton (1803 - 1808) considered that "all matters are composed of small particles called atoms which are not further divisible".

Dalton's Atomic Theory :

It is based on two laws :

i) law of conservation of mass.

ii) law of definite / constant proportion

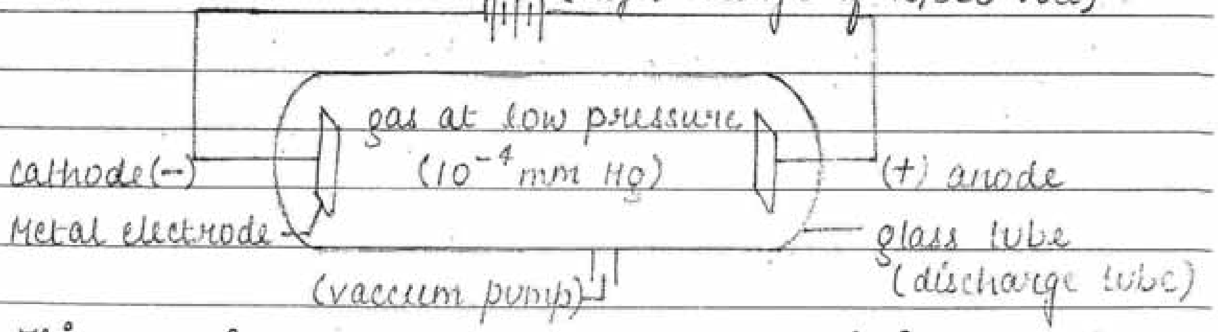
Features of Daltons Atomic Theory :

It includes five postulates.

MODULE 1 (Pg 157)

1. Discovery of Electron.

Cathode ray tube experiment:



This experiment was conducted by William crookes and Julius Plunker in 1879.

Apparatus:

The cathode ray discharge tube consist of a long glass tube at the ends of which two metal electrodes are placed. those two electrodes are connected to a source of high voltage and a vaccum pump is attached to the glass tube which can control the pressure of the gas filled in the tube.

Working:

- when a high voltage of 10000 V is applied across the electrodes. In between these electrodes a gas at low pressure is present. Then, a stream of particles were observed that were flowing from cathode towards anode. These rays were termed as cathode rays.
- For the verification of cathode rays, few holes were made in the anode and the tube behind the anode was coated with a flurošcent material like zinc sulphide.
- When the cathode ray pass through the anode and strike the zinc sulphide coating, they form a bright spot over the coating. This verified that some particles were moving from cathode side towards anode side and thus these particles were known as cathode rays.

Properties of cathode rays:

MODULE 1 (Pg 157)

* Characteristics of cathode ray does not depend on the nature of the gas and the electrodes used in the discharged tube.

* The specific charge e/m ratio ( charge/ mass ratio) of cathode rays (electron) does not depends on the nature of gas and electrodes present in the discharged tube. Hence, we can say that electrons are the basic constituents of all the atoms.

2 Discovery of Proton: (Anode rays or canal rays)
Goldstein observed that certain rays are moving from the side of anode towards cathode in a discharged tube. For verifying he used a perferoated cathode and coated the tube behind the cathode with a fluresence material called zinc sulphide. he observed that some bright spots are formed on the zinc sulphide coating, which verified that certain rays were moving from the side of the anode towards the cathode. Hence, he named them as anode rays or canal rays.

Properties of Anode rays
MODULE 1 (Pg 157 and 158)

* The nature of anode rays depends upon the nature of the gas present in the discharged tube.
* The specific charge of anode rays depends upon the nature of the gas present in the discharged tube.
* The specific charge value for the anode rays was maximum when the hydrogen was filled in the discharge tube. It indicates that the positively charge ion from hydrogen is lightest.

This lightest positively charged particle was named as Proton.

3. Discovery of Neutron :

James chadwick in 1932 bombarded a thin sheet of Beryllium with fast moving alpha particles. It was observed that highly penetrating rays of neutral particles were produced. These particles were named as neutrons.

$$_{4}^{9}Be + _{2}^{4}He \rightarrow _{6}^{12}C + _{0}^{1}n$$

{α - particle} {neutron}

The electron :

Properties of electron :

MODULE 1 (Pg 158)

The Proton :

Properties of proton :

MODULE 1 (Pg 158)

The Neutron :

Properties of Neutron :

MODULE 1 (Pg 159)

Other fundamental particles :

- Neutrino and Antineutrino
- Positron (positive electron $_{1}e^{0}$)
- Mesons
- Anti Proton

Q.1. Pick out the correct sequence for the order of the mass.

i) $e > p > n > \pi$ (mu) [meson]

ii) $p > e > \pi > n$

iii) $n > p > e > \pi$

iv) $n > p > \pi > e$

Ans : iv)

Q.2 Pick out the correct sequence for e/m ratio:

i) $e > p > n > \alpha$

ii) $p > e > \alpha > n$

iii) $e > \alpha > p > n$

iv) $e > p > \alpha > n$

Ans : iv)

e/m ratio of e $= \frac{1.6 \times 10^{-19}\,C}{9.1 \times 10^{-28}\,g} = 1.76 \times 10^{8}\,c/g$

e/m ratio of p $= \frac{1.6 \times 10^{-19}\,C}{1.67 \times 10^{-24}\,g} = 9.58 \times 10^{4}\,c/g$

e/m ratio of n $= 0$

e/m ratio of $\alpha = \frac{2 \times 1.6 \times 10^{-19}}{4 \times 1.67 \times 10^{-24}} = \frac{9.58 \times 10^{4}}{2}\,c/g$

Q.3. Pick out the correct sequence for the e/m ratio:

i) $H^{+} > D^{+} > He^{+} > He^{+2}$

ii) $H^{+} > D^{+} > He^{+2} > He^{+}$

iii) $H^{+} > D^{+} = He^{+2} > He^{+}$

iv) $H^{+} > D^{+} = He^{+} > He^{+2}$

Ans : iii)

e/m ratio of $H^+ = \frac{1.6 \times 10^{-19} c}{1.67 \times 10^{-24} g} = 9.58 \times 10^4 c/g$

e/m ratio of $He^+ = \frac{1.6 \times 10^{-19} c}{4 \times 1.67 \times 10^{-24} g} = \frac{9.58 \times 10^4 c/g}{4}$

e/m ratio of $He^{+2} = \frac{2 \times 1.6 \times 10^{-19} c}{4 \times 1.67 \times 10^{-24} g} = \frac{9.58 \times 10^4 c/g}{2}$

e/m ratio of $D^+ = \frac{1.6 \times 10^{-19} c}{2 \times 1.67 \times 10^{-24} g} = \frac{9.58 \times 10^4 c/g}{2}$

Representation of an atom of an element

$^{A}_{Z}X$

A → Mass no

X → Symbol of an element

Z → Atomic no.

Mass no = no. of proton + no. of neutrons = no. of nucleons

Atomic no = no. of proton = nuclear charge.

i) For a neutral atom,
no. of electrons (e) = no of proton (p) = Z.

ii) For a charged atom (ion)
no. of electrons (e) = Z - (charge on atom)

iii) No. of neutrons.
Mass no(A) - Atomic no (Z)

- For a neutral atom,
The no of electron = no of protons.
e = p.

- When an ion of an atom is formed, the electrons are transferred. Therefore, an atom and its ions differ in the no. of electron

- Mass no is always a whole namber.

Q.4. Find the value of Mass no (A), Atomic no (Z), no. of proton (p), electron (e) and neutron (n).

i) $^{14}_{7}N^{-3}$

a) $A = 14$
b) $Z = 7$
c) $p^+ = Z = 7$
d) $e^- = A - Z - (\text{charge}) = 7 - (-3) = 7 + 3 = 10$
e) $n^o = A - Z = 14 - 7 = 7$

ii) $^{16}_{8}O^{-2}$

a) $A = 16$
b) $Z = 8$
c) $p^+ = Z = 8$
d) $e^- = Z - (\text{charge}) = Z - (-2) = 8 + 2 = 10$
e) $n^o = A - Z = 16 - 8 = 8$

iii) $^{23}_{11}Na$

a) $A = 23$
b) $Z = 11$
c) $p^+ = Z = 11$
d) $e^- = 11$
e) $n^o = 23 - 11 = 12$

iv) $^{24}_{12}Mg^{+2}$

b) $Z = 12$

c) $p^+ = Z = 12$

d) $e^- = Z - (\text{charge}) = 12 - 2 = 10.$

e) $n^0 = A - Z = 24 - 12 = 12$

v) $^{27}_{13}Al$

a) $A = 27$

b) $Z = 13.$

c) $p^+ = Z = 13.$

d) $e^- = 13$

e) $n^0 = A - Z = 27 - 13 = 14$

vi) $^{19}_{9}F^-$

a) $A = 19$

b) $Z = 9.$

c) $p^+ = Z = 9$

d) $e^- = Z - (\text{charge}) = Z - (-1) = 9 + 1 = 10$

e) $n^0 = A - Z = 19 - 9 = 10$

vii) $^{39}_{19}K^+$

a) $A = 39$

b) $Z = 19$

c) $p^+ = Z = 19$

d) $e^- = Z - (\text{charge}) = 19 - 1 = 18$

e) $n^0 = A - Z = 39 - 19 = 20$

viii) $^{40}_{20}Ca$

a) $A = 40$

b) $Z = 20$

c) $p^+ = Z = 20$

d) $e^- = 20$

e) $n^0 = A - Z = 40 - 20 = 20$

Q.5. If in $A^{-3}$, the total no. of electrons are 18 and mass no. is 31, then find the value of Atomic no, proton and neutron

No. of $e^-$ = Z - (charge)

$18 = Z - (-3)$

$18 - 3 = Z$

$\therefore Z = 15$

No of $p^+$ = 15

No of $n^0$ = A - Z = 31 - 15 = 16

## Some important definitions

i) Atomic number (Z) :

MODULE 1 (Pg 159)

ii) Mass number (A) :

MODULE 1 (Pg 157)

Mass number ≈ Atomic weight

- Mass no. of an atom is always a whole no. but atomic weight may be in decimal because atomic weight is the average of weights of all the isotops of that element.

element $(Y_1, Y_2, Y_3)$; Mass $(w_1, w_2, w_3)$; % or ratio $(x_1, x_2, x_3)$

$$\text{Atomic weight} : \frac{w_1x_1 + w_2x_2 + w_3x_3}{x_1 + x_2 + x_3}$$

iii) Isotops :

MODULE 1 (Pg 161)

iv) Isobars :

MODULE 1 (Pg 163)

v) Isotones / Isoneutronic / Isotonic :

MODULE 1 (Pg 163)

vi) Isodiaphers :

MODULE 1 (Pg 163)

common mistake :

we sometimes shifts the value of ($n^o - p^+$) to (A - z) which are supposed to be isotones

vii) Isosters :

MODULE 1 (Pg 163)

viii) Isoelectronic :

MODULE 1 (Pg 163)

Q.6. If in $X^{+2}$, the mass no (A) = 55 and the no. of protons ($p^+$) = 25, then find out the value of mass no (A), Atomic no (Z), no of protons ($p^+$) no of neutrons ($n^o$) and electrons ($e^-$) in $X^{-3}$

$X^{+2} \Rightarrow$ A = 55

$p^+ = 25 = z$

$n^o = A - Z = 55 - 25 = 30$

$e^- = Z - (\text{charge}) = 25 - 2 = 23.$

$X^{-3} \Rightarrow$ A = 55

$z = 25$

$p^+ = 25$

$n^o = A - Z = 55 - 25 = 30$

$e^- = Z - (\text{charge}) = 25 - (-3) = 28$

Q.7. If in $X^{-2}$, no. of $p^+ = 16$, then find the number of $e^-$ in $X^{+2}$

$X^{-2} \Rightarrow p^+ = 16 = Z$

$e^- = Z - (\text{charge}) = 16 - (-2) = 18$

$X^{+2} \Rightarrow e^- = Z - (\text{charge}) = 16 - 2 = 14$

$\because Z = p^+ = 16$

Q.8. If in ${}^{12}_{6}C$, atoms of the mass of the proton is halved, neutron is tripled and that of electron is doubled, then what will the mass of ${}^{12}_{6}C$ atom and by how much % will it change.

Initial ${}^{12}_{6}C \Rightarrow$ Mass of an atom = Mass of $(p^+ + n^\circ)$

no. of $p^+ = 6$

no. of $n^\circ = A - Z = 12 - 6 = 6$

$\because$ Mass of 1 proton = 1 amu

Mass of 6 proton = 1×6 = 6 amu

$\because$ Mass of 1 neutron = 1 amu

Mass of 6 neutron = 1×6 = 6 amu.

Total mass = (6+6) amu = 12 amu

New ${}^{12}_{6}C \Rightarrow$ Mass of $p^+ = \frac{1}{2} \times 6$ amu = 3 amu

Mass of $n^\circ = 3 \times 6$ amu = 18 amu.

Total mass = (3+18) amu = 21 amu

The mass of $e^-$ is not taken into consideration because its mass is negligiable.

$$\text{Change in \%} = \frac{\text{New mass} - \text{Initial mass}}{\text{Initial mass}} \times 100$$

$$= \frac{21 - 12}{12} \times 100$$

$$= \frac{9}{12} \times 100 = 75\%$$

Hence, it increases by 75%.

Q.9 If in $^{14}_{7}N$, the mass of $p^+$ is doubled and $e^-$ is halfed and mass of neutron is same. Then what will be % change in Atomic weight

$^{14}_{7}N \Rightarrow$ no. of $p^+ = 7$

Mass of 1 $p^+$ = 1 amu

Mass of 7 $p^+ = 1 \times 7 = 7$ amu

no. of $n^0 = 14 - 7 = 7$

mass of 1 $n^0$ = 1 amu

Mass of 7 $n^0 = 1 \times 7 = 7$ amu

$\therefore$ Total mass = 7+7 = 14 amu.

given condition.

$^{14}_{7}N \Rightarrow$ mass of $p^+ = 2 \times 7 = 14$ amu.

mass of $n^0$ = 7 amu.

$\therefore$ Total mass = 14 + 7 = 21 amu

$$\% \text{ change} = \frac{21-14}{14} \times 100$$

$$= \frac{7}{14} \times 100 = 50\%$$

Hence atomic weight increases by 50%

Q-10. If in a $^{16}_{8}O$ atom, the mass of $p^+$ is doubled, mass of $e^-$ is halfed and mass of $n^0$ weigh $\frac{1}{4}$ Then, find the percentage change in the atomic weight.

$^{16}_{8}O \Rightarrow$ no. of $p^+$ = no of $n^0$ = 8.

Mass of 1 $p^+$ = Mass of 1 $n^0$ = 1 amu

no of $(p^+ + n^0) = 8 + 8 = 16$.

mass of $(p^+ + n^0)$ = 8 + 8 amu = 16 amu

given condition,

$^{16}_{8}O \Rightarrow$ mass of $p^+ = 2 \times 8 = 16$ amu

mass of $n^0 = \frac{1}{4} \times 8 = 2$ amu mass of $(p^+ + n^0) = 16 + 2 = 18$ amu

Change in percentage $= \frac{18-16}{16} \times 100$.

$= \frac{2}{16} \times 100 = 12.5\%$

Hence, atomic weight increases by 12.5%

Q.11 Assuming that atomic weight of ${}^{12}_{6}C$ is 150 units from the atomic table, then what will be the weight of ${}^{16}_{8}O$ atom and ${}^{14}_{7}N$.

${}^{12}_{6}C \Rightarrow$ no. of $p^+$ + no of $n^0 = 12$.

mass of $(p^+ + n^0) = 12$ amu

given condition,

${}^{16}_{8}O \Rightarrow$ no of $p^+$ + no. of $n^0 = 16$.

mass of $(p^+ + n^0) = 16$ amu.

$\because$ 12 amu = 150 units

1 amu $= \frac{150}{12}$ units and.

16 amu $= \frac{150}{12} \times 16 = 200$ units

${}^{14}_{7}N \Rightarrow$ no. of $p^+$ + no of $n^0 = 14$

mass of $(p^+ + n^0) = 14$ amu

$\therefore$ 14 amu $= \frac{150}{12} \times 14 = 175$ units.

Q.12. Chlorine exist in the nature in the form of two isotops ${}^{35}_{17}Cl$ and ${}^{37}_{17}Cl$. If the ratio of their occurence in the nature is 3:1 respectively Determine the average atomic weight of Cl.

Atomic weight $= \frac{w_1x_1 + w_2x_2}{x_1 + x_2}$

$$\frac{35\times3 + 37\times1}{3+1} = \frac{105 + 37}{4}$$

$$= \frac{142}{4} = 35.5$$

Q.13. Boron has two isotops ${}^{10}_{5}B$ and ${}^{11}_{5}B$. If their relative percentage of occurence in nature is 80% and 20% respectively. then, determine its average atomic weight.

$$\text{Atomic weight} = \frac{w_1x_1 + w_2x_2}{x_1 + x_2}$$

$$= \frac{10\times80 + 11\times20}{80+20}$$

$$= \frac{800 + 220}{100} = \frac{1020}{100} = 10.2$$

Q.13. The average atomic weight of an element Y is 41.8. If it exist in the form of two isotops ${}^{40}Y$ and ${}^{42}Y$, then, calculate their percentage of occurence in the nature.

$$\text{Atomic weight} = \frac{w_1x_1 + w_2x_2}{x_1 + x_2}$$

percentage of occurence = $x\%$ and $(100-x)\%$

$$41.8 = \frac{40\times x + 42\times(100-x)}{x + (100-x)}$$

$$41.8 = \frac{40x + 4200 - 42x}{100}$$

$$4180 - 4200 = -2x$$

$$-20 = -2x$$

$$\therefore x = \frac{-20}{-2} = 10\%$$

$$(100-x) = 100-10 = 90\%$$

Q.14. An element has three isotops and their weights are 11, 12 and 13 units respectively. If their relative percentage in nature is 85, 10 and 5 respectively then find out its average atomic weight.

$$\text{Average Atomic weight} = \frac{w_1x_1 + w_2x_2 + w_3x_3}{x_1 + x_2 + x_3}$$

$$= \frac{11 \times 85 + 12 \times 10 + 13 \times 5}{85 + 10 + 5}$$

$$= \frac{935 + 120 + 65}{100}$$

$$= \frac{1120}{100} = 11.2$$

Models of atoms :

i) Thomson's model of atom (1904)

MODULE 1 (Pg 165)

- He was the first scientist to propose a detailed model of an atom.
- According to his model, electrons are embedded in positively charged sphere of an atom
- An atom is electrically neutral because it contains equal number of protons and electrons.
- This model of an atom is also known as
  - Plum - Pudding Model
  - Raisin Pudding Model
  - Water Melon Model

Drawbacks :

- The mass and the positive charge of the atom is considered to be evenly spread.

- It represented a static model that is electrons were stable.

ii) Rutherford's $\alpha$-scattering experiment:

Observation:

MODULE 1 (Pg 166)

- Most of the $\alpha$-particles passed undeflected.
- Few of the $\alpha$-particles got deflected through small angles.
- A few of the $\alpha$-particle (1 out of 20,000) retraced back its path.

Conclusion:

- Most of the particles passed undeflected, indicating that lots of spaces in an atom was empty.
- The positively charged were not uniformly distributed, as thomson said because only few particles got deflected. The positive charge was concentrated in a small region in an atom which ~~was dat~~ later came to be known as ~~neutrons~~ nucleus
- The size of the nucleus is much smaller as compared to the size of an atom

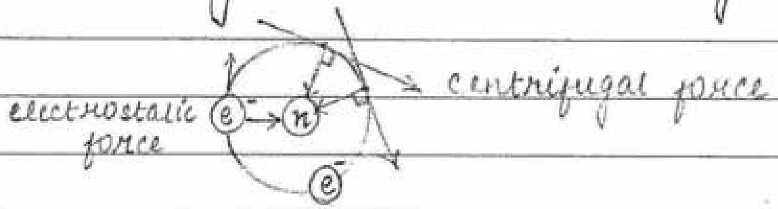
MODULE 1 (Pg 165 and 166)

The proposed structure of an atom :

- The positive charge and mass of the entire atom is concentrated in a small region known as nucleus in the centre of the atom.

- The negatively charged electrons revolves around the nucleus in the fixed orbit in the same way like planets revolves around the sun. Hence, it is also known as 'Planetary model of an atom'

- The electrostatic force of attraction acts between the electrons ($e^-$) and nucleus of an atom and this forced is balanced by centrifugal force acting on electron in tangential direction.



APPLICATION of Rutherford Model :

MODULE 1 (Pg 166)

i) $$\frac{\text{Radius of an atom}}{\text{Radius of nucleus}} = \frac{r_A}{r_N} = \frac{10^{-10}\,m}{10^{-15}\,m} = 10^5\,m$$

$$\therefore r_A = 10^5\,r_N$$

Radius of an atom is $10^5$ times the radius of a nucleus.

ii) $\frac{\text{volume of an atom}}{\text{volume of the nucleus}} = \frac{4/3\pi(r_A)^3}{4/3\pi(r_N)^3} = \frac{(10^{-10})^3}{(10^{-15})^3}$

$= \frac{10^{-30}}{10^{-45}} = 10^{15}$

$\therefore$ vol$^m$ of an atom = $10^{15}$ vol$^m$ of the nucleus.

iii) The radius of the nucleus is proportional to the cube root of the number of nucleons (mass no.)

$\therefore R \propto A^{1/3}$

$\Rightarrow R = R_0 A^{1/3}$ cm

where $R_0 = 1.33 \times 10^{-13}$ cm (constant)

A = mass no ($p^+ + n^\circ$)

R = Radius of the nucleus.

iv) The relation between number of deflected particles and deflected angle $\theta$.

$\therefore \mu \propto \frac{1}{\sin^4 \frac{\theta}{2}}$ ($\theta$ increases, $\mu$ decreases)

where $\mu$ = deflected particles

$\theta$ = deflected angle.

Q.15. Calculate the radius of a nucleus that contains 64 nucleons in it.

$\because R = R_0 A^{1/3}$, $R_0 = 1.33 \times 10^{-13}$ cm

$= 1.33 \times 10^{-13}$ cm $\times (64)^{1/3}$

$= 1.33 \times 10^{-13}$ cm $\times (4)^{3 \times \frac{1}{3}}$

$= 1.33 \times 10^{-13}$ cm $\times 4$

$= 5.32 \times 10^{-13}$ cm

Q.16. If 120 particles are deflected at an angle of 60° calculate the number of deflected particle at an angle of 90°

$$\because \mu \propto \frac{1}{\sin^4 \frac{\theta}{2}}$$

$$120 = \frac{K}{\sin^4 \frac{60°}{2}} = \frac{K}{\sin^4(30°)} \quad —①$$

$$\mu = \frac{K}{\sin^4 \frac{90°}{2}} = \frac{K}{\sin^4(45°)} \quad —⑪$$

Dividing ① from ⑪

$$\frac{120}{\mu} = \frac{\frac{K}{\sin^4(30°)}}{\frac{K}{\sin^4(45°)}}$$

$$\Rightarrow \frac{120}{\mu} = \frac{K}{\sin^4(30°)} \times \frac{\sin^4(45°)}{K} = \frac{(1/\sqrt{2})^4}{(1/2)^4}$$

$$\therefore \frac{120}{\mu} = \frac{1}{4} \times \frac{16}{1} = 4$$

$$\therefore \mu = \frac{120}{4} = 30°$$

∴ Number of deflected particle = 30

Drawbacks :

MODULE 1 (Pg 166 and 167)

- He was not able to explain the stability of an atom

- The loss of energy by electron was not continuous in an atom. because if electrons loses its energy continuously, the spectrum observed should be continuous but the actual observed spectrum consist of defined lines of definite frequency

- He was not able to explain the arrangement of electrons and their energy

ELECTROMAGNETIC WAVES (EM WAVES) OR radiant energy / electromagnetic radiation :

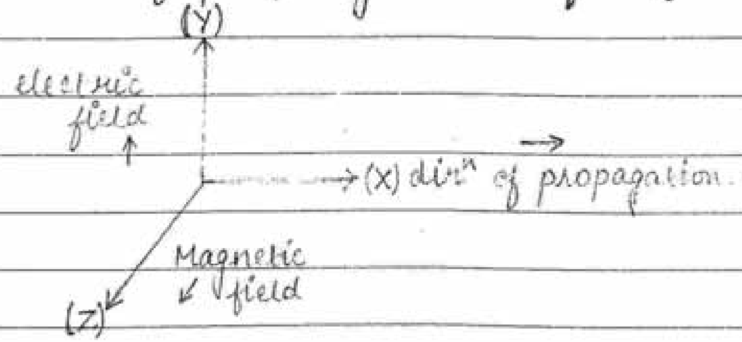
MODULE 1 (Pg 167)

- It is a form of energy transmitted from one body to another in a continuous manner in the form of waves are called electromagnetic waves.

- It is of two types:
  i) wave theory : proposed by Maxwell
  ii) Particle theory: proposed by Planck

- It does not require a material medium for proporation and it travels with the speed of the light ($3 \times 10^8$ m/s).

- If a charged particle undergoes acceleration, it ~~gets both electric~~ generates both electric as well as magnetic field which are perpendicular to each other and are also perpendicular to the direction of propargation of light



Characterstics of wave :
MODULE 1 (Pg 167)

a) Wavelength : ($\lambda$) (Lambda)
It is the distance between two consecutive crest or two consecutive trough.

$1\,m = 10^2\,cm = 10^9\,nm = 10^{12}\,pm = 10^{10}\,\overset{\circ}{A}$
$1\,cm^{-1} = 10^2\,m^{-1}$ and $1\,cm = 10^{-2}\,m$

b) Frequency : ($\nu$) (nu)
It is the number of waves which pass through a point in 1 sec.

$1\,Hz = 1\,sec^{-1} = 1\,cps.$

c) Time period : (T)
Time taken by a wave to pass through 1 point.
$T = \frac{1}{\nu}\,sec$

d) Velocity : (c) (speed of light = $3 \times 10^8$ m/s)

It is the distance covered by a wave in 1 sec

Frequency is inversely proportional to $\lambda$.

$$\lambda \propto \frac{1}{\nu} = \frac{c}{v} \text{ (constant)}$$

c= speed of light in vaccum = $3 \times 10^6$ m/sec.

e) Wave number :($\bar{v}$) (nu bar)

It is number of waves present in 1 cm and it is reciprocal of wave length

$$\bar{v} = \frac{1}{\lambda}$$

$1 \text{ cm}^{-1} = 100 \text{ m}^{-1}$

f) Amplitude : (a)

It is height of crest or depth of though

Q-17 ~~Th~~ Calculate the wave number of a radiation whose frequency is $5 \times 10^{16}$ Hz

$$\bar{v} = \frac{1}{\lambda}$$

$$\lambda = \frac{c}{v} = \frac{3 \times 10^8 \text{ m/s}}{5 \times 10^{16} \text{ Hz}}$$

$$\therefore \bar{v} = \frac{5 \times 10^{16-8}}{3 \text{ m}} = 1.6 \times 10^8 \text{ m}^{-1}$$

Q-18. A radio station is broadcasting at 100 ~~mgH~~ MHz. If the distance between the station and the receiver is 300 km. Then, how long would it take the signal to reach the receiver. Find wavelength and wave number

$\nu = 100\ \text{mHz} = 100 \times 10^6 = 10^8\ \text{Hz}$

$\lambda = 300\ \text{km} = 300 \times 1000 = 3 \times 10^5\ \text{m}$

$$\text{Time } (T) = \frac{\text{displacement } (\lambda)}{\text{velocity } (c)}$$

$$= \frac{3 \times 10^5}{3 \times 10^8} = 10^{5-8} = 10^{-3}\ \text{sec}$$

$$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{3 \times 10^8} = \cancel{10^{8-5}} = \cancel{10^3}\,3\text{m}$$

$$\bar{\nu} = \frac{1}{\lambda} = \frac{1}{3\text{m}} = 0.33\ \text{m}^{-1}$$

Q-19. The wave number of a beam of light is $400\ \text{cm}^{-1}$ what is the wavelength of light in nm. also, find out the frequency of light.

$\bar{\nu} = 400\ \text{cm}^{-1}$

$$\lambda = \frac{1}{\bar{\nu}} = \frac{1}{400}\ \text{cm} = \frac{1}{400} \times 10^{-2}\ \text{m}$$

$$= \frac{1}{400} \times 10^{-2} \times 10^9\ \text{nm.} \quad \left\{ \begin{array}{l} 1\ \text{cm} = 10^{-2}\ \text{m} \\ 1\ \text{m} = 10^9\ \text{nm} \end{array} \right\}$$

$$\lambda = \frac{10^7}{4 \times 10^2}\ \text{nm} = \frac{10^{7-2}}{4} = \frac{10^5}{4} = 25000\ \text{nm.}$$

$$\nu = \frac{c}{\lambda} = \frac{3 \times 10^8\ \text{m/s}}{25000\ \text{nm}} = \frac{3 \times 10^8\ \text{m/s}}{25 \times 10^3 \times 10^{-9}\ \text{m}}$$

$$= \frac{3 \times 10^8\ \text{m/s}}{25 \times 10\ \text{m}} = \frac{3 \times 10^8}{25 \times 10^{-6}}\ \text{s.}$$

$$= 0.12 \times 10^{14} = 1.2 \times 10^{13}\ \text{s.}$$

Q.20 Calculate the wave number and the frequency of a radiation whose wavelength is 6000 Å.

$\lambda = 6000\ \mathring{A}$

$1\ \mathring{A} = 10^{-10}\ m$

$\therefore 6000\ \mathring{A} = 6000 \times 10^{-10} = 6 \times 10^{-7}\ m.$

$$\bar{\nu} = \frac{1}{\lambda} = \frac{1}{6 \times 10^{-7}\ m} = 0.16 \times 10^{7}\ m^{-1} = 1.66 \times 10^{6}\ m^{-1}$$

$$\nu = \frac{c}{\lambda} = \frac{3 \times 10^{8}\ m/s.}{6 \times 10^{-7}\ m} = 0.5 \times 10^{15}\ Hz = 5 \times 10^{14}\ Hz$$

The electromagnetic spectrum:

MODULE 1 (Pg 168)

- On the basis of increasing wavelength.
  Cosmic rays < $\gamma$ rays < x-rays < ultra-violet < visible spectrum < Infrared < Micro wave < Radio wave.

Planck's Quantum theory:

MODULE 1 (Pg 168)

- The radiant energy is emitted or absorbed discontinuously by a body in the form of small discrete ~~parti~~ packects of energy called quantum.

- In case of light, the smallest packet is 'photon'.

energy of 1 mole quantum:

$$E = Nh\nu = \frac{Nhc}{\lambda} \quad J mol^{-1} \text{ or } erg\ mol^{-1}$$

$\therefore N = 6.023 \times 10^{23}.$

{'mol$^{-1}$' signifies that, we need to calculate in mole so instead of n, it will be $N = 6.023 \times 10^{23}$}

$$E = \frac{2.859}{\lambda\ cm}\ (calorie\ mol^{-1})$$

Q.21 Calculate the wavelength of photon whose energy is 1 electron volt.

1 electron volt (eV) = $1.6 \times 10^{-19}$ J

$\because E = \frac{hc}{\lambda} \quad \therefore \lambda = \frac{hc}{E}$

$= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{1.6 \times 10^{-19}}$

$= \frac{19.878 \times 10^{-7}}{1.6} = 12.4 \times 10^{-7}$ m.

Q.22. If the wavelength of a photon whose energy is 'E' is 6000 Å, then find out the wavelength of a photon whose energy is 3E.

$E_1 = \frac{\cancel{hc}}{\lambda_1}$

$E_2 = \frac{\cancel{hc}}{\lambda_2}$

$\therefore \frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1}$

$\frac{E}{3E} = \frac{\lambda 2}{6000} \Rightarrow \frac{1}{3} = \frac{\lambda 2}{6000}$

$\therefore \lambda_2 = \frac{6000}{3}$ Å $= 2000$ Å

Q.23. $3 \times 10^{8}$ photons of a certain light radiation are found to produce 1.5 Joule of energy. Calculate the wavelength of the radiation. (m)

$\because E = \frac{nhc}{\lambda} \quad \therefore \lambda = \frac{nhc}{E}$

$$\lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8} \times 3 \times 10^{8}}{1.5}$$

$$= \frac{6.626 \times 9 \times 10^{-18}}{1.5} \text{ m}$$

$$= 39.7 \times 10^{-18} \text{ m}$$

24 A 100 watt bulb emits monocromatic light of wavelength 1986 nm. calculate the no of photon emitted per sec by the bulb.

$1 \text{ watt} = 1 \text{ J/sec}$

$\therefore 100 \text{ watt} = 100 \text{ J/sec.}$

$1 \text{ nm} = 10^{-9} \text{ m}$

$\therefore 1986 \text{ nm} = 1986 \times 10^{-9} \text{ m}$

$$E = \frac{nhc}{\lambda}$$

$$100 = n \times \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{1986 \times 10^{-9}}$$

$$1986 \times 10^{-9} \times 10^{2} = 6.626 \times 3 \times 10^{-26} \times n$$

$$1986 \times 10^{-7} = 19.86 \times 10^{-26} \times n$$

$$19.86 \times 10^{-5} = 10^{-26} \times 19.86 \times n$$

$$\therefore n = \frac{10^{-5}}{10^{-26}} = \frac{10^{26}}{10^{5}}$$

$$n = 10^{26-5} = 10^{21}$$

unit convention.

- 1 calorie = 4.2 J
- 1 Joule = $10^{7}$ erg
- 1 electron volt = $1.6 \times 10^{-19}$ J

$E = \frac{nhc}{\lambda}$, unit of $\lambda$ and c should be in m and m/s respectively. and unit of h should be according to energy

Bohr's atomic model :

MODULE 1 (Pg 169)

Some important formulae:

Coulombic force: $\frac{Kq_1q_2}{r^2}$

centrifugal force: $\frac{mv^2}{r}$

Angular momentum : mvr

Bohr's Postulates :

MODULE 1 (Pg. 169).

It includes six postulates.

- nth excited state will represent (n+1)th energy level

  $\Delta E = E_{higher} - E_{lower}$ = energy of a quantum.

- During transition, defenit amount of energy is released and absorbed.

Application of Bohr's model

i) Radius of various orbits (shell):

MODULE 1 (Pg 170)

$$r_n = 0.529 \times \frac{n^2}{Z} \mathring{A}$$

where, n = no of shells and

Z = atomic no.

case I : If n is constant, $r \propto \frac{1}{z}$

$$\therefore \frac{r_1}{r_2} = \frac{Z_2}{Z_1}$$

case II : If z is constant, $r \propto Z$

$$\therefore \frac{r_1}{r_2} = \frac{(n_1)^2}{(n_2)^2}$$

case III : neither (n) nor (z) is constant

$$\therefore \frac{r_1}{r_2} = \frac{(n_1)^2}{(n_2)^2} \times \frac{Z_2}{Z_1} \text{ or } \frac{(n_1)^2}{Z_1} \times \frac{Z_2}{(n_2)^2}$$

25. If the radius of the 1st orbit of hydrogen atom is x Å, then the radius of its 3rd orbit will be.

$$\frac{r_1}{r_2} = \frac{(n_1)^2}{(n_2)^2}$$

$$\Rightarrow \frac{x}{r_2} = \frac{(1)^2}{(3)^2} = \frac{1}{9}$$

$$\therefore r_2 = 9x.$$

∴ radius of 3rd orbit = 9x

26 Calculate the radius of 3rd orbit of $Li^{+2}$

$$r_n = \left(0.529 \times \frac{n^2}{Z}\right) \text{Å}$$

$$= \left(0.529 \times \frac{3^2}{3}\right) \text{Å}$$

$$= 0.529 \times \frac{9}{3} = 1.578 \text{ Å}$$

Q.27 calculate the ratio of radius of 2nd to 3rd orbit for hydrogen atom.

$$\frac{r_1}{r_2} = \frac{(n_1)^2}{(n_2)^2}$$

$$\frac{r_1}{r_2} = \frac{(2)^2}{(3)^2} = \frac{4}{9.} = 4:9.$$

$$r_1 : r_2 = 4:9$$

Q.28 calculate the radius ratio of 3rd orbit of hydrogen atom to 2nd orbit of $He^+$

$$\frac{r_1}{r_2} = \frac{(n_1)^2}{z_1} \times \frac{z_2}{(n_2)^2}$$

$$= \frac{(3)^2}{1} \times \frac{2}{(2)^2} = \frac{9 \times 2}{4} = \frac{9}{2}$$

$$\therefore r_1 : r_2 = 9:2$$

Q.29 calculate the diameter and circumference of 3rd orbit of $Li^{+2}$.

$$r_n = \left(0.529 \times \frac{n^2}{z}\right) \mathring{A}$$

$$= \frac{0.529 \times (3)^2}{3.} = \frac{0.529 \times 9}{3}$$

$$r_n = 1.587 \mathring{A}$$

$$\text{diameter} = r_n \times 2 = (1.587 \times 2) \mathring{A} = 3.174 \mathring{A}$$

$$\text{circumference} = 2\pi r.$$

$$= (2 \times 3.14 \times 1.587) \mathring{A}$$

$$= 9.965 \mathring{A}$$

Q.30. The ratio of radius of two bore orbit for hydrogen atom is 4:1, then the orbit will be.

i) K and L

ii) N and L

iii) L and K

iv) Both (ii) and (iii)

Ans: iv)

$$\frac{r_1}{r_2} = \frac{(n_1)^2}{(n_2)^2} = \frac{(2)^2}{(1)^2} = 4:1$$

31 Find out the ratio of radius of 2nd orbit of $Li^{+2}$ to 3rd orbit of $He^+$

$$\frac{r_1}{r_2} = \frac{(n_1)^2}{Z_1} \times \frac{Z_2}{(n_2)^2}$$

$$\frac{r_1}{r_2} = \frac{(2)^2}{3} \times \frac{2}{(3)^2} = \frac{4}{3} \times \frac{2}{9} = \frac{8}{27}$$

$$\therefore r_1 : r_2 = 8 : 27$$

32 Find out the ratio of circumference of 1st excited state of $Li^{+2}$, 2nd excited state of H and 3rd excited state of $He^+$.

radius of $Li^{+2}$ : H : $He^+$

$$0.529 \frac{n^2}{Z} = \frac{(2)^2}{3} : \frac{(3)^2}{1} : \frac{(4)^2}{2}$$

$$= \frac{4}{3} : \frac{9}{1} : \frac{16}{2}$$

circumference of $Li^{+2}$ : H : $He^+$

$$2\pi r = 2\pi \times 0.529 \times \frac{4}{3} : 2\pi \times 0.529 \times 9 : 2\pi 0.529 \times 8$$

$$= \frac{4}{3} : 9 : 8$$

$$= 4 : 27 : 24$$

Q.33 Find out the ratio of radius of 2nd orbit of hydrogen to 1st orbit of $Li^{+2}$ to 3rd orbit of $He^+$.

Radius of H : $Li^{+2}$ : $He^+$

$$0.529 \times \frac{n^2}{z} = \frac{(2)^2}{1} : \frac{(1)^2}{3} : \frac{(3)^2}{2}$$

$$= 4 : \frac{1}{3} : \frac{9}{2}$$

$$= 24 : 2 : 27$$

Q.34. Calculate the angular momentum of an electron in 4th orbit of $He^+$.

Angular velocity $= mvr = \frac{nh}{2\pi}$

$$= \frac{4h}{2\pi} = \frac{2h}{\pi}$$

ii) Velocity of electron in Bohr orbit:

MODULE 1 (Pg 171)

$$v = \left(2.18 \times 10^6 \frac{z}{n}\right) m/s.$$

OR

$$v = \left(2.18 \times 10^8 \frac{z}{n}\right) cm/s$$

where, n = no. of shells and

z = atomic no.

Case I : If z is constant, ~~$\therefore$~~ $v \propto \frac{1}{n}$

$$\therefore \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

case II: If n is constant, $v \propto Z$

$$\frac{v_1}{v_2} = \frac{Z_1}{Z_2}$$

case III: neither (n) nor (Z) is constant.

$$\frac{v_1}{v_2} = \frac{Z_1}{n_1} \times \frac{n_2}{Z_2}$$

Q.35 Calculate the ratio of velocity of electron in 2nd orbit of $Li^{+2}$ to 3rd orbit of $He^+$

$$\frac{v_1}{v_2} = \frac{Z_1}{n_1} \times \frac{n_2}{Z_n}$$

$$= \frac{3}{2} \times \frac{3}{\cancel{3}2} = \frac{9}{4} = 9:4$$

$\therefore v_1 : v_2 = 9:4$

Q.36 Calculate the velocity of an electron in 3rd orbit of $Li^{+2}$

$$v = \left(2.18 \times 10^6 \frac{Z}{n}\right) m/s$$

$$= \left(2.18 \times 10^6 \times \frac{3}{3}\right) m/s.$$

$$= 2.18 \times 10^6 \; m/s.$$

Q.37 If $v_1$, $v_2$, $v_3$ and $v_4$ are the velocities of an electron in 1st orbit of H, $He^+$, $Li^{+2}$, $Be^{+3}$ respectively. then pick out the correct relation.

i) $v_1 < v_2 < v_3 < v_4$

ii) $v_1 > v_2 > v_3 > v_4$

iii) $v_1 = v_2 = v_3 = v_4$

iv) None of these.

Ans) i)

$$v_1 : v_2 : v_3 : v_4$$

$$\frac{z_1}{n_1} : \frac{z_2}{n_2} : \frac{z_3}{n_3} : \frac{z_4}{n_4}.$$

$$\because n = \text{constant}$$

$$\therefore v \propto z$$

$$1 : 2 : 3 : 4$$

$$\therefore v_1 < v_2 < v_3 < v_4$$

Q.38 If $v_1$, $v_2$, $v_3$ and $v_4$ are the velocities of an electron in 1st, 2nd, 3rd and 4th orbit of H atom respectively, then pick out the correct relation.

i) $v_1 < v_2 < v_3 < v_4$

ii) $v_1 > v_2 > v_3 > v_4$

iii) $v_1 = v_2 = v_3 = v_4$

iv) None of these

Ans) ii

$$v_1 : v_2 : v_3 : v_4.$$

$$\because z = \text{constant}$$

$$\therefore v \propto \frac{1}{n}$$

$$\therefore v_1 > v_2 > v_3 > v_4$$

Q-39. If $v_1$, $v_2$, $v_3$ and $v_4$ are the velocities of an electrons in 1st orbit of H, 2nd orbit of He, 3rd orbit of $Li^{+2}$ and 4th orbit of beryllium, then pick out the correct [redacted]

i) $v_1 < v_2 < v_3 < v_4$

ii) $v_1 > v_2 > v_3 > v_4$

iii) $v_1 = v_2 = v_3 = v_4$

iv) None of these

Ans) iii)

$$v_1 : v_2 : v_3 : v_4$$

Here, $\frac{Z}{n}$ = constant.

$$\therefore \frac{v_1}{n_1} : \frac{v_2}{n_2} : \frac{v_3}{n_3} : \frac{v_4}{n_4} = K$$

$$\therefore v_1 = v_2 = v_3 = v_4$$

iii) Total energy of electron in Bohr model:

MODULE I (Pg 171)

Potential energy: $\frac{-KZe^2}{r}$

Kinetic energy: $\frac{KZe^2}{2r}$

Total energy : Potential energy + Kinetic energy

$$= \frac{-KZe^2}{r} + \frac{KZe^2}{2r}$$

$$= \frac{-KZe^2}{2r}.$$

$$\therefore T.E = -KE = \frac{PE}{2}$$

$$T.E = (-2.18 \times 10^{-18}) \times \frac{Z^2}{n^2} \text{ J/Atom}$$

$$= -13.6 \times \frac{Z^2}{n^2} \text{ eV/Atom}$$

$$\therefore E\,(\text{energy}) \propto -\frac{Z^2}{n^2}$$

$$= \frac{-13.6 \times 1^2}{2^2} = \frac{-13.6}{4} \text{ eV/atom}$$

$$= -3.4 \text{ eV/atom}$$

Energy of an electron in 3rd orbit

$$= \frac{-13.6 \cdot \times 1^2}{3^2} = \frac{-13.6}{9} \text{ eV/ atom}$$

$$= -1.51 \text{ eV/atom}$$

Energy of an electron in 4th orbit

$$= -\frac{13.6 \times 1^2}{4^2} = \frac{-13.6}{16} \text{ eV/atom}$$

$$= -0.85 \text{ eV/ atom}$$

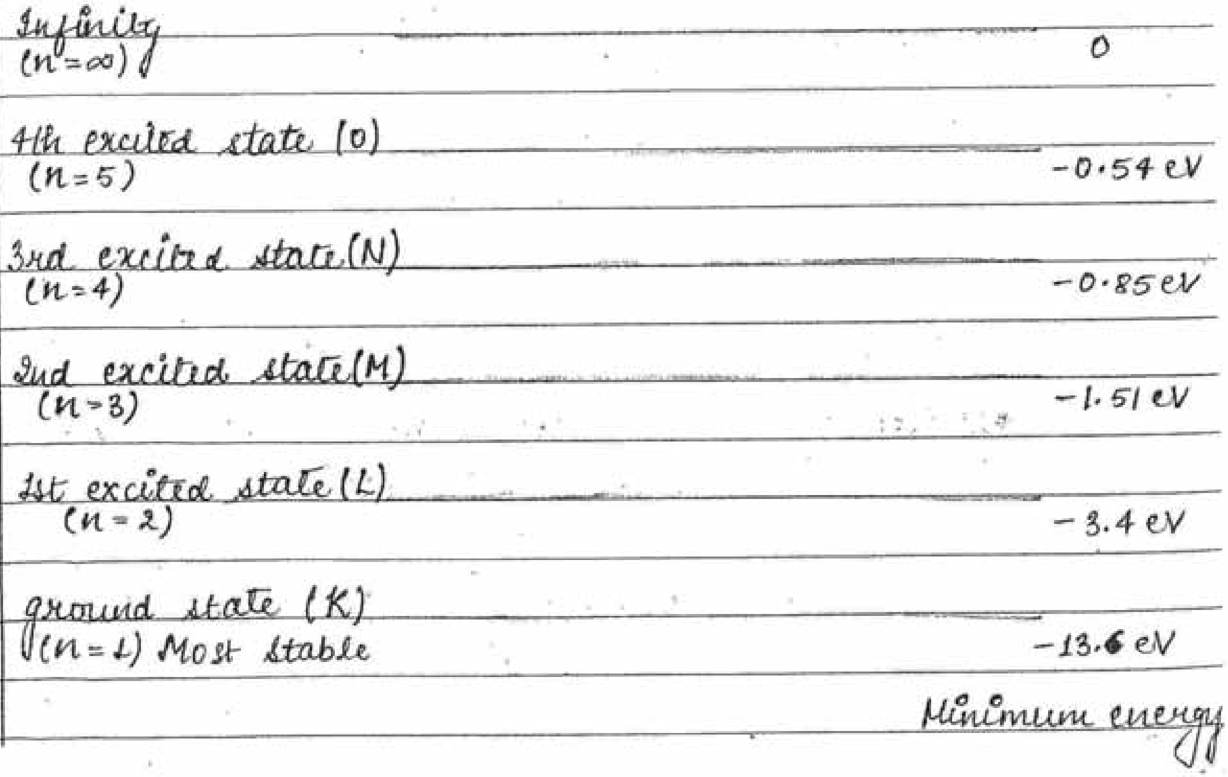
Energy of an electron in 5th orbit

$$= -\frac{13.6 \times 1^2}{5^2} = \frac{-13.6}{25} = \text{ eV/atom}$$

$$= -0.54 \text{ eV/ atom}$$

Energy of an electron at infinity

$$= \frac{-13.6 \times 1^2}{\infty^2} = 0$$



$$T.E. \ \alpha \ \frac{-Z^2}{n^2}$$

Case I: If $n$ is constant, $E \ \alpha \ -Z^2$ .

$$\therefore \ Z \uparrow \Rightarrow E \downarrow$$

$$\therefore \frac{E_1}{E_2} = \frac{(Z_1)^2}{(Z_2)^2}$$

Case II: If $Z$ is constant, $E \ \alpha \ \frac{-1}{n^2}$

$$\therefore \ n \uparrow \Rightarrow E \uparrow$$

$$\therefore \frac{E_1}{E_2} = \frac{(n_2)^2}{(n_1)^2}$$

Case III: neither $(n)$ nor $(Z)$ is constant

$$\frac{E_1}{E_2} = \frac{(Z_1)^2}{(n_1)^2} \times \frac{(n_2)^2}{(Z_1)^2}$$

Q. 40. calculate the energy of an electron in 1st 2nd, 3rd, 4th and 5th orbit of H atom. and also calculate its energy at infinity.

~~Et~~ Energy of an electron in 1st orbit:

$$-13.6 \times \frac{Z^2}{n^2} \ eV/atom$$

$$= -13.6 \times \frac{1^2}{1^2} = -13.6 \ eV/atom$$

Energy of an electron in 2nd orbit:

Energy difference :

- (K-L) shell : $-3.4-(-13.6) = 13.6-3.4 = 10.2$ eV
- (L-M) shell : $-1.51-(-3.4) = 3.4-1.51 = 1.89$ eV
- (M-N) shell : $-0.85-(-1.51) = 1.51-0.85 = 0.66$ eV
- (N-O) shell : $-0.54-(-0.85) = 0.85-0.54 = 0.31$ eV

a) Ionization energy:
MODULE 1 (Pg 169)

Minimum amount of energy required to remove an electron from its ground state to infinity.

$$IE = E_{\infty} - E_1$$
$$= 0 - E_1 = -E_1$$ (Kinetic energy in 1st she

For eg: In case of hydrogen atom.
in 1st shell, $-(-E_1) = -(-13.6)$ eV
$= +13.6$ eV

- Ionization energy is equal to the energy of an electron in its ground state with a reverse sign.

- Ionization energy is always positive (+ve).

b) Seperation energy:
MODULE 1 (Pg 170)

Minimum amount of energy required to remove an electron from its excited state to infinity is called seperation energy

$$SE = E_\infty - E_n \quad [n = 2, 3, 4, 5 \ldots\ldots]$$
$$0 - E_n = -E_n$$

For eg: In case of hydrogen atom

1st $S.E = -E_2 = +3.4\,eV$

2nd $S.E = -E_3 = +1.51\,eV$

- The energy of an electron in that state from which it is removed with a reverse sign.

- Seperation energy is always positive (+ve).

c) Excitation Energy:

MODULE 1 (Pg 170)

The amount of energy required to shift an electron from ground state to any other excited state.

$$EE = E_n - E_1 \quad [n = 2, 3, 4, 5 \ldots\ldots]$$

For eg: In case of hydrogen atom

1st $EE = E_2 - E_1 = -3.4 - (-13.6)$

$= 13.6 - 3.4 = 10.2\ eV$

2nd $E.E = E_3 - E_1 = -1.51 - (-13.6)$.

$= 13.6 - 1.51 = 12.09\ eV$

3rd $E.E = E_4 - E_1 = -0.85 - (-13.6)$.

$= 13.6 - 0.85 = 12.75\ eV$

* The total energy of an electron is always (-ve) ~~positive~~ and its maximum value is at infinity. ($E_\infty = 0$)

For any particular species : (applicable of all)

- $TE_1 < TE_2 < TE_3 < TE_4$
- $KE_1 > KE_2 > KE_3 > KE_4$
- $PE_1 < PE_2 < PE_3 < PE_4$
- $E_2 - E_1 > E_3 - E_2 > E_4 - E_3 > E_5 - E_4$

* TRICKS :( for any species)

i) $\underset{\text{(any species)}}{E_n} = \underset{\text{(H atom)}}{E_n} \times z^2$

ii) $\underset{\text{(any species)}}{\Delta E = (E_2 - E_1)} = \underset{\text{(H atom)}}{\Delta E (E_2 - E_1)} \times z^2$

iii) $E_n = \frac{E_1}{n^2}$ * [Do not use either of the tricks in ratio]

Q. 41. Calculate the energy of an electron in 2nd orbit of $Li^{+2}$.

$$E = -13.6 \times \frac{z^2}{n^2} = -13.6 \times \frac{9}{4} \text{ eV}$$

$$= -30.6 \text{ eV}$$ OR

Using trick (1),

$$\underset{(Li^{+2})}{E_2} = \underset{(H)}{E_2} \times z^2$$

$$= -3.4 \times 9 = -30.6 \text{ eV}$$

Q.42 The energy of an $e^-$ in 1st orbit of H-atom is -E eV. Calculate the energy in 3rd orbit

$$\frac{E_1}{E_2} = \frac{(n_2)^2}{(n_1)^2}$$

$$\frac{-E}{E_2} = \frac{9}{1}$$

$$\therefore \quad E_2 = \frac{-E}{9.} \quad \text{OR}$$

Using trick (iii)

$$E_n = \frac{E_1}{n^2} \Rightarrow E_2 = \frac{-E}{9.}$$

43. Calculate the difference of energy between 3rd and 2nd Orbit of $He^+$.

$$\Delta E = E_3 - E_2$$

$$= -\frac{13.6 \times 4}{9} - \left(-\frac{13.6 \times 4}{4}\right)$$

$$= -13.6 \left[\frac{4}{9} - \frac{4}{4}\right]$$

$$= -13.6 \times \frac{16-36}{36} = -13.6 \times \frac{(-20)}{36.}$$

$$= 13.6 \times \frac{5}{9} = 7.56 \text{ eV} \quad \text{OR}$$

Using trick (ii).

$$\underset{He^+}{\Delta E_{(3-2)}} = \underset{H}{\Delta E_{(3-2)}} \times z^2$$

$$= -1.51 - (-3.4) \times 4$$

$$= (3.4 - 1.51) \times 4 = 7.56 \text{ eV}$$

.44 Calculate the ratio of ΔE between 3rd and 2nd orbit of $He^+$ to 2nd ~~orbit of $Li^{+2}$~~ and 1st Orbit of $Li^{+2}$

$$\frac{E_3 - E_2}{E_2 - E_1} = \frac{-13.6 \times z^2/n^2 + 13.6\ z^2/n^2}{-13.6 \times z^2/n^2 + 13.6\ z^2/n^2}$$

$$\underset{(He^{+})}{\Delta E_1\ (E_3 - E_2)} = -13.6 \times \frac{4}{9} + 13.6 \times \frac{4}{4}$$

$$\underset{(Li^{+2})}{\Delta E_2\ (E_2 - E_1)} = -13.6 \times \frac{9}{4} + 13.6 \times \frac{9}{1}$$

$$\therefore \frac{E_3 - E_2}{E_2 - E_1} = \frac{-\frac{4}{9} + 1}{-\frac{9}{4} + 9.}$$

$$= \frac{5}{9} \times \frac{4}{27} = \frac{20}{243.}$$

$$\frac{\Delta E\ (He^{+})}{\Delta E\ (Li^{+2})} = \frac{20}{243} \Rightarrow 20 : 243.$$

Q.45. Calculate the energy of an electron in ground state of H, $He^{+}$ and $Li^{+2}$

- $E_1\ (H) = -13.6 \times \frac{1}{1} = -13.6$ eV
- $E_1\ (He^{+}) = -13.6 \times \frac{4}{1} = -54.4$ eV
- $E_1\ (Li^{+2}) = -13.6 \times \frac{9}{1} = -122.4$ eV

Q.46 Calculate the ionization energy of H, $He^{+}$, $Li^{+2}$.

- $-(-E_1)_H = -(-13.6\text{ eV}) = +13.6$ eV
- $-(-E_1)_{He^{+}} = -(-13.6 \times 4) = +13.6 \times 4$
  $= +54.4$ eV
- $-(-E_1)_{Li^{+2}} = -(-13.6 \times 9) = +13.6 \times 9$
  $= +122.4$ eV

Q.47 Calculate the energy of an $e^-$ in IIIrd excited state of $Li^{+2}$

$$E = -13.6 \times \frac{Z^2}{n^2}$$

$$= -13.6 \times \frac{9}{16} = -7.65 \text{ eV}$$

Q.48 Calculate the 2nd excitation energy of $He^+$.

2nd excitation energy $= E_3 - E_1$

$$\Delta E \,(E_3 - E_1) = -\frac{13.6 \times 4}{9} - \left(-\frac{13.6 \times 4}{1}\right)$$

$$= +13.6 \times 4 - 13.6 \times \frac{4}{9}$$

$$= 13.6 \times 4 \left[1 - \frac{1}{9}\right] = 13.6 \times 4 \times \frac{8}{9}$$

$$= 1.51 \times 32 = 48.36 \text{ eV} \quad \text{OR}$$

Using trick (ii)

$$\Delta E_{(3-2)\,He^+} = \Delta E_{(3-2)\,H} \times Z^2$$

$$= 12.09 \times 4 = 48.36 \text{ eV}$$

Q.49 How much minimum energy should be absorbed by an $e^-$ of H atom in ground state to reach the excited state.

a) 13.6 eV

b) 3.4 eV

c) 12.09 eV

d) 10.2 eV

Ans) d)

1st excited state = $E_2$

$$\therefore \Delta E(2-1) = -3.4 - (-13.6)$$

$$= 13.6 - 3.4 = 10.2 \text{ eV}$$

Q.50 In which of the following ~~condition~~ transition, minimum energy is released?

i) $n = 1$ to $n = 2$

ii) $n = 1$ to $n = \infty$

iii) $n = 3$ to $n = 1$

iv) $n = 3$ to $n = 2$

Ans) iv)

Released: transition from higher energy level to lower energy level.

Q.51. In which of the following transition, radiation of maximum energy is absorbed?

i) $n = 1$ to $n = 2$

ii) $n = 1$ to $n = 3.$

iii) $n = \infty$ to $n = 1$

iv) $n = 1$ to $n = \infty$

Ans) iv)

Absorbed: transition from lower energy level to higher energy level.

Q.52 The ionization energy of an atom is 100 eV then calculate.

i) Energy of 2nd orbit.

ii) 1st excitation energy

iii) Amount of energy required to excite an $e^-$ from $n = 1$ to $n = 2$

iv) calculate the frequency of photon absorbed when $e^-$ excites from $n = 1$ to $n = 2$

$IE = 100$ eV

$-E_1 = 100$ eV $(\because IE = -E_1)$

$\therefore E_1 = -100$ eV

i) $E_n = \frac{E_1}{n^2} = \frac{-100}{4} = -25$ eV $(E_2)$.

ii) 1st excited state = $E_2 - E_1$

$= -25 \text{ eV} - (-100 \text{ eV})$.

$= 100 \text{ eV} - 25 \text{ eV} = 75 \text{ eV}$

iii) $E_2 - E_1 = 75$ eV

iv) $\because \Delta E = h\nu$

$\therefore \nu = \frac{\Delta E}{h} = \frac{(E_2-E_1)(1.6\times10^{-19})}{6.626\times10^{-34}}$

$\nu = \frac{75\times 1.6 \times 10^{15}}{6.626}$

$= 18\times10^{15}$ Hz

Q.53. The ionization energy of H is $1.3\times10^{6}$ J mol$^{-1}$ calculate the ~~frequency~~ energy required to excite an $e^-$ from $n=1$ to $n=2$

$IE = 1.3\times10^{6}$ J mol$^{-1}$

$\therefore E_1 = -1.3\times10^{6}$ J mol$^{-1}$ $[\because IE = -E_1]$

Using trick (iii)

$E_n = \frac{E_1}{n^2} = \frac{-1.3\times10^{6}}{4}$

$E_2 = -0.328 \times10^{6}$ J mol$^{-1}$

$\therefore$ Required energy $= E_2 - E_1$

$= (-0.328\times10^{6}) - (-1.3\times10^{6})$ J mol$^{-1}$

$= 1.3\times10^{6} - 0.328 \times10^{6}$

$= 10^{6}(1.3 - 0.328)$

$= 0.984 \times 10^{6}$ J mol$^{-1}$

Q.54 If the 2nd exciation energy of an atom is 1210 eV, then find out its atomic no.

$E_3 - E_1 = 1210$ eV

Using trick (ii),

$$\Delta E_{(3-1)\,'Z'} = \Delta E_{(3-1)\,H} \times Z^2$$

$$1210 = -1.51 - (-13.6) \times Z^2$$

$$1210 = 13.6 - 1.51 \times Z^2.$$

$$\therefore Z^2 = \frac{12.09}{1210} \simeq 100.$$

$$\therefore Z = \sqrt{100} = 10.$$

Hence, atomic no = 10

Q.55 Calculate the potential energy of an $e^-$ in IInd excited state of $He^+$

$$TE_{n\,He^+} = TE_{n\,H} \times Z^2 \quad \text{(Using trick i.)}$$

$$= -1.51 \times 4 = -6.04 \text{ eV}$$

$$\because \frac{PE}{2} = TE$$

$$\therefore PE = 2TE$$

$$= 2 \times (-6.04) = -12.08 \text{ eV and.}$$

$$KE = -TE = -6.04 \text{ eV}$$

Q.56 ☆ If the potential energy of an $e^-$ in IInd orbit ~~is~~ for $Li^{+2}$ is $x$, then find out the total energy for $He^+$ in the 2nd orbit.

$$\because \frac{PE}{2} = TE$$

$$(PE_2)_{Li^{+2}} = x$$

$$\therefore (TE_2)_{Li^{+2}} = \frac{x}{2}$$

Using, $\frac{E_1}{E_2} = \frac{(Z_1)^2}{(Z_2)^2}$

$$\Rightarrow \frac{E_1 (Li^{+2})}{E_1 (He^+)} = \frac{9}{4}$$

$$\Rightarrow \frac{x/2}{E_1 (He^+)} = \frac{9}{4}$$

$$\therefore E_1 (He^+) = \frac{x}{2} \times 4 \times \frac{1}{9} = \frac{2x}{9}.$$

$$(TE_2)\, He^+ = \frac{2x}{9}$$

Q.57 Calculate the 1st seperation energy for $Li^{+2}$

$SE = -(-E_n)$, where $n = 2$.

$= -(-E_2)$ (1st seperation energy).

$= +E_2$

$$\underset{Li^{+2}}{(TE_2)} = \underset{H}{(TE_2)} \times Z^2 \text{ (Using trick i)}$$

$= -3.4 \times 9. = -30.6$ eV

$\therefore$ 1st seperation energy $= -(-TE_2)\, Li^{+2}$

$= -(-30.6)$

$= 30.6$ eV

Q.58 The potential energy of an $e^-$ in H atom is $-6.8$ eV then determine that the $e^-$ will be present in which excited state.

$PE = -6.8$ eV

$$\therefore TE = \frac{-6.8}{2} = -3.4 \text{ eV} \left( \because TE = \frac{PE}{2} \right)$$

$$E_n = \frac{-13.6 \times Z^2}{n^2} \quad \therefore n^2 = \frac{-13.6 \times 1}{-3.4} = 4$$

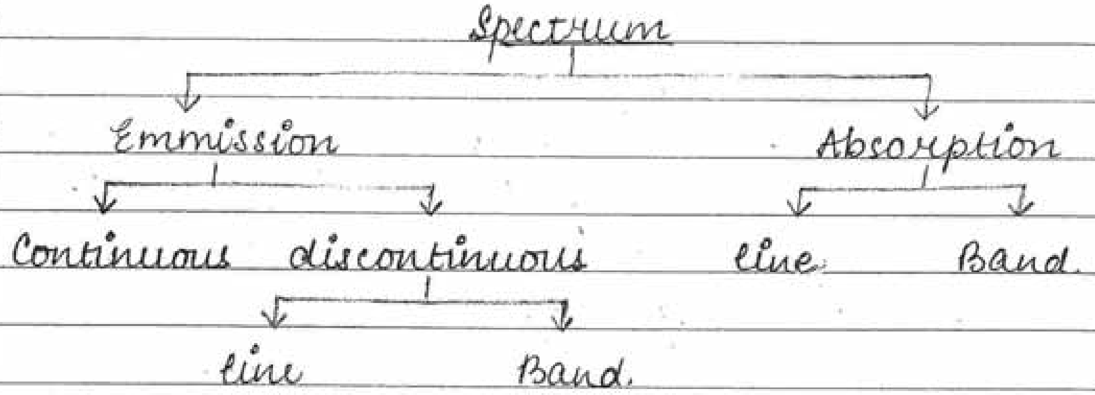
$n^2 = 4 \quad \therefore n = \sqrt{4} = 2$, $n = 2$, 1st E.S.

Using trick i,

$$TE_1 = \frac{-6.8}{2} = -3.4 \text{ eV}, \text{ (1st excited state)}$$

Spectrum:

When a radiation is passed through a prism, it splits into radiations (electro-magnetic waves) of various wavelength. When these radiations are made to fall on a photographic film, the impression produced is known as spectrum.



i) Emmission spectrum:

When a radiation from light-emiting source like sun, bulb, burner, A gas in the discharged tube, a heated substance etc is passed through a prism and then made to fall on a photo-graphic film, the impression so obtained is known as the emmission spectrum.

For eg:

- The spectrum of sunlight (white light) is a continuous emmission spectrum.
- The spectrum of atoms is a line emmission spectrum. (discontinuous)
- The spectrum of molecule is a band emmission spectrum. (discontinuous)

* The spectrum of an element is the fingerprint of that element i.e. the spectrum of two element can't be same.

* The spectrum of same electron species can be ~~same~~ similar but can't be same.

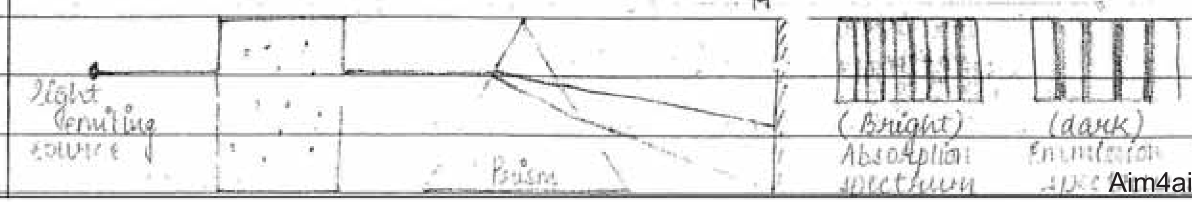
ii) Absorption spectrum:
when a radiation is passed through an absorbing sample and then it is made to ~~fall~~ pass through a prism and then made to fall ~~upon~~ a photographic film. The impression obtained is known as absorption spectrum.

- when a radiation is passed through an atomic gas, then the obtained spectrum is absorbed line spectrum.
- when a radiation is passed through a molecule, then the obtained spectrum is absorbed band spectrum.

* In absorption spectrum, dark lines are obtained in otherwise bright spectrum.

* These dark line corresponds to the wavelength absorbed by the sample.

* The absorbed spectrum can be called the photo-negative of the initial spectrum.



Hydrogen spectrum (emmission line)
MODULE 1 ( Pg 172)

- Total no. of spectral line (TSL) where e⁻ tends from $n_2$ to $n_1$ (emmission line)

$$\therefore TSL = \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

- For any transition:

i) 1st line is called 'α' line
$\therefore n_2 = n_1 + 1$

ii) 2nd line is called 'β' line
$\therefore n_2 = n_1 + 2$

iii) 3rd line is called 'γ' line
$\therefore n_2 = n_1 + 3$.

iv) For any 'x' line:
$\therefore n_2 = n_1 + x$

- Last / Marginal / Limiting line:
$\therefore n_2 = \infty$

- Criteria/ Basis: 1st line and last line

| Criteria/ Basis: | 1st line ↓ | last line ↓ |
|---|---|---|
| i) Energy: (E): | Minimum | Maximum |
| ii) Frequency: ($\nu$): | Minimum | Maximum |
| iii) Wavelength: ($\lambda$): | Maximum | Minimum |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59. calculate total no of spectral lines when an $e^-$ transits from 6th energy level to ground state. Also calculate the no of lines in each series and also determine the no. of lines formed in ultra, visible and Infrared region

- $$TSL = \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

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

$$= \frac{5 \times 6}{2} = 15 \text{ lines.}$$

- No. of lines in each series:

i) Lyman's series(UV regions) : $\because n_2 = n_1 + 1$
$\therefore n_1 = n_2 - 1 \Rightarrow 6 - 1 = 5$

ii) Balmer's series (visible regions) : $\because n_2 = n_1 + 2$
$\therefore n_1 = n_2 - 2 \Rightarrow 6 - 2 = 4$

iii) Paschen's series (IR region) : $n_2 = n_1 + 3.$
$\therefore n_1 = n_2 - 3 \Rightarrow 6 - 3 = 3.$

iv) Brackett series : $n_1 = n_2 - 4 \Rightarrow 6 - 4 = 2$

v) Pfund series : $n_1 = n_2 - 5 \Rightarrow 6 - 5 = 1$

vi) Humphery series : $n_1 = n_2 - 6 \Rightarrow 6 - 6 = 0$

- Total number of lines in ultra region : 5
- Total number of lines in visible Regions : 4
- Total number of lines in Infrared regions :
$3 + 2 + 1 = 6$

.60. calculate total no of spectral line when an $e^-$ transits from 7th energy level to 1st excited state. Also, calculate the no of lines in each series and also determine the number of lines formed in ultra, visible and Infrared regions

- $$T.S.L = \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

  $$= \frac{(7-2)(7-2+1)}{2}$$

  $$= \frac{5 \times 6}{2} = 15 \text{ lines}$$

- No of lines in each series:

i) Lyman's series : $n_1 = n_2 - 1 = 0$ (Lyman's series)
ii) Balmer's series : $n_1 = n_2 - 2 = 7 - 2 = 5$
iii) Paschen's series : $n_1 = n_2 - 3 = 7 - 3 = 4$
iv) Brackett series : $n_1 = n_2 - 4 = 7 - 4 = 3$
v) Pfund series : $n_1 = n_2 - 5 = 7 - 5 = 2$
vi) Humphery series : $n_1 = n_2 - 6 = 7 - 6 = 1$

- Total no. of lines in ultra regions = 0
- Total no. of lines in visible regions = 5
- Total no. of lines in Infrared regions = $4 + 3 + 2 + 1 = 10$

Q.61 Calculate total no. of spectral line when an $e^-$ transmits from 6th energy level to 3rd energy levels. Also calculate the no. of lines in each series and also determine the no. of lines formed in ultra, visible and Infrared regions.

- $$T.S.L = \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

  $$= \frac{(6-3)(6-3+1)}{2}$$

  $$= \frac{3 \times 4}{2} = 6 \text{ lines}$$

- No of lines in each series:

Lyman's series: $n_1 = n_2 - 1 = 0$ (Lyman's series)

Balmer's series: $n_1 = n_2 - 2 = 0$ (Balman's series)

Paschen's series: $n_1 = n_2 - 3 = 6 - 3 = 3.$

Brackett's series: $n_1 = n_2 - 4 = 6 - 4 = 2$

Pfund series: $n_1 = n_2 - 5 = 6 - 5 = 1$

Humphery series: $n_1 = n_2 - 6 = 6 - 6 = 0.$

- No. of lines in Ultra regions: 0
- No of lines in visible regions: 0
- No of lines in Infrared regions: $3+2+1 = 6.$

62 An $e^-$ in hydrogen jumps from higher orbit ($n_2$) to ground state taking multiple transitions If the total no. of lines formed in the spectrum are 21. then find out the value of $n_2$?

$$T.S.L. = \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

$$21 = \frac{(n_2 - 1)(n_2 - 1 + 1)}{2}$$

$$42 = n_2 (n_2 - 1)$$

$$(n_2)^2 - n_2 - 42 = 0.$$

$$(n_2)^2 - 7n_2 + 6n_2 - 42 = 0.$$

$$n_2 (n_2 - 7) + 6(n_2 - 7) = 0.$$

$$n_2 = -6 \text{ and } n_2 = 7$$

$n_2 = -6$ (not possible)

$\because$ No. of lines can't be negative.

$\therefore n_2 = 7.$

Q.63. Determine the transitions made by the $e^-$ from $n_2$ energy level to $n_1$ energy level for the following lines.

i) 5th line in the Lyman's series.

ii) $\gamma$ line in the Brackett's series

iii) $\alpha$ line in the Humphery's series.

iv) $\beta$ line in the Paschen's series

v) 4 th line in the Balmer's series.

vi) last line in the Pfund series.

i) $n_2 = n_1 + 5$ (∵ $n_1 = 1$ for Lyman series)
$= 1 + 5 = 6$. (6th to 1st)

ii) $n_2 = n_1 + 3.$ (∵ $n_1 = 3$ for Brackett series)
$= 4 + 3 = 7$ (7th to 4th)

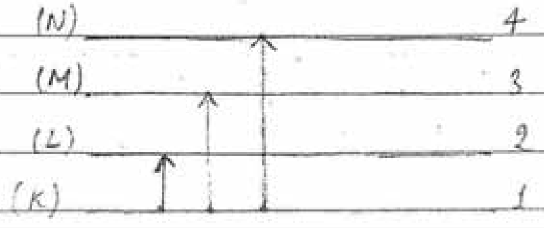
iii) $n_2 = n_1 + 1$ (∵ $n_1 = 1$ for Humphery series)
$= 6 + 1 = 7$ (7th to 6th).

iv) $n_2 = n_1 + 2$ (∵ $n_1 = 2$ for Paschen series)
$= 3 + 2 = 5$ (5th to 3rd)

v) $n_2 = n_1 + 4$ (∵ $n_1 = 4$ for Balmer series)
$= 2 + 4 = 6$ (6th to 2nd).

vi) $n_2 = n_1 + 5$ (∵ last line in Pfund series)
$= 5 + \infty = \infty$ ($\infty$ to 5th)

* In the absorption spectrum of hydrogen only dark lines of lyman's series are obtained. This verifies / shows that an $e^-$ does not make multiple transitions during excitations.



Q-64 If an atom contains 5 permitted orbit, then find out the total no. of lines formed in emmission and absorption spectrum

$n_2 = 5$ and $n_1 = 1$.

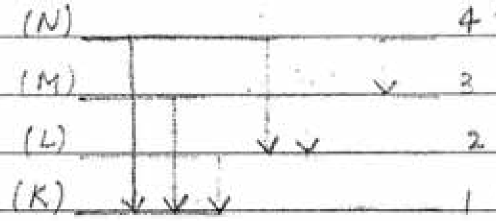
$$T.S.L = \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

$$= \frac{(5-1)(5-1+1)}{2}$$

$$= \frac{4 \times 5}{2} = 10 \text{ lines.}$$

- Total no. of lines in emmission spectrum = 10 lines.
- Total no. of lines in absorption spectrum = = Lyman's series = $(n_2 - 1)$ = 5 − 1 = 4 lines.

Q.65 In the emmission spectrum of hydrogen, following lines are obtained.



How many of these lines will be obtained in absorption spectrum?

No of lines obtained in absorption spectrum = No of lines of Lyman's series.

Hence,

Total no. of lines obtained = 3

where, $n_1 = 1$.

Rydberg formula:

MODULE I (Pg - 173)

i) $\bar{v} = \frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

ii) $v = RCZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

iii) $E = -Rch\frac{z^2}{n^2}$

iv) $\Delta E = RChZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

where $R = 1.1 \times 10^5\ cm^{-1}$ or $1.1 \times 10^7\ m^{-1}$

$C = 3 \times 10^8\ m/s.$

$h = 6.626 \times 10^{-34}\ J$

$Z$ = atomic no., and.

$n_1$ = no. of lower energy level

$n_2$ = no. of higher energy level.

v) $\frac{1}{R} = 912\ \mathring{A}.$

Q.66. Calculate the wavelength for the 1st line of the lyman's series in Hydrogen atom

$n_1 = 1$ and $n_2 = n_1 + 1 = 1+1 = 2$

$\therefore \frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$= R(1)^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$$= R\left[1 - \frac{1}{4}\right]$$

$$\frac{1}{\lambda} = R\left[\frac{3}{4}\right] = \frac{3R}{\cancel{R}4}$$

$$\therefore \lambda = \frac{4}{3R} \text{ units.}$$

67 calculate the frequency of radiation of the Balmer line of Hydrogen atom

$n_1 = 2$ and $n_2 = n_1 + 1 = 2+1 = 3.$

$$\therefore \quad \nu = RCZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$= RC(1)^2\left[\frac{1}{(2)^2} - \frac{1}{(3^2)}\right]$$

$$= RC\left[\frac{1}{4} - \frac{1}{9}\right]$$

$$\nu = RC\left[\frac{5}{36}\right] = \frac{5RC}{36} \text{ units}$$

68 An $e^-$ shows transition according to first line of Paschen in Hydrogen atom then, calculate the energy of the electronic transitions.

$n_1 = 3$ and $n_2 = n_1 + 1 = 3 + 1 = 4$

$$\because \quad \Delta E = RCh\, Z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$= RCh(1)^2\left[\frac{1}{3^2} - \frac{1}{4^2}\right]$$

$$= RCh\left[\frac{1}{9} - \frac{1}{16}\right]$$

$$= RCh\left[\frac{7}{144}\right] = \frac{7RCh}{144} \text{ units}$$

Q.69. An $e^-$ shows transition according to first brackett line in Hydrogen atom. then calculates its wave no.

$n_1 = 4$ and $n_2 = n_1 + 1 = 4+1 = 5$

$$\because \bar{\upsilon} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$= R(1)^2\left[\frac{1}{4^2} - \frac{1}{5^2}\right]$$

$$= R\left[\frac{1}{16} - \frac{1}{25}\right].$$

$$= R\left[\frac{9}{400}\right] = \frac{9R}{400} \text{ units.}$$

Q.70 An $e^-$ shows transition according to the limiting line of the Pfund series in Hydrogen atom. then, calculate the wavelength of this in Å.

$n_1 = 5$ and $n_2 = \infty$

$$\because \bar{\upsilon} = \frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$= R(1)^2\left[\frac{1}{5^2} - \frac{1}{\infty^2}\right]$$

$$= R\left[\frac{1}{25} - 0\right] \qquad \left[\because R = \frac{1}{912\,\text{Å}}\right]$$

$$\frac{1}{\lambda} = \frac{R}{25}$$

$$\therefore \lambda = \frac{25}{R} = \left[\frac{25 \times 912}{1}\right]\text{Å}$$

$$= 22800\ \text{Å}$$

Q.71 If the shortest wavelength of Lyman's series of $Li^{+2}$ is $x$, then find out the maximum wavelength of Balman's series of ~~hydrogen atom~~. $He^+$

For Lyman's series.

$n_1 = 1$ and $n_2 = \infty$ (maximum wavelength)

$$\frac{1}{\lambda} = RZ^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$= R(3)^2 \left[\frac{1}{1^2} - \frac{1}{\infty^2}\right]$$

$$= 9R(1-0) = 9R$$

$$\therefore \lambda = \frac{1}{9R} = x.$$

$$\therefore R = \frac{1}{9x} \quad — ①$$

For Balman's series

$n_1 = 2$ and $n_2 = 2+1 = 3$. (min wavelength)

$$\frac{1}{\lambda} = RZ^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$= R(2)^2 \left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$$= 4R \left[\frac{1}{4} - \frac{1}{9}\right]$$

$$\frac{1}{\lambda} = 4R \left[\frac{5}{36}\right] = \frac{5R}{9}$$

$$\therefore \lambda = \frac{9}{5R}$$

Putting R from eq ①

we get.

$$\lambda = \frac{9}{5 \times \frac{1}{9x}} = \frac{9 \times 9x}{5}$$

$$= \frac{81x}{5} \text{ units}$$

Q.72 If the maximum frequency of Balmer's series of H-atom is x, then find out the maximum frequency of Paschen series of He⁺.

For Balmer's series.

$$\nu = RCZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \quad (n_1 = 2, n_2 = \infty)$$

$$= RC(1)^2\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right]$$

$$= RC\left[\frac{1}{4} - 0\right] = \frac{RC}{4} = x.$$

$$\therefore \; RC = 4x. \quad — ①$$

For Paschen's series.

$$\nu = RCZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$n_1 = 3 \text{ and } n_2 = \infty$$

$$= RC(2)^2\left[\frac{1}{3^2} - \frac{1}{\infty^2}\right]$$

$$= 4RC\left[\frac{1}{9} - 0\right] = \frac{4RC}{9} \quad — ⑪$$

By putting eq ① in ⑪, we get

$$= \frac{4 \times 4x}{9} = \frac{16x}{9}$$

Limitations of Bohr Model:

MODULE 1 (Pg 173)

- Fine spectral lines indicates the presence of sub-energy shells in an orbit and their energy will be nearly same.

It includes five drawbacks.

## Sommerfield Extension of the Bohr model:

MODULE 1 (Pg - 174)

Sommerfield theory was related to the explanation of fine spectral line i.e the existence of the sub orbits. Sommerfield introduced the concept of sub-energy level in an orbit according to sommerfield. in a main energy shell the energies of the sub shells are slightly different from another.

Hence. on jumping of an electron from one energy level to another energy level will involve slightly different amount of energy as it will depend on the subshell

∴ Number of $\overset{\text{fine}}{\wedge}$ lines in a spectral line resulting from a ~~transitional~~ between $n_2$ and $n_1$ energy level = $n_2 \times n_1$

## de Broglie concept (Dual nature of matter)

MODULE 1 (Pg - 174)

$$\lambda = \frac{h}{mv} = \frac{h}{p}$$

where, $\lambda$ = wavelength
$h$ = plank's constant
$m$ = mass
$v$ = velocity
$p$ = momentum

~~Important~~

$$\lambda = \frac{h}{mc}$$

when particle ~~p~~ travels with the velocity of light

Important point concerned with de-broglie concept:

MODULE 1 (Pg - 175)

$$\lambda = \frac{h}{\sqrt{2m K.E}}$$

when a charged particle carrying Q coulomb is accelerated by applying potential difference V, then.

MODULE 1 (Pg - 175)

$$\lambda = \frac{h}{\sqrt{2m QV}}$$

- The wave nature of electron was varified experimentally by Davisson and Germer in a 'Crystal diffraction of cathode rays' in 1927. (electron microscope are used on this basis)
- An object undergoes diffraction has wave nature and it is associated with sub micro-scopic particles like electron, proton etc., when it is in motion.

- Number of waves made by an electron when it revolves in a particular Bohr orbit = Orbit number (n).

$$\therefore \quad n = \frac{2\pi r}{\lambda}$$

Q.73. Calculate the wave ~~number~~ length of an electron moving with kinetic energy of $4.55 \times 10^{-25}$ J

$$\because \lambda = \frac{h}{\sqrt{2m\,KE}}$$

$$= \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 4.55 \times 10^{-25}}}$$

$$= \frac{6.626 \times 10^{-34}}{\sqrt{9.1 \times 9.1 \times 10^{-56}}}$$

$$= \frac{6.626 \times 10^{-34}}{9.1 \times 10^{-28}}$$

$$= 0.72 \times 10^{-6} \text{ m}$$

Q.74 Two particles A and B are in motion. the wavelength of particle A is $5 \times 10^{-5}$ m. If the mass of the particle B is 50% of A and its velocity is 25% of A, then calculate the wavelength of particle B. ?

$$\lambda_A = \frac{h}{m_A v_A} = 5 \times 10^{-5} \text{ m}$$

$$\lambda_B = \frac{h}{\frac{m_A}{2} \times \frac{v_A}{4}}$$

$$\therefore \frac{\lambda_A}{\lambda_B} = \frac{h / m_A v_A}{8h / m_A v_A} = \frac{h}{8h}$$

$$\therefore \frac{\lambda_A}{\lambda_B} = \frac{h}{8h} = \frac{1}{8}$$

$$\therefore \lambda_B = \lambda_A \times 8$$
$$= 5 \times 10^{-5} \times 8$$
$$= 40 \times 10^{-5} \text{ m}$$

Q.75. Calculate the de broglie wavelength of a particle of mass 10 grams with a velocity of 200m/s.

$$\lambda = \frac{h}{mv}, \quad m = 10 \text{ gms} = 10 \times 10^{-3} \text{ kg}$$

$$= \frac{6.626 \times 10^{-34}}{10 \times 10^{-3} \times 200}$$

$$= \frac{6.626 \times 10^{-34}}{2 \times 10^{-3} \times 10^{3}}$$

$$= 3.313 \times 10^{-34} \text{ m}$$

Q.76 Calculate the de broglie wavelength of an e⁻ moving in 2nd orbit of H atom.

$$\lambda = \frac{2\pi r_n}{n}$$

$$= \frac{2 \times \pi \times 0.529 \times 4}{2} \text{ Å}$$

$$= 2.11 \pi \text{ Å}$$

## Heisenberg uncertainity Principle:

MODULE 1 (Pg - 176)

According to Heisenberg uncertainity principle "It is impossible to measure simultaneously the exact position and the exact momentum of a body as small as an electron"

$$\Delta x . \Delta p \geqslant \frac{h}{4\pi} \quad \text{OR} \quad \Delta x . \Delta v \geqslant \frac{h}{4\pi m}$$

where $\frac{h}{4\pi} = 0.527 \times 10^{-34}$ J sec.

$\lambda$ (Incident light) $\propto$ Size of an object

* Heisenberg ruled out the concept of fixed no. of orbit given by Bohr. According to heisenberg, we can only specify a region in space where the probability of finding electron is maximum

77 If the uncertainity in position of a particle is 0. then find out uncertainity in its momentum

$$\because \Delta x . \Delta p = \frac{h}{4\pi}$$

$$\therefore \Delta p = \frac{h}{4\pi \Delta x} = \frac{h}{4\pi \times 0.}$$

$$= \frac{h}{0} = \infty$$

$$\therefore \Delta p = \infty.$$

Q.78 The uncertainity in position of an $e^-$ is 1 Å then calculate the uncertainity in its. velocity (m/s)

$$\Delta x . \Delta p = \frac{h}{4\pi}$$

$$\therefore \Delta v = \frac{h}{4\pi m \Delta x}$$

$$= \frac{0.527 \times 10^{-34}}{9.1 \times 10^{-31} \times 10^{-10}} \quad \left[ \because 1 \text{Å} = 10^{-10} m \right]$$

$$\frac{0.527 \times 10^{-34}}{9.1 \times 10^{-41}} = 5.7 \times 10^{5} \text{ m/s.}$$

Q 79. An e⁻ is moving with a velocity of 300 m/s. if the uncertainity in velocity is 0.01% calculate the uncertainity in position.

$v = 300$ m/s.

$$\therefore \Delta v = \frac{300}{100} \times 0.01 = 0.03 \text{ m/s}$$

$$\therefore \Delta x = \frac{h}{4\pi\, m \Delta v}$$

$$= \frac{0.527 \times 10^{-34}}{9.1 \times 10^{-31} \times 0.03.}$$

$$= \frac{0.527 \times 10^{-3}}{9.1 \times 3} = \frac{5.7}{3} \times 10^{-3.}$$

$$= 1.9 \times 10^{-3} \text{ m}$$

Q.80. The uncertainity in position of an electron is double the uncertainity in position of He atom. If the uncertainity in momentum of electron is $x$ then, the uncertainity in momentum of He atom.

$$\Delta p(H) = \frac{h}{4\pi\, \Delta x(He)}$$

$$\Delta p(e^-) = \frac{h}{4\pi\, \Delta x(e^-)}$$

$$\therefore \frac{\Delta p(H)}{\Delta p(e^-)} = \frac{\Delta x(e^-)}{\Delta x(H)} = \frac{2\, \Delta x(H)}{\Delta x(H)}$$

$$\therefore \frac{\Delta p(H)}{x} = 2.$$

$$\therefore \Delta p(H) = 2x.$$

## Wave mechanical ~~orde~~ model:

- It was based on the dual nature of electron i.e. the particle as well as the wave nature.

- This model was given by Schrodinger and was represented by the following equation

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2} + \frac{8\pi^2 m}{h^2}[E-V]\psi = 0$$

Or

$$\nabla^2\psi + \frac{8\pi^2 m}{h^2}(E-V) = 0.$$

Where $\nabla^2$ = Lapelacion operator
$\psi$ (Psi) = wave function
(Amplitude of wave)
$x, y, z$ = space-coordinate
$E$ = Total energy
$V$ = Potential energy
$\partial$ = dell

- The solution of the Schrodinger equation gives a set of three quantum number n, l and m.

## Orbitals:

- It is a region in space where the probability of finding electron is maximum (greater than 95%) or it is an electron cloud which has a definite size, shape and orientiation.

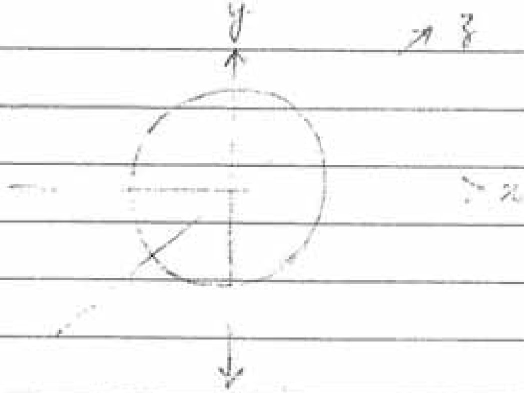
- An orbital is represented as follows:
  [$\Psi_{nlm}$]

Shapes of Atomic orbitals:

i) 's'- orbital.

MODULE 1 (Pg-175)

- The shape of the 's' orbitals is represented as a symmetrical sphere
- The 's' orbitals are symmetrical along all the axis.
- The 's' orbitals are non-directional in nature.

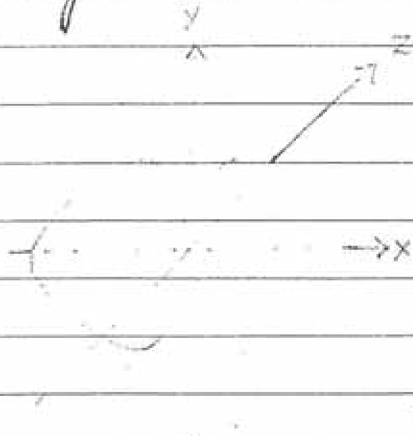


ii) 'p' orbital

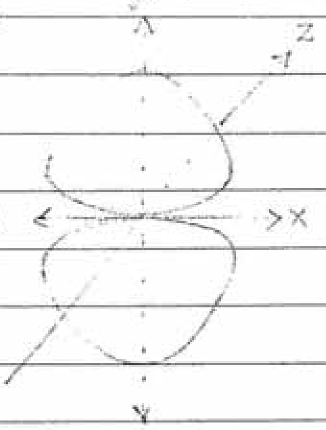
MODULE 1 (Pg-175)

- The shape of a p-orbital is ~~a dumb~~ represented as a dumb-bell (2 lobes)
- There are three types of p-orbital, $p_x$, $p_y$ and $p_z$ which are directed along each axis.
- The angle between p-orbitals is 90°
- p-orbitals are directional in nature.

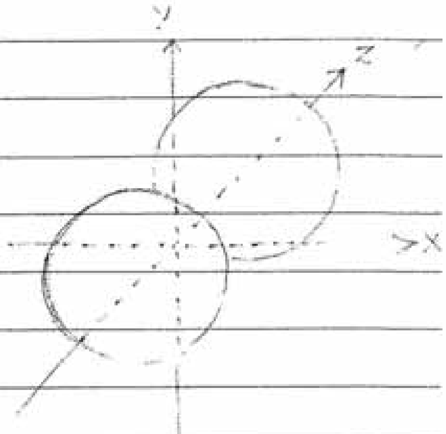
- In the absence of an external field, the energy of the p-orbitals in the same orbit is equal and hence they are called as '3 fold degenerate orbitals degenerate: Same energy levels.



($P_x$)



($P_y$)

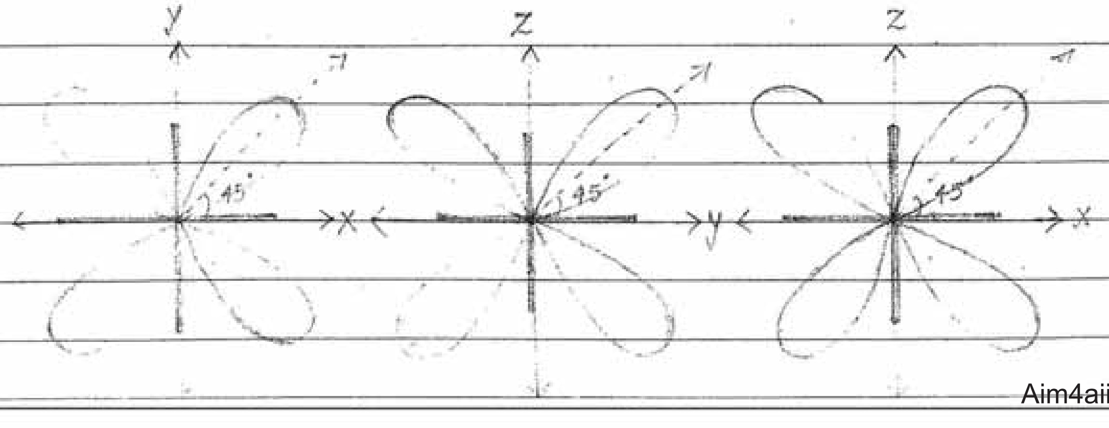


($P_z$)

iii) 'd'- orbital

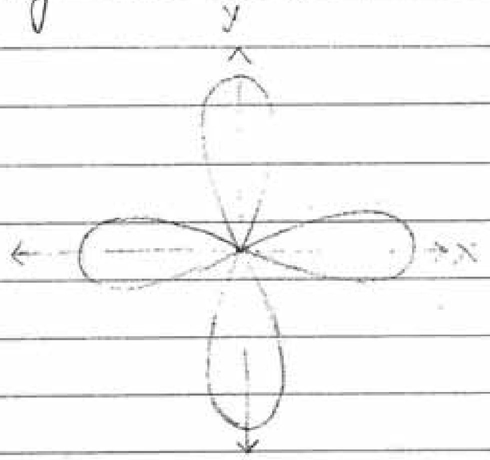
- The shape of a 'd'- orbital is represented as a double dumb-bell (4 lobes)
- There are five types of 'd-orbitals'
  Between the axis : ($d_{xy}$, $d_{yz}$, $d_{xz}$) and along the axis : ($d_{x^2-y^2}$, $d_{z^2}$)
- These d-orbitals are categorised into two parts :

a. Between the axis. (

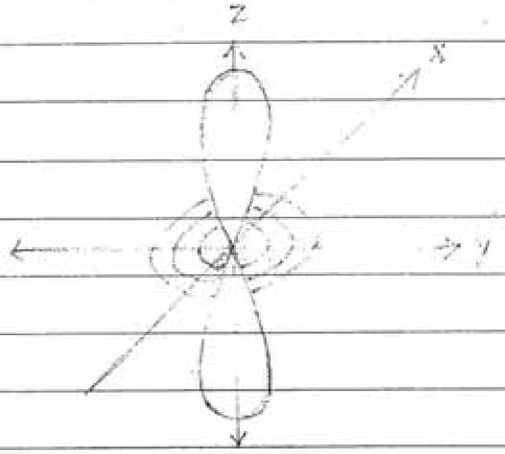


these d-orbitals are symmetrical and they make an angle of 45° with each axis.

b. Along the axis.



$(Px^2-y^2)$



$(Pz^2)$

It is also known as baby soother or doughnut, because it consists of two lobes along with an e-ring in x-y plane

- d-orbitals are directional in nature,
- In absence of an external field, the energy of the d-orbital in the same orbit are equal. hence, they are called as 5-fold degenerate orbitals.

iv) f-orbital

- The shape of f-orbital is highly complex in nature.
- There are seven f-orbital

## Quantum Number:

MODULE 1 (Pg 176)

- Quantum numbers are the address of an electron.
- Quantum numbers determines the position and the energy of an electron in an atom.
- An orbital is designated by three quantum no. n, l and m
- An electron is designated by four quantum numbers n, l, m and s

- n = Principal Quantum number.
  Shell ( K, L, M, N ..... )
- l = Azimuthal Quantum number.
  Sub-shell ( s, p, d, f ..... )
- m = Magnetic Quantum number.
  Orbitals ( $s, p_x, p_y, p_z, d_{xy}, d_{yz}, d_{xz}, d_{x^2-y^2}, d_{z^2}$ ..... )
- s or $m_s$ = Spin Quantum number.

## Principal Quantum number (n)

MODULE 1 (Pg - 176)

- It was given by Bohr.
- It represents the name, size and energy of a shell.
- The possible value of n are positive integers. (1, 2, 3, 4 .....) and nomenclatured as (K, L, M....)
- It also represents the distance of $e^-$ from the nucleus.

- As the value of n increases, the energy and the distance of an electron from the nucleus also increases.
- Total number of electron in a shell are given by $2n^2$.

2. Azimuthal / Angular / Subsidary / Secondary Quantum number ($l$)

MODULE 1 (Pg - 177)

- It was given by summerfield.
- It signifies a subshell and determines the shape of an orbital.
- The possible value of $l$ are from 0 to $(n-1)$

When $l = 0$ (s - subshell),
when $l = 1$ (p - subshell),
when $l = 2$ (d - subshell),
when $l = 3$ (f - subshell),
when $l = 4$ (g - subshell) and so on

- Relation between n and $l$:

when $n = 1$, $l = 0$ ( s - subshell)
when $n = 2$, $l = 0, 1$ (s, p - subshell)
when $n = 3$, $l = 0, 1, 2$ (s, p, d - subshell)
when $n = 4$, $l = 0, 1, 2, 3$. (s, p, d, f - subshell)
It shows that forth shell contains four subshell i.e. s, p, d and f.

- Hence, nth shell = n subshell.

- It represents the orbital angular momentum of an electron.

  Orbital angular momentum = $\sqrt{l(l+1)}\,\frac{h}{2\pi}$

  $s = 0$ $(\because l = 0)$

  $p = \frac{h}{\sqrt{2}\pi}$ $(\because l = 1)$

  $d = \frac{\sqrt{6}h}{2\pi}$ $(\because l = 2)$

  $f = \frac{\sqrt{12}h}{2\pi} = \frac{\sqrt{3}h}{\pi}$ $(\because l = 3)$.

- Number of electron in a subshell = $2(2l+1)$

  $s = 2$ $(\because l = 0)$

  $p = 6$ $(\because l = 1)$

  $d = 10$ $(\because l = 2)$

  $f = 14$ $(\because l = 3)$

- Number of orbitals in a subshell = $(2l+1)$

  $s = 1$ $(\because l = 0)$

  $p = 3$ $(\because l = 1)$

  $d = 5$ $(\because l = 2)$

  $f = 7$ $(\because l = 3)$

- Maximum number of electron in an orbital are two.

- It represents/signifies the energy of a subshell in a particular orbit.

  when $l$ = 0 1 2 3

  $s < p < d < f$

Its applicable only for muti electron species

- In single electron species like hydrogen, s = p = d = f. because effective nuclear charge will be same

Q. 81 Calculate the orbital angular momentum of an electron in p-subshell.

Orbital angular momentum = $\sqrt{l(l+1)}\frac{h}{2\pi}$

for p-subshell, $l = 1$

$$= \sqrt{1(1+1)}\frac{h}{2\pi}$$

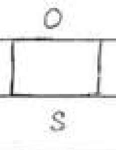
$$= \sqrt{2}\frac{h}{2\pi} = \frac{\sqrt{2}h}{2\pi} \times \frac{h}{\sqrt{2}\pi}$$

3. Magnetic Quantum number (m)

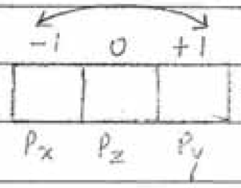
MODULE 1 (Pg - 178)

- It was given by Linde.
- It represents the orientation of an orbital
- The possible values of m is from (−l) to (+l) including zero.

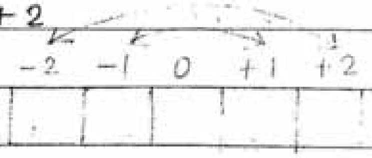
when $l = 0$, $m = 0$.
(s-subshell → 1 orbital)



when $l = 1$, $m = -1, 0, +1$
(p-subshell → 3 orbitals)



when $l = 2$, $m = -2, -1, 0, +1, +2$
(d subshell → 5 orbitals)



- Number of values of 'm' in a subshell : $(2l+1)$

4 Spin Quantum number (s)
MODULE 1 (Pg - 179)

- It was given by Uhlenbeck and Goudschmidt
- It represent the direction of rotation of an electron about its own axis.
- The possible value of s are $\left(+\frac{1}{2}\right)$ and $\left(-\frac{1}{2}\right)$

that represent clockwise and anti-clockwise rotation. $\boxed{\uparrow\downarrow}$

- It represent the spin angular momentum of an electron.

when $s = +\frac{1}{2}$

spin angular momentum = $\sqrt{s(s+1)}\,\frac{h}{2\pi}$

when $s = +\frac{1}{2}$ $= \sqrt{\frac{1}{2}\left(\frac{1}{2}+1\right)}\,\frac{h}{2\pi}$

$= \sqrt{\frac{1}{2}\left(\frac{3}{2}\right)}\,\frac{h}{2\pi}$

$= \sqrt{\frac{3}{4}}\,\frac{h}{2\pi} = \frac{\sqrt{3}h}{2\times 2\pi} = \frac{\sqrt{3}h}{4\pi}$

when $s = -\frac{1}{2}$

spin angular momentum is not possible.

- Total number of spin = $\pm\frac{1}{2} \times$ (no of unpaired $e^-$)

## Formula's Association :

i) Total no of electron in a shell : $2n^2$
ii) No. of Orbitals in a shell: $n^2$
iii) Total no. of electron in a subshell: $2(2l+1)$
iv) No. of orbitals in a subshell : $(2l+1)$
(Total no of values of 'm' in a subshell)
v) Maximum no. of electron in a orbital : 2
vi) Orbital angular momentum ($\mu_l$) : $\sqrt{l(l+1)}\,\frac{h}{2\pi}$
vii) spin angular momentum ($\mu_s$) : $\sqrt{s(s+1)}\,\frac{h}{2\pi}$
viii) Total angular momentum ($\mu$) : ($\mu_l$) + ($\mu_s$)
ix) nth shell : n subshell

Q.82 Find out the values of n, l and m for the following orbitals.

i) $4d_{z^2}$ :
$n = 4 \quad l = 2 \quad m = 0$

ii) 5S :
$n = 5 \quad l = 0 \quad m = 0$

iii) $3P_z$ :
$n = 3 \quad l = 1 \quad m = 0$

iv) $2P_x$ :
$n = 2 \quad l = 1 \quad m = \pm 1$

Q.83 Identify the orbitals for the following value of n, l and m.

i) $n = 4$ $l = 1$ $m = -1$
Orbital : $4p_x$ or $4p_y$

ii) $n = 3$ $l = 2$ $m = 0$
Orbital : $3d_{z^2}$

iii) $n = 2$ $l = 0$ $m = 0$
Orbital : 2s

iv) $n = 3$ $l = 2$ $m = 2$
Orbital : $3d_{x^2-y^2}$ or $3d_{xy}$

v) $\psi_{420}$
here $n = 4$ , $l = 2$ , $m = 0$.
$\therefore$ orbital : $4d_{z^2}$

84 Which of the following set of quantum number is possible :

i) $n = 3$ $l = 2$ $m = -3$ $s = +1/2$
ii) $n = 3$ $l = 3$ $m = 2$ $s = -1/2$
iii) $n = 3$ $l = 1$ $m = 0$ $s = +1/2$
iv) $n = 3$ $l = 1$ $m = 0$ $s = +1$

Ans : (iii) $n = 3$, $l = 1$, $m = 0$ and $s = +/2$
It is possible because $m \neq -3$ and $l \neq 3$ and $s \neq +1$.
$l < n$ and $m = (-l)$ to $l$
and $s = +1/2$

Q.85 Which of the following orbitals are not possible.

i) 1p [×]
Not possible because if $n = 1$, then $l = 0$
$\because l = 0$, $\therefore$ only 's-orbital' is possible

ii) 2s [✓]
Possible because if $n = 2$, then $l = 0, 1$
when $l = 0$ i.e. ~~'s-orbital'~~ 's-subshell'

iii) 3f [×]

Not possible because if $n = 3$ then $l = 0, 1, 2$ (s, p and d subshell).

Hence, 'f-subshell' is not possible

iv) 4f [✓]

Possible because if $n = 4$ then $l = 0, 1, 2, 3$ hence $l = 3$, 'f-subshell'.

v) 2d [×]

Not possible because if $n = 2$, then $l = 0, 1$ (s, p subshell)

Q.86 Calculate the total no of electrons which can be present in a 4th d subshell

Total no. of $e^-$ = $2(2l+1)$

= $2(2 \times 2 + 1)$

= $2(4+1) = 2 \times 5 = 10$

Q.87 Find out the ~~value of~~ total no. of 'm' for an $e^-$ present in the 5th shell.

$\therefore n = 5$

$l = 0, 1, 2, 3, 4$

when $l = 0$, $m = 0$

when $l = 1$, $m = -1, 0, +1$

when $l = 2$, $m = -2, -1, 0, +1, +2$

when $l = 3$, $m = -3, -2, -1, 0, +1, +2, +3$

when $l = 4$, $m = -4, -3, -2, -1, 0, +1, +2, +3, +4$

hence total value of m = $1 + 3 + 5 + 7 + 9$ = 25 electrons.

OR

no. of $e^-$ in a shell = $\cancel{2}n^2 = \cancel{2} \times 5^2$

$= \cancel{2} \times 25$ electrons.

88 Find out the no. of $e^-$ in M shell having the value of magnetic quantum no as $-1$

when $m = -1$

~~then $l = 1$~~

M shell, $\therefore n = 3.$

$\therefore l = 0, 1, 2$

when $l = 0$, $m = 0$

when $l = 1$, $m = \textcircled{-1}, 0, +1$

when $l = 2$, $m = -2, \textcircled{-1}, 0, +1, +2$

~~hence, total no. of $e^-$ i.e value of 'm' =~~

$1 + 3 + 5 = 9$

Total no. of $e^-$ having magnetic quantum as $-1 = 2 \times 2 = 4$ electrons.

89 In orbitals of $n = 3$ and $l = 2$, find out the total no of electrons having the value of spin quantum no. as $-1/2$.

when $n = 3$, $l = 2$, ~~1~~ ~~0~~

Total no. of orbital : 3d

Total no. of $e^-$ in 3d = 10

$\therefore$ no of $e^-$ having $s = -1/2 = 5$

90. Find out the maximum no. of orbitals in the 4th shell having an electron with a value of spin quantum no $+1/2$

Total no. of ~~orbital~~ electrons in a shell $= 2n^2$

$\because n = 4$

$\therefore$ no of ~~orbitals~~ electrons $= 2 \times 4^2 = 16 \times 2 = 32 e^-$

$\because$ spin quantum no $= +1/2$

$\therefore$ no of electrons $= \frac{32 e^-}{2} = 16 e^-$

Hence, 16 electron can have $+1/2$ spin quantum no

Q.91 for $n+l = 5$, find out the no. of subshell, total no of orbital and total no of electro

i) Total no. of subshell;

Possible outcomes $= 5+0 = 5s$

$= 4+1 = 4p$

$= 3+2 = \underline{3d.}$

$3$

Hence, no. of subshell = 3.

ii) Total no. of orbitals :

In 5s = 1

In 4p = 3

In 3d = $\underline{5}$

$\underline{9}$

Hence, no of orbitals = 9.

iii) Total no of $e^-$ :

In 5s = 2

In 4p = 6

In 3d = $\underline{10}$

18.

Hence, no of electrons = 18

Q.92. If The value of $n+l$ is not more than 3, then find out the total no. of subshell, total no. of orbitals and total no of electrons.

Possible outcomes :

when $n+l = 3$.

$3+0 = 3$, (3s ~~Orb. subshell~~ orbital)

$2+1 = 3$. , (2p ~~subshell~~ orbital)

when $n+l = 2$

$2+0 = 2$, ( 2s ~~subshell~~ orbital)

when $n+l = 1$

$1+0 = 1$, (1s ~~subshell~~ orbital)

Hence,

total no. of subshell = 4

total no of orbital = 1+3+1+1

= 6

total no of electrons = 12

Nodes:

- It is a region in space where the probability of finding $e^-$ is zero.
- It is of two types:

i) Radial node / spherical node / Nodal surface:

value of radial node = $(n-l-1)$

ii) Angular node / Non-spherical node / nodal plane:

value of angular node = $l$ (azimuthal q.n.)

∴ Value of total no. of nodes = (value of radial) + (angular node)

$= (n-l-1) + l$

$=$ ~~$(n-l)$~~ $(n-1)$

Q.93 Calculate the number of radial, angular and total no. of nodes for the following:

i) 4d : $n = 4$ and $l = 2$

Radial node = $(n-l-1) = 4-2-1 = 1$

Angular node = $l = 2$

Total node = $(n-1) = 4-1 = 3$

ii) 5s : $n = 5$ and $l = 0$

Radial node = $(n-l-1) = 5-0-1 = 5-1 = 4$

Angular node = $(l)$ = 0
Total node = $(n-1)$ = 5 - 1 = 4

iii) ~~3d:~~ 3p: $n = 3$ and $l = 1$
Radial node = $(n-l-1) = 3-1-1 = 1$
Angular node = $(l)$ = 1
Total node = $(n-1)$ = 3 - 1 = 2

- Number of nodal plane $(l)$:

i) s-orbital: s = 0
ii) p-orbital: $p_x$ = yz plane
$p_y$ = xz plane
$p_z$ = xy plane
iii) d-orbital: $d_{xy}$ = xz plane and yz plane
$d_{yz}$ = xy plane and xz plane
$d_{xz}$ = xy plane and yz plane
$d_{x^2-y^2}$ = 0
$d_{z^2}$ = 0

## Rules of filling orbitals:

i) Aufbau Principle:

ii) $(n+l)$ rule:

iii) Pauli's exclusion principle:
he stated that no 2 electrons can have the same value of all four quantum numbers
eg: In 2s orbital.
$\boxed{\uparrow\downarrow}$ $\boxed{\cancel{\uparrow\uparrow}}$ (not possible)

In 2s orbital: $n_1 = 2$ and $n_2 = 2$
(eg:) $l_1 = 0$ and $l_2 = 0$
$m_1 = 0$ and ~~l~~ $m_2 = 0$
$s_1 = +\frac{1}{2}$ and $s_2 = -\frac{1}{2}$

(iv) Hund's rule of Maximum multiplicity:
Electrons are distributed in a way to give maximum no. of unpaired electrons with parallel spin.

Reasons:

- due to symmetrical distribution of electrons the inner electronic repulsion becomes minimum.

- As the number of electrons with the same spin increases, the number of exchanges will increase and thus the exchange energy will increase which ultimately leads to increase in the stability of an electron.

$\boxed{\uparrow}\boxed{\uparrow}\boxed{\downarrow}$ (X) $\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\phantom{\uparrow}}$ (X)
(opposite spin) (Pairing)

Result:
Half filled and full filled orbitals are more stable.

eg:
$$\text{less stable}\left\{\begin{matrix} p^3 < p^6 \\ d^5 < d^{10} \\ f^7 < f^{14} \end{matrix}\right\}\text{more stable}$$

## Electronic configuration of ions :

- Cations are positively charged and anions are negatively charged.

- Electronic configuration of anions are same as that of Aufbau Principal but for the electronic configuration of cations the electrons from the outermost shell (n) with higher energy loses earlier.

eg: $_{30}Zn$ : $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} \boxed{4s^2}$

∴ $_{30}Zn^{+2}$ : $1s^2 \; 2s^2 \; 2p^6 \; 3s^2 \; 3p^6 \; 3d^{10}$

$_{24}Cr$ : $1s^2 \; 2s^2 \; 2p^6 \; 3s^2 \; 3p^6 \boxed{4s^1 \; 3d^5}$

∴ $_{24}Cr^{+2}$ : $1s^2 \; 2s^2 \; 2p^6 \; 3s^2 \; 3p^6 \; 3d^4$

Some general points :

i) The elements having unpaired electrons are called paramagnetic and the elements with no ~~p~~ unpaired electrons are called dimagnetic

ii) Magnetic movement / Paramagnetic ~~mom~~movemen

$= \sqrt{n(n+2)}$ BM

where, n = no. of unpaired electrons.

BM = bohr magneton (constant)

BM = $9.27 \times 10^{-24}$ Joule/sec.

∴ $\sqrt{n(n+2)}$ BM = $9.27 \times 10^{-24}$ J/s.

iii) Total spin = $\pm \frac{1}{2} \times$ no. of unpaired $e^-$.

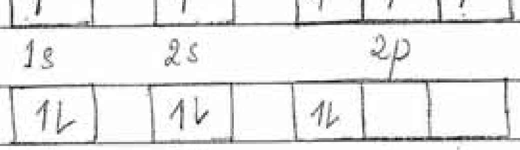
iv) Kernel : It is the remaining part of an atom after the removal of outermost shell.

v) core ~~energy~~ charge : Remaining portion after Kernel. i.e. = Atomic no − no. of $e^-$ in Kernel.

94. For which element of the periodic table, Pauli's exclusion principal is not applicable?
It is not applicable for hydrogen ($H_2$) because it doesn't contains (minimum number) ~~of~~ two electrons in its shell.

95 Determine the first element of periodic table for which hund's rule is applicable.
carbon, because from this element, the pairing of the electron starts.

96. In the following configuration, which rules are violated.

i) 

Aufbau principal

ii) 

Hunds rule

iii) 

Hunds and Pauli's rule

iv) 

Pauli's Principal

Q.97 If principal quantum no. more than 4 is not possible, then find out the total no. of possible element in nature?

$n \leq 4$

Total no. of electron in a shell = $2n^2$

when $n = 1$ ; no of $e^-$ = $2(1)^2$ = 2

when $n = 2$ ; no of $e^-$ = $2(2)^2$ = 8

when $n = 3$ ; no of $e^-$ = $2(3)^2$ = 18

when $n = 4$ ; no of $e^-$ = $2(4)^2$ = 32

$\because 2 + 8 + 18 + 32 = 60$

Hence, total no. of possible elements = 60.

Q.98. If principle quantum no. more than 4 is not possible in the electronic configuration of an element then find out the maximum no. of electrons.

$n \leq 4$

configuration : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p$

Hence, maximum no of electrons present in the element = ~~36~~ $2 + 2 + 6 + 2 + 6 + 2 + 10 + 6$

= 36 electrons.

Q.99 In an atom, how many electrons can have these value of quantum no.

$n = 4$ ; $l = 2$ ; $m = 1$ and $s = +1/2$

Only one electron can have the above values because according to Pauli's exclusion rule, 'No two electrons can have the same value of all the four quantum number.'

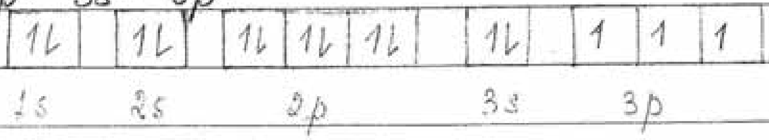
Q.100 Write down the electronic configuration of Phosphorus ?

i) Find out the total no. of $e^-$ in phosphorus for which

electronic configuration of phosphorus:

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

~~n = 3~~



- $n = 3$

  no. of $e^-$s = 3+2 = 5 electrons
- $n = 3$ and $l = 1$

  no of $e^-$s = 3 electrons
- $n = 3$ and $m = 0$

  no of $e^-$s = 3 electrons
- $n = 2$ and $m = -1$

  no of $e^-$s = 2 electrons
- $l = 1$

  no. of $e^-$s = 6+3 = 9 electrons
- $l = 0$ and $s = +1/2$

  no. of $e^-$s = 3 electrons

ii) Total spin: $\pm \frac{1}{2} \times$ no. of unpaired electron

$$= \pm \frac{1}{2} \times 3 = \pm \frac{3}{2}$$

iii) Magnetic moment: $\sqrt{n(n+2)}$ BM.

$$= \sqrt{3(3+2)} \text{ BM}$$

$$= \sqrt{3 \times 5} \text{ BM} = \sqrt{15} \text{ BM}$$

iv) Write down the set of four quantum numbers for:

- 4th electron

$n = 2;\quad l = 0\quad m = 0\quad s = \pm 1/2$

- 11th electron

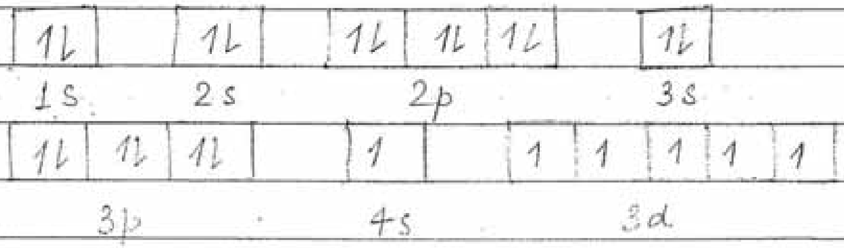
$n = 3;\quad l = 0\quad m = 0\quad s = \pm 1/2$

- 15th electron

$n = 3;\quad l = 1\quad m = +1, 0, -1\quad s = \pm 1/2$

Q.101 For chromium atom determine the followings:

∵ Chromium (Cr) is an exception,
∴ its electronic configuration =
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$



- No of unpaired electrons : 1+5 = 6 electrons
- No of paired electrons : 2+2+6+2+6 = 18 electron
- No of pair of electron : 9 electron pair
- No of s, p and d electron : s-subshell = 7
  p subshell = 12 $e^-$s and d subshell = 5$e^-$

~~Total no of paramagnetic movement:~~
~~= total no. of unpaired electrons = 6 electrons~~

- No. of p-orbital: 3+3 = 6 orbital
- No of $e^-$ with (n+l) = 4 : (4s and 3p orbitals)
  = 6 + 1 = 7 electrons
- No of $e^-$ with m = 0 : (1s, 2s, 3s, 4s, $3p_z$ and $3d_{z^2}$ Orbitals)
  = 2 + 2 + 2 + 2 + 2 + 1 + 1 = 12 electrons
- No of $e^-$ with l = 1 and s = +1/2 : (2p and 3p orbitals) = 3 + 3 = 6 electrons.

- no. of electrons with $n = 2$ and $l = 0$ (2s orbital) = 2 electrons.
- no. of electrons with $n = 3$ and $m = -2$ (3d orbital) = 1 electron
- Total spin : $\pm \frac{1}{2} \times$ no. of unpaired e⁻

$$= \pm \frac{1}{2} \times 6 = \pm 3$$

- Paramagnetic movement : $\sqrt{n(n+2)}$ BM

$$= \sqrt{6(6+2)} \text{ BM}$$
$$\sqrt{6 \times 8} \text{ BM} = \sqrt{48} \text{ BM}$$

- Write down the configuration for 19th and last electron for chromium

For 19th electron of chromium,

$\because 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ \boxed{4s^1}$

$\therefore n = 4,\ l = 0,\ m = 0,\ s = \pm 1/2$

For last electron of chromium,

$\because 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ \boxed{3d^5}$

$\therefore n = 3,\ l = 2,\ m = -2 \text{ to } +2,\ s = \pm 1/2$

Q·102 Calculate the total spin and magnetic movement of $Fe^{+2}$, $Zn^{+2}$ and $Cr^{+3}$

i) $Fe^{+2}$ : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$

$\therefore$ Total spin = $\pm \frac{1}{2} \times$ no. of unpaired e⁻

$$= \pm \frac{1}{2} \times 4 = \pm 2$$

Magnetic movement = $\sqrt{n(n+2)}$ BM

$$= \sqrt{4(4+2)} \text{ BM}$$
$$= \sqrt{4 \times 6} \text{ BM} = \sqrt{24} \text{ BM}$$

ii) $Zn^{+3}$ : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$.

Total spin = $\pm \frac{1}{2} \times$ no. of unpaired $e^-$

$$= \pm \frac{1}{2} \times 0 = 0$$

Magnetic movement = $\sqrt{n(n+2)}$ BM

$$= \sqrt{0(0+2)} \text{ BM} = 0$$

iii) $Cr^{+3}$ : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$

Total spin = $\pm \frac{1}{2} \times$ no. of unpaired electrons.

$$= \pm \frac{1}{2} \times 3 = \pm \frac{3}{2}$$

Magnetic movement = $\sqrt{n(n+2)}$ BM

$$= \sqrt{3(3+2)} \text{ BM}$$

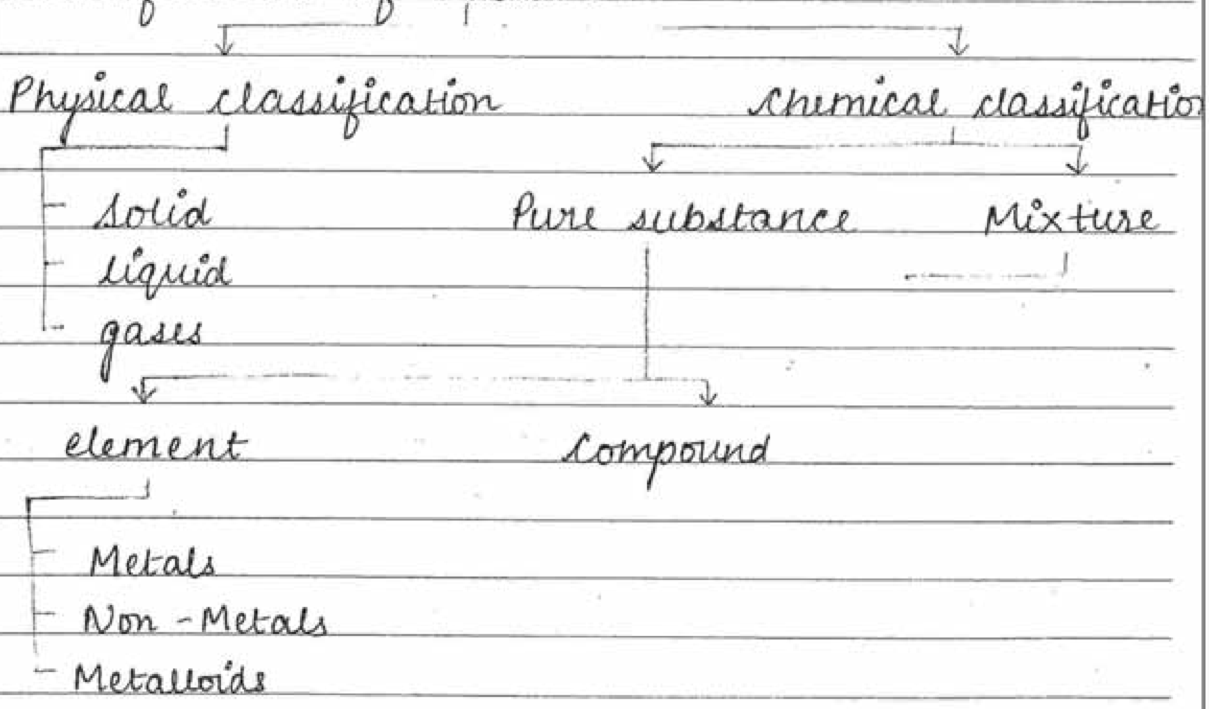
$$= \sqrt{3 \times 5} \text{ BM} = \sqrt{15} \text{ BM}$$

# SOME BASIC CONCEPT OF CHEMISTRY

Chemistry: It is a branch of science which deals with study of matter, its chemical composition and its physical and chemical properties and the changes which it undergoes in energy and composition during various process. It is also called study of elements and molecules and their transformation.

Matter: Anything which has mass and occupies space is called matter.

Classification of Matter:



## Branches of chemistry:

| Organic | Inorganic | Physical |
|---|---|---|
| Study of hydrocarbons and their ~~derivatior~~ derivatives | Study of all the known elements, compounds and ~~mixture~~ mixture except hydrocarbons | It deals with the laws which governers chemistry. |

| Solid | Liquid | Gas |
|---|---|---|
| Definite shape and volume | Definite volumes but shape indefinite | No definite shape or volume |
| Particles are held very closely in ordered ~~matt~~ manner | Particles are less closely packed | Particles are far apart. |
| Strong intermolecular forces | Moderate or Interminute molecular forces | Weak intermolecular forces (vanderwall force) |
| Particles do not move freely around | Particles can move slightly | Particles can move easily and very fast |
| It possess minimum energy | Moderate energy | Maximum energy |

Pure substance: It is made of only one type of substance

element: It is the pure substance which contains only one type of atom.
eg: H, He, Li, Mg, Na

compounds: It is the pure substance which have more than one type of atom in fixed ratio by mass
eg: $CO_2$, $H_2O$, NaCl, $KNO_3$, $HNO_3$, $BF_3$

Molecules: It is the simplest form of element or compound which exist independently.
eg: $H_2$, $O_2$, $P_4$, $NH_3$, $H_2O$, $H_2SO_4$, $PCl_5$ etc.

Types of molecules:

- Molecules of element
  eg: He, Ar, $O_3$, $P_4$, $S_8$
- Molecules of compound
  eg: $H_2O$, $PCl_3$, $NO_2$, KCl

* All compounds are molecules but all molecules are not compound.

Pure substances ~~cano~~ cannot be seperated by using physical methods. (distillation, crystalisation, mechanical seperation, hand-picking etc).

Mixtures can be seperated by using physical methods and chemical methods.

Compounds can be seperated by using chemical methods.
eg: $2HgO \xrightarrow{\Delta} 2Hg + O_2\uparrow$

Atomicity: Total no. of atoms present in one molecule of given substance
eg: Atomicity (2) = $O_2$, $N_2$, $H_2$
Atomicity (3) = $O_3$, $SO_2$, $NO_2$

Mixture: It contains more than one type of substance in variable proportion.

- Homogenous Mixture: Mixture which have uniform composition throughout and similar property

[Single phase (exact density, property) etc]
eg: Mixture of gases, Alloy, True solution, water + salt, $H_2O$ + glucose, Petrol, Diesel, Kerosene

- Heterogenous Mixture: Mixture which have non-uniform composition and different properties.

~~eg:~~ [different phase]
eg: Sand + $H_2O$, sugar + salt, Oil + water, Fe + S, Diamond + graphite, Milk (liquid : solid sol)

Q. 1. which of the following is not a mixture

| | | |
|---|---|---|
| i) | Milk | Heterogenous |
| ii) | Petrol | Homogenous |
| iii) | Steam | $H_2O$ compound |
| iv) | Air | Homogenous |

Ans) iii) Steam

Since Steam is a $H_2O$ compound, therefore it's not a mixture.

Q. 2. classify the following into elements, compounds and Mixture :

i) Diamond – element
ii) Steel – Homogenous Mixture
iii) Marble – $(CaCO_3)$ – compound
iv) Smoke – Heterogenous Mixture
v) laughing gas – compound
vi) LPG – Homogenous mixture
vii) Dry Ice – $CO_{2(s)}$ – compound
viii) ~~cloud~~ cloud – Heterogenous mixture
ix) Coin – Homogenous mixture
x) Diesel – Homogenous mixture

Properties and Measurement of Matters :

Physical Properties : Properties which can be measured ~~and~~ or observed without any change in the composition or identity of the substances.

Chemical Properties : Properties in which chemical substances occurs in the substance.

eg: Reactivity, combustibility. Acidity (replacing OH) and Basicity (replacing H)

Physical Quantity: All such quantities which can be measured during scientific studies.

Physical Quantity = Pure no × unit.

Units: It is defined as the standard or reference which choose to measure any physical quantities.

Some important unit conversions:

1. Length (SI unit : m)
also measured in yard, feet, inch and miles.

i) 1 mile = 1760 yards
ii) 1 yard = 3 feet
iii) 1 foot = 12 inch
iv) 1 inch = 2.54 cm

* Inter atomic distances and wavelength are reported in smaller units like nm, Å, pm etc.

i) 1 nm = $10^{-9}$ m = $10^{-7}$ cm
ii) 1 Å = $10^{-10}$ m = $10^{-8}$ cm
iii) 1 pm = $10^{-12}$ m = $10^{-10}$ cm
iv) 1 Fermi = $10^{-15}$ m = $10^{-13}$ cm

2. Mass: (SI unit : Kg)

also measured in g, mg, pound, lb, ton, quintal, amu.

i) 1 metric ton = $\overset{1000}{\cancel{10000}}$ kg

ii) 1 quintal = 100~~0~~ kg

iii) 1 kg = 2.205 lb

iv) 1 kg = 1000 g

v) 1 amu = $1.66 \times 10^{-24}$ g = $1.66 \times 10^{-27}$ kg

3. Temperature: (SI unit : K)

also measured in °C and °F

i) K = °C + 273.15

ii) $\frac{°C}{5} = \frac{°F - 32}{9}$

4. Volume : (SI unit : $m^3$)

also measured in l, ml, cc, $cm^3$, $dm^3$

i) 1 $m^3$ = 1000 l

ii) 1 ml = 1 cc = 1 $cm^3$

iii) 1 l = 1 $dm^3$ = $10^{-3}$ $m^3$

iv) 1 l = 1000 ml = 1000 cc

5. Energy: (SI unit : J)

also measured in erg, ev, cal, L-atm, watt-hr.

i) 1 cal = 4.18 ≃ 4.2 J

ii) 1 J = $10^7$ erg

iii) 1 eV = $1.6 \times 10^{-19}$ J

iv) 1 L- atm = 1 L × 1 atm.

$= (10^{-3}\ m^3) \times (10^5 \times 1.013\ Pa)$

$= 10^2 \times 1.013 \simeq 100\ J$

$= 101.3\ J$

Q.2 Arrange the unit of energy in the increasing order:

$\because$ 1eV = $1.6 \times 10^{-19}$ J

1 erg = $10^{-7}$ J

1 J = 1 J

1 cal = 4.2 J

1 L - atm = 100 J

$\therefore$ 1 eV < 1 erg < 1 J < 1 cal < 1 L-atm

6. Pressure: (SI unit: Pascal)
also measured in atm, bar, torr.
cm of Hg, mm of Hg

i) 1 atm = $1.01325 \times 10^5$ Pa

ii) 1 atm = 1.013 bar

iii) 1 atm = 760 mm of Hg

iv) 1 atm = 76 cm of Hg

v) 1 atm = 760 torr of Hg

* 1 torr is the pressure exerted by 1 mm column of Hg

$\therefore$ 1 mm = 1 torr.

Some important Prefix:

1 deci = $10^{-1}$
1 centi = $10^{-2}$
1 mili = $10^{-3}$
1 micro = $10^{-6}$
1 kg = $10^{3}$
1 mego = $10^{6}$

Larger the unit, smaller will be the numerical value

$\because \quad n \propto \frac{1}{u}$ where n = numerical value and u = unit.

- 1 Km = 1000 m = $10^5$ cm = $10^6$ mm
- density of $H_2O$ = $1 g/cm^3$

$$= \frac{10^{-3} kg}{10^{-6} m^3} = 10^3 kg/m^3$$

Unit conversion:

Q.3 Convert the following:

i) 1 mile into m

1 mile = 1760 yard
= 1760 × 3 feet
= 1760 × 3 × 12 inch
= 1760 × 3 × 12 × 2.54 cm
= $1760 \times 3 \times 12 \times 2.54 \times 10^{-2}$ m
= 1609.5 ≃ 1609 m

ii) 2 cal into J

$\because$ 1 cal = 4.2 J

$\therefore$ 2 cal = 4.2 × 2 = 8.4 J

iii) 10 atm into torr

$\because$ 1 atm = 760 torr

$\therefore$ 10 atm = 760×10 = 7600 torr

iv) 22.4 l into cc

$\because$ 1 l = 1000 cc

$\therefore$ 22.4 l = 22.4 × 1000 = 22400 cc

v) 1 ton into pound.

$\because$ 1 ton = 1000 kg

= 1000 × 2.205 lb.

= 2205 lb

vi) 25°C into K and °F

$\because$ 0°C = 273 K

$\therefore$ 25°C = 273 + 25 K

= 298 K

and

$$\because \frac{°C}{5} = \frac{°F - 32}{9}$$

$$\therefore \frac{25}{5} = \frac{°F - 32}{9}$$

$\therefore$ °F = 45 + 32 °F

= 77°F

Q-4 Convert the following:

i) 10 l into $m^3$, $dm^3$ and cc

$\because$ 1 l = $10^{-3}$ $m^3$

$\therefore$ 10 l = $10 \times 10^{-3}$ $m^3$

= $10^{-2}$ $m^3$

- $1\ l = 1\ dm^3$ and
- $1\ l = 1000\ cc$

ii) 1 l - atm into J and eV

- $1\ l\text{-}atm = 101.3\ J$ and
- $1\ l\text{-}atm = 100\ J$

$$= 100 \times \frac{1}{1.6 \times 10^{-19}}\ eV$$

$$= 6.25 \times 10^{20}\ eV$$

iii) 1 pm ~~≠~~ into nm, Å and km

- $\because 1\ pm = 10^{-12}\ m$

$$= 10^{-12} \times 10^{9}\ nm$$

$$= 10^{-3}\ nm$$

~~$1\ pm = 10^{-10}\ \text{Å}\ m$~~

~~$= 10^{-10} \times 10^{10}\ \text{Å}$~~

~~$= 10^{-10+10}\ \text{Å}$~~

~~$= 10^{0}\ \text{Å} = 1\ \text{Å}$~~

~~$1\ pm = 10^{-10}$~~

- $1\ pm = 10^{-12}\ m$

$$= 10^{-12} \times 10^{10}\ \text{Å}$$

$$= 10^{-2}\ \text{Å}$$

- $1\ pm = 10^{-12}\ m$

$$= 10^{-12} \times 10^{-3}\ km$$

$$= 10^{-15}\ km$$

# Mole Concept:

Mole: It was given by Ostwald in 1896
latin word, meaning heap or pile.

Mole is the SI unit which gives amount
of substances

* Definition: A mole is defined as amount
of substances that contains as many
particles as their are total no. of
atom present in 12 gm of C-12 isotope

1 mole = total no of atoms present in
12 g of C-12 atom

IR • Mass of one C-12 atom = $1.99 \times 10^{-23}$ g
(Mass spectrometer)

i.e. 1 gm of C12 = [illegible]

Total no of atoms present in 12g of
C-12 atom $= \dfrac{12\,g}{1.99 \times 10^{-23}\,g} = 6.022 \times 10^{23}$

where $6.022 \times 10^{23} = N_A$ or $N_0$ i.e
Avogadro no.

1 mole always contains $6.022 \times 10^{23}$
particles. These particles may be
atoms / molecules / ions / electrons /
proton etc.

1 mole of H atom = $6.022 \times 10^{23}$ H atom
1 mole of $CO_2$ molecule = $6.022 \times 10^{23}$ $CO_2$ molecule
1 mole of $K^+$ ion = $6.022 \times 10^{23}$ $K^+$ ion
1 mole of $e^-s$ = $6.022 \times 10^{23}$ $e^-s$.

$$1 \text{ amu} = \frac{1}{12} \times \text{mass of C-12 atom}$$
$$= 1.66 \times 10^{-24} \text{ g}$$

* For defining atomic masses of an element C-12 atom is taken as reference atom and mass of one C atom is exactly 12 amu.

* Atomic Mass (relative atomic mass)
$$\boxed{\text{Atomic Mass (relative atomic mass)} = \frac{\text{mass of 1 atom of an element}}{\frac{1}{12} \times \text{mass of C-12 atom}}}$$

* ∴
$$\boxed{\text{Atomic Mass} = \frac{\text{Mass of 1 atom}}{1 \text{ amu}}}$$

Atomic Mass of few elements :

i) Hydrogen : 1
ii) Helium : 4
iii) Lithium : *
iv) Beryllium :
v) Boron :
vi) Carbon : 12
vii) Nitrogen : 14
viii) Oxygen : 16

ix) Fluorine :
x) Neon :
xi) Sodium : 23
xii) Magnesium :
xiii) Aluminium :
xiv) Silicon :
xv) Phosphorus :
xvi) Sulphur : 32
xvii) Chlorine : 35.5
xviii) Argon :
xix) Potassium :
xx) Calcium : 40
xxi) Scandium :
xxii) Titanium :
xxiii) Vanadium :
xxiv) Chromium :
xxv) Manganese :
xxvi) Iron : 56
xxvii) Cobalt :
xxviii) Nickel :
xxix) copper : 63.5 63.5
xxx) Zinc :

Mercury : 200
Silver : 108
Bromine : 80
Iodine : 127

## Gram atomic Mass:

$1\ amu = \frac{1}{12} \times (\text{Mass of C-12 atom})$

$= \frac{1.99 \times 10^{-23}}{12} g = 1.66 \times 10^{-24} g$

☆☆ $\boxed{1\ amu = \frac{1}{N_A} g}$ $\left[\begin{array}{l} \because 12g = N_A \times 12\ amu \\ \therefore 1g = N_A \times 1\ amu \end{array}\right]$

gram atomic mass( Molar Mass)
It is the mass of 1 mole atom expressed in the gram

- 1 O-atom = 16 amu

$1 \text{ mole of O-atom} = 16\ amu \times N_A$

$= 16 \times \frac{1}{N_A} g \times N_A$

$= 16\ g$

- 1 Al-atom = 27 amu

$1 \text{ mole of Al-atom} = 27\ amu \times N_A$

$= 27 \times (1.66 \times 10^{-24} g \times 6.022 \times 10^{23}$

$= 27 \times \frac{1}{6.022 \times 10^{23}} g \times 6.022 \times 10^{23}$

$= 27 \times 1\ g$

$= 27\ g$

Molecular Mass:
It is the sum of masses of all the atoms present in one molecule

* Relative Molecular Mass: It is the no. which indicates that a molecule is how many times heavier than $\frac{1}{12}$ part mass of C-12 atom

eg: $CO_2 \Rightarrow 12 + 32 = 44$ amu
$NH_3 \Rightarrow 14 + 3 = 17$ amu
$SO_3 \Rightarrow 32 + 48 = 80$ amu
$H_2SO_4 \Rightarrow 2 + 32 + 64 = 98$ amu

Gram Molecular mass (Molar mass)
It is the mass of 1 mole molecules in gram.

eg: 1 $H_2O$ molecule = 18 amu
1 mole of $H_2O$ molecule = 18 amu × $N_A$
$= 18 \times \frac{1}{N_A} g \times N_A$
$= 18$ g

* It is also known as Molar mass because it is the mass of 1 mole substance
eg: 1 mole of $H_2SO_4$ = 98g (Molar mass)

1 mol atom

↓ $6.022 \times 10^{23}$ atoms

↓ GAM (Gram atomic mass)

↓ 1g atom

1 mol Molecule

| | | |
|---|---|---|
| $6.022 \times 10^{23}$ molecule | GMM (gram molecular mass) | 1 g molecul |

☆ In modern practise, mol is also known as

- gram atom (1 mol atom)
- gram molecule (1 mol molecule)
- gram ion (1 mol ion)
- gram mol. (1 mol)

eg: 5 g atom of nitrogen = 5 g nitrogen atom
5 mol nitrogen atom = 5 g nitrogen atom.

∴ 5 g atom of nitrogen = 5 mol nitrogen atom

Q. 5 Find the mass of the following:

i) 2.5 g molecule of $SO_2$
= 2.5 mole of $SO_2$ atom
= 2.5 × (32 + 32)
= 2.5 × 64 = 160 g

ii) 0.2 g of atom of O
= 0.2 g atom of O
= 0.2 mol of O
= 0.2 × 16 = 3.2 g

iii) 5 g ion of $Na^+$
= 5 mole of $Na^+$
= 5 × 23 = 115 g

iv) 2 g molecule of sugar ($C_{12}H_{22}O_{11}$)
= 2 mole of $C_{12}H_{22}O_{11}$
= 2 × 342 = 684 g

v) 1 g molecule of $CuSO_4 \cdot 5H_2O$
= 1 mole of $CuSO_4 \cdot 5H_2O$
= 1 [63.5 + 32 + 64 + (5×18)]
= 249.5 g

* Hence, Mole is also defined as the amount of substance that have mass equal to its gram atomic mass / gram molecular mass

2. Calculation of mole if mass of the substance is given:

$$\boxed{\text{Mol}(n) = \frac{\text{Mass of the substance (gm)}}{\text{Molar Mass}}}$$

* $$\boxed{\text{Mol}(n) = \frac{\text{given mass (gm)}}{\text{Molar mass}}}$$

$$\boxed{n = \frac{w}{M}}$$

6 Find the no. of moles present in 10g of $CaCO_3$

$$\text{Mol}(n) = \frac{\text{given mass}}{\text{Molar mass}}$$

$$= \frac{10\text{ g}}{(40+12+48)\text{ g}} = \frac{10}{100} = 0.1 \text{ mol}$$

Q.7 Find the no of moles present in 15.6g of $C_6H_6$

$$\text{Mol (n)} = \frac{\text{given mass}}{\text{Molar mass}}$$

$$= \frac{15.6\ g}{(72+6)\ g}$$

$$= \frac{15.6}{78} = 0.2\ \text{mol}$$

Q.8 ~~Find~~ In the 49 gm of $H_2SO_4$ sample

i) no of moles

ii) no of molecules

iii) no of atom

iv) no of $e^-$s

i)

$$\text{Mol (n)} = \frac{\text{given mass (gm)}}{\text{Molar mass}}$$

$$= \frac{49\ g}{(2+32+64)\ g}$$

$$= \frac{49}{98} = \frac{1}{2} = 0.5\ \text{mole.}$$

ii)

$$\because\ 1\ \text{mol} = 6.022 \times 10^{23}\ \text{molecules}$$

$$\therefore\ 0.5\ \text{mol} = 0.5 \times 6.022 \times 10^{23}\ \text{molecules}$$

$$= 3.09 \times 10^{23}\ \text{Molecules.}$$

iii)

$$\because\ 1\ \text{molecule} = 0.5 \times N_A$$

$$\therefore\ \text{no of atom} = 0.5 \times N_A \times \text{no of atoms in 1 molecule.}$$

$$= 0.5 \times N_A \times 7\ \text{atoms}$$

$$= 0.5 \times 7 \times 6.022 \times 10^{23}\ \text{atoms}$$

$$= 21 \times 10^{23}\ \text{atoms}$$

$$= 2.1 \times 10^{24}\ \text{atoms}$$

(iv) ∵ 1 molecule = $0.5 \times N_A$

∴ no. of $e^-$s = $0.5 \times N_A \times$ no. of $e^-$ in one molecule

$= 0.5 \times N_A \times 50$ (2+16+32)

$= 25 \times 6.022 \times 10^{23}$ $e^-$s

$= 150 \times 10^{23}$ $e^-$s.

Find the mass of $3.01 \times 10^{22}$ molecules of $NH_3$

no of moles in $3.01 \times 10^{22}$ molecules $= \frac{1}{N_A}$

$$\left[\begin{array}{l} \because 1 \text{ mole} = N_A \text{ molecules} \\ \therefore 1 \text{ molecule} = \frac{1}{N_A} \text{ mole} \end{array}\right]$$

$$= \frac{3.01 \times 10^{22}}{6.02 \times 10^{23}} = \frac{1}{20} \text{ mol.}$$

**OR**

$$n = \frac{\text{no of particles}}{N_A}$$

$$= \frac{3.01 \times 10^{22}}{6.02 \times 10^{23}} = \frac{1}{20} \text{ mol.}$$

$$\because n = \frac{\text{given mass}}{\text{Molar mass}}$$

$$\frac{1}{20} = \frac{w}{(14+3)}$$

$$\therefore w = \frac{17}{20} = 0.85 \text{ g.}$$

How many copper atoms are present in 0.635 g of Cu piece

$$\text{Mol } (n) = \frac{\text{given mass}}{\text{Molar Mass}}$$

$\because n = \frac{w}{M}$

$= \frac{0.635\ g}{63.5\ g} = \frac{1}{100} = 0.01$ mol

$\because$ 1 mole = $N_A$ atoms

$\therefore$ 0.01 mole = $0.01 \times 6.022 \times 10^{23}$ atoms

= $6.022 \times 10^{21}$ atoms

OR

Atomic weight of Cu = 63.5 g (Molar Mass)

$\therefore$ 63.5 g has $6.02 \times 10^{23}$ Cu atoms

$\therefore$ 1g has = $\frac{6.02 \times 10^{23}}{63.5}$ Cu atoms

Hence, 0.635 g has $\frac{6.02 \times 10^{23}}{63.5} \times 0.635$

= $6.02 \times 10^{21}$ Cu atoms.

Q. 11 Find the no of Helium atom present in

i) 100 amu of He

$n = \frac{w}{M} = \frac{100\ amu}{4} = 25$

ii) 100 g of He

$n = \frac{w}{M} = \frac{100\ g}{4g} =$ 25 mole.

$\because$ no of atoms = $25 \times N_A$

Q.12 Which of the following has maximum no. of atoms :

i) 36 g of C

ii) 54 g of Al

iii) 28 g of N

iv) All are same

Ans) i) 36 g of c

It is because

- $n = \frac{w}{M} = \frac{36}{12} = 3$ mol $= 3 N_A$ atom
- $n = \frac{w}{M} = \frac{54}{27} = 2$ mol $= 2 N_A$ atom
- $n = \frac{w}{M} = \frac{28}{14} = 2$ mol $= 2 N_A$ atom
- ~~n~~ All aren't same.

3. Calculation of Mole if volume of any gas ~~substance~~ is given :

$$PV = nRT$$

where n = no. of mole and.

$R$ = gas constant $= 8.314 \text{ J mol}^{-1} K^{-1}$

$= 1.987 \simeq 2 \text{ cal mol}^{-1} K^{-1}$

$= 0.0821 \text{ l-atm mol}^{-1} K^{-1}$

* [Vol^m of 1 mole gas at STP or NTP
T = 273 K and P = 1 atm]

∴ volume of 1 mole gas (n = 1)

$$V = \frac{nRT}{P} = \frac{1 \times 0.082 \times 273}{1}$$

$= 22.4$ l

$= 22400$ ml

(Molar volume)

Hence, 1 mole of any gas occupies 22.4 l as volume at NTP or STP. This is also known as Molar volume.

*
$$\boxed{\text{Mol } (n) = \frac{\text{vol}^m \text{ of gas at STP or NTP}}{22.4\ l}}$$

*
$$\boxed{n = \frac{V\ (ml)}{22400}}$$

Q. 13 Find the no of moles present in.

i) 5.6 l $NH_3$ (g) at STP

$$\because\ n = \frac{V}{22.4\ l} = \frac{5.6\ l}{22.4\ l} = 0.25 \text{ mol}$$

ii) 44.8 l $CO_2$ (g) at NTP

$$\because\ n = \frac{V}{22.4 l} = \frac{44.8}{22.4} = 2 \text{ mol}$$

iii) 1.21 l $O_2$ (g) at NTP

$$\because\ n = \frac{V}{22.4 l} = \frac{1.21}{22.4} = 0.05 \text{ mol}$$

Q. 14 Find the volume of 128 g $SO_2$ (g) at STP

$$\because\ n = \frac{\text{given mass}}{\cancel{2}\ \text{Molar mass}}$$

$$= \frac{128 g}{(32+32) g} = \frac{128 g}{64 g} = 2 \text{ mol.}$$

$$\because\ n = \frac{V}{22.4 l}$$

$\therefore V = n \times 22.4\ l$

$= 2 \times 22.4\ l$

$= 44.8 l$

15 Find the Mass of 11.2 l of $CH_4 (g)$ at STP

$\because n = \frac{V}{22.4 l} = \frac{11.2 l}{22.4 l} = \frac{1}{2}$ mol.

$\because n = \frac{w}{M}$

$\frac{1}{2} = \frac{w}{12+4}$

$\therefore w = \frac{16}{2} = 8g$

16 Find the no. of moles present in 1l water at STP (density of water = 1g/ml)

[ $n = \frac{V}{22.4}$ will not be applicable because it's only for ~~water~~ gases. ]

$\therefore$ density = $\frac{\text{Mass}}{\text{volume}}$

$\therefore m = d \times V$

$= \frac{1\,g}{ml} \times 1000\ ml$

$= 1000 g$

$\because n = \frac{\text{given mass}}{\text{molar mass}} = \frac{1000\ g}{18\ g} = 55.5$ mol.

$= 55.5$ mol.

Q. 17 find the no of protons present in 180 ml of $H_2O$

$$\because \quad d = \frac{M}{V}$$

$$\therefore \quad m = d \times V$$

$$= \frac{1\,g}{ml} \times 180\,ml$$

$$= 180\,g$$

$$\because \quad n = \frac{\text{given mass}}{\text{Molar mass}}$$

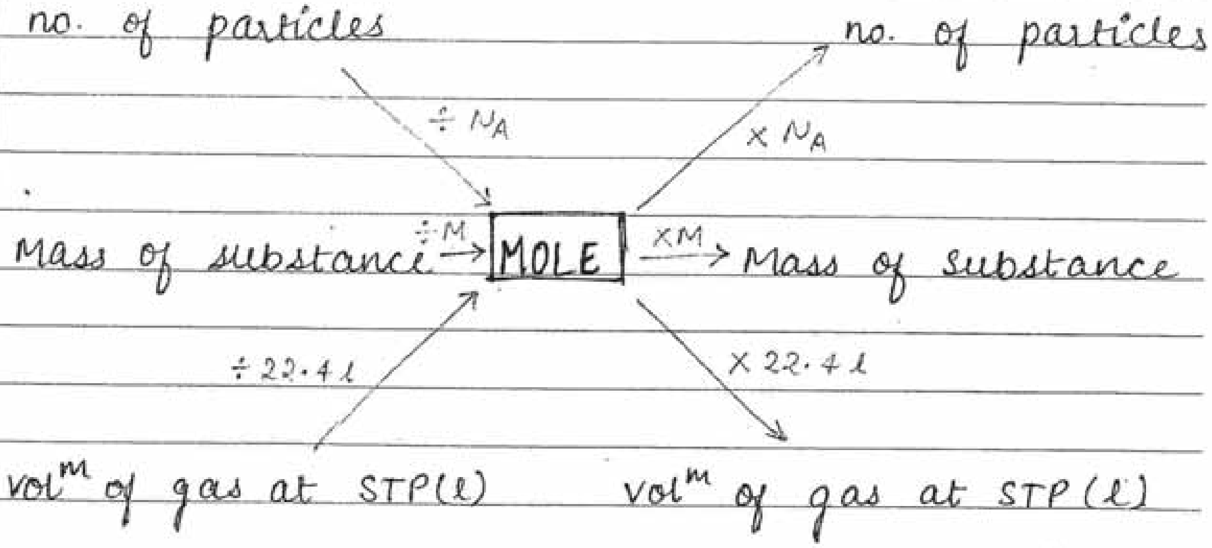
$$= \frac{180\,g}{18\,g} = 10 \text{ mol}$$

$\because$ no. of molecules = $10 \times N_A$

$\therefore$ no. of protons = $10 \times 10 \times N_A$

$= 100\,N_A$

☆☆ Conclusion :



i.e

☆

$$\boxed{n = \frac{\text{no. of particles}}{N_A} = \frac{W(g)}{M} = \frac{\text{vol}^M \text{ at STP}}{22.4}}$$

* Calculation of mole if molarity and volume of ~~substance is given:~~ solution is given:

$$\therefore \text{Mole}(n) = \text{Molarity}(M) \times \text{vol}^m(V)$$

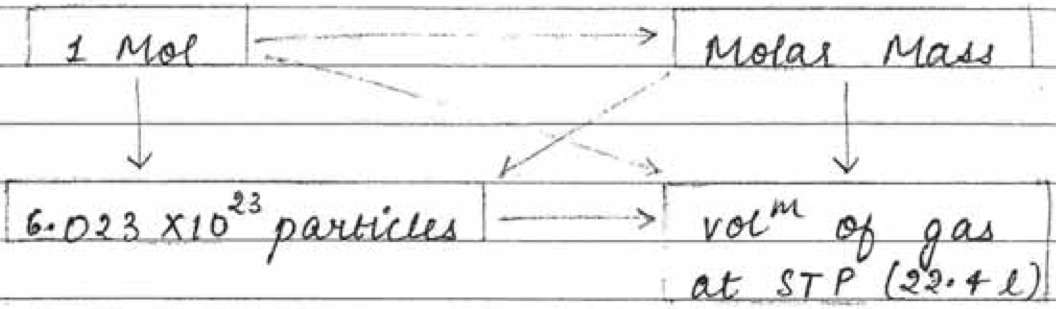
i.e. $n = M \times V(l)$

$$\therefore \boxed{M = \frac{n}{V_{(l)}}}$$

Q. 18 Find no. of moles of solute present in 5l solutions of 0.2 molar concentration.

$$\because n = M \times V$$
$$= 0.2 \times 5l$$
$$= 1 \text{ mole}$$

* Relation:



Q.19 Identify the element with maximum no. of molecules:

i) 5.6 l $NH_3(g)$ at STP

ii) 1.2 l $CO_2(g)$ at STP

iii) 2.24 l $O_2(g)$ at STP

iv) 4.48 l $H_2(g)$ at STP

Ans) i) 5.6 l $NH_3(g)$ at STP

It is because of the following:

i) ∵ $n = \frac{V(l)}{22.4 l} = \frac{5.6}{22.4} = \frac{1}{4}$ mole

∴ no of molecules = $\frac{N_A}{4}$ molecules.

ii) ∵ $n = \frac{V(l)}{22.4 l} = \frac{1.2}{22.4} = \frac{1}{19}$ mole

∴ no. of molecules = $\frac{N_A}{19}$ molecules

iii) ∵ $n = \frac{V(l)}{22.4 l} = \frac{2.24}{22.4} = \frac{1}{10}$ mole

∴ no of molecules = $\frac{N_A}{10}$ molecules

iv) ∵ $n = \frac{V(l)}{22.4 l} = \frac{4.48}{22.4} = \frac{1}{5}$ mole

∴ no of molecules = $\frac{N_A}{5}$ molecules

∴ $\frac{N_A}{4} > \frac{N_A}{5} > \frac{N_A}{10} > \frac{N_A}{19}$

Q. 20 Which contains maximum no of molecules

i) 28 g of $N_2$
ii) 32 g of $O_2$
iii) 64 g of $SO_2$
iv) 8 g of $H_2$

Ans) iv) 8 g of $H_2$

It is because.

i) molecules = $N_A \times n = \frac{N_A \times 28}{28}$ = $N_A$ molecules

ii) molecules = $N_A \times n = \frac{N_A \times 32}{32}$ = NA molecules

iii) molecules = $N_A \times n = \frac{N_A \times 64}{64}$ = NA molecules

iv) molecules = $N_A \times n = \frac{N_A \times 8}{2} = 4 N_A$

$\because 4 N_A > N_A$

21 Find the no. of ~~mo~~ atoms present in 0.1 mol.

i) $6.02 \times 10^{22}$

ii) $1.8 \times 10^{22}$

iii) $1.8 \times \cancel{10^{22}}\ 10^{23}$

iv) $1 \times 10^{23}$

Ans) iii) $1.8 \times \cancel{10^{23}}\ 10^{23}$

no. of molecules = $N_A \times n$

$\therefore$ no. of atoms = $N_A \times n \times$ atomicity

$= 0.1 \times \textcircled{3} \times N_A$

$= 0.3 \times 6 \times 10^{23}$

$= 1.8 \times 10^{23}$

Here atomicity = 3 because when gas is not specified it is considered as monoatomic i.e. ideal.

22. For 42 g of $N^{-3}$, find:

i) no. of $N^{-3}$ ion

$n = \frac{\text{given mass}}{\text{molar mass}} = \frac{42\ g}{14\ g} = 3$ mol.

ii) No. of moles of $e^-$s and $p^+$s.

$e^-$s ⇒ $n \times$ no of $e^- = 3 \times 10 = 30$ mol $e^-$

$p^+$s ⇒ $n \times$ no of $p^+ = 3 \times 7 = 21$ mol $p^+$

iii) No. of $e^-$s and $p^+$s.

no of $e^-$s ⇒ $n \times N_A \times$ no. of $e^- = 3 \times N_A \times 10 = 30 N_A$

no of $p^+$s ⇒ $n \times N_A \times$ no. of $p^+ = 3 \times N_A \times 7 = 21 N_A$

Q. 23. For 1.12 l of $NH_3$ (g) at STP , find:

i) no. of moles : $\cancel{n = \frac{w}{M}} =$

$$n = \frac{V}{22.4 l} = \frac{1.12 \ l}{22.4 \ l} = \frac{1}{20} \text{ mol.} = 0.05 \text{ mol}$$

ii) no. of molecules : $\frac{1}{20} \times N_A$ molecule

$$= \frac{N_A}{20} = \overset{0.05}{\cancel{0.5}} N_A$$

iii) Moles of atoms : n × atomicity

$$\frac{1}{20} \times 4 = \frac{1}{5} = 0.2$$

iv) no. of atoms : n × NA × atomicity

$$\frac{1}{20} \times N_A \times 4 = \frac{N_A}{5} = 0.2 \ N_A$$

v) mol of $e^-$, $p^+$ and $n^\circ$'s : n × no. of $e^-/p^+/n^\circ$'s present in a molecule

∵ no of $e^-$ = no of $p^+$ in a neutral atom

∴ mole of $e^-$ = n × 10

$$= \frac{1}{20} \times 10 = \frac{1}{2} = 0.5 \text{ mol}$$

~~no of $e^-$ = no of $p^+$ = 0.~~

mole of $e^-$ = mole of $p^+$ = 0.5

mole of $n^\circ$ = n × 7 = $\frac{1}{20} \times 7$ = 0.35 mol

∵ neutrons are absent in H

vi) no of $e^-$s, $p^+$s and $n^\circ$s :

$n \times N_A \times$ no of $e^-/p^+/n^\circ$ in a molecule

no. of $e^-$ = no of $p^+$ = $n \times N_A \times 10$

$= \frac{1}{20} \times 10 \times N_A = 0.5\ N_A$

no. of $n^\circ$ = $n \times N_A \times 7$

$= \frac{1}{20} \times 7 \times N_A = 0.35\ N_A$

vii) mol of N- atom : $n \times$ atomicity of N

$= \frac{1}{20} \times 1 = 0.05$ mol

viii) Mol of H atom : $n \times$ atomicity of H

$= \frac{1}{20} \times 3 = 0.15$ mol

ix) no. of N-atom : $n \times N_A \times$ atomicity of N

$= \frac{1}{20} \times N_A \times 1 = 0.05\ N_A$

x) no. of H-atom : $n \times N_A \times$ atomicity of H

$= \frac{1}{20} \times N_A \times 3 = 0.15\ N_A$

.24 From 176 g of $CO_2$, $9.03 \times 10^{23}$ molecules are removed, find mole of $CO_2$ left

-Initial mole (n) $= \frac{w}{M}$

$= \frac{176\ g}{44\ g} = 4$ mol

Moles of $CO_2$ removed (n) = $\frac{\text{no. of particles}}{N_A}$

$$= \frac{9.03 \times 10^{23}}{6.2 \times 10^{23}} = 1.5 \text{ mol.}$$

∴ Remaining mole = 4 mol − 1.5 mol

= 2.5 mol.

OR

Initial mass = 176 g

Mass of $CO_2$ removed,

∵ 44 g has $N_A$ particles.

1 particle = $\frac{\cancel{44}\ 1}{N_A}$ g

$$\therefore 44\,g = \frac{44}{N_A}\,g$$

$$= \frac{44 \times 9.03 \times 10^{23}}{6.023 \times 10^{23}} = 66\,g$$

Remaining Mass = 176 g − 66 g = 110 g

∵ 1 mole = 44 g of $CO_2$

∴ 1 g of $CO_2$ = $\frac{1}{44}$ mole

Hence, 110 g of $CO_2$ = $\frac{110}{44}$ mole

= 2.5 mol

Q.25 How many years it would take to spend 1 mol Rs @ 10 lac per second.

∵ 1 mol Rs = $6.023 \times 10^{23}$

∴ Rs spend in one year = $10^6 \times 60 \times 60 \times 24 \times 365$

∴ no of years = $\frac{6.023 \times 10^{23}}{10^6 \times 60 \times 60 \times 24 \times 365}$

$$= \frac{6.023 \times 10^{14}}{31{,}536} = 1.9 \times 10^{10} \text{ yrs}$$

# Vapour Density (Relative density)

- It is defined for only gases and vapour
- It is the ~~velocity~~ density of ~~hydrogen~~ ~~at~~ any gas relative to density of hydrogen at same pressure and temperature

☆ $$\boxed{\text{Vapour density} = \frac{\text{density of gas}}{\text{density of hydrogen}}}$$

$$\text{density of } H_2 = 0.089 \text{ g/l}$$
$$= 0.089 \times 10^{-3} \text{ kg/l}$$
$$= 0.000089 \text{ Kg/l}$$

- It is unitless

$$\because PV = nRT$$
$$\therefore P = \frac{nRT}{V}$$
$$= \frac{w}{M}\frac{RT}{V} \quad \left[\because n = \frac{w}{M}\right]$$
$$\therefore P = \frac{d}{M}RT \quad \text{where } d = \text{density.}$$

☆☆☆☆☆ $$\therefore \boxed{d = \frac{PM}{RT}}$$

$$\therefore \text{Vapour density} = \left[\frac{\frac{PM_{gas}}{RT}}{\frac{PM_{(H_2)}}{RT}}\right] \quad \text{at constant } P \text{ and } T$$

$$\therefore \ V.D. = \frac{M_{gas}}{M_{H_2}} = \frac{M_{gas}}{2}$$

☆ $\therefore \ \boxed{M_{gas} = 2 \times VD}$

Q.26 Find the vapour density of $SO_3$ and $O_2$ gas

$\because \ M_{gas} = 2 \times VD$

$$\therefore \ VD = \frac{M_{gas}}{2} = \frac{48+32}{2}$$

$$= \frac{80}{2} = 40$$

$$\therefore \ VD(SO_3) = \frac{80}{2} = 40$$

$$\therefore \ VD(O_2) = \frac{32}{2} = 16$$

Q.27 Find the molecular weight of the gas whose V.D is 32

$$\because \ M_{gas} = 2 \times V.D$$

$$= 2 \times 32 = 64\,g$$

Hence, the gas $SO_2$ gas

Q.28 Which of the following gas has VD = 8

i) CO

ii) $CH_4$

iii) $SO_2$

iv) $O_2$

Ans) (i) $CH_4$

$$\because \ M_{gas} = 2 \times VD$$

$$= 2 \times 8$$

$$= 16\,g$$

- $12 + 16 = 28\,g$
- $12 + 4 = 16\,g$

- $32 + 32 = 64 g$
- $16 + 16 = 32 g$

Q. 29 Find the value of n in a given compound $(CO)_n$ whose V.D. = 70

$M_{gas} = 2 \times VD$

$= 2 \times 70 = 140 g$

$n = \frac{\text{given mass}}{\text{total mass}}$

$= \frac{140 g}{28 g} = 5.$

$\therefore n = 5$

30 Find the density of 1 mole at S.T.P

i) Find the density of 1 mole of $N_2$ gas at STP.

$\because \text{density} = \frac{\text{Mass}}{\text{volume}} = \frac{\text{GMM}}{\text{volume}}$

$= \frac{28 g}{22.4 l}$

$= \frac{5}{4} g/l = 1.25 g/l$

ii) Find the density of 1 mole of $O_2$ gas at STP

$\because \text{density} = \frac{\text{Mass}}{\text{volume}} = \frac{\text{GMM}}{\text{volume}}$

$= \frac{32 g}{22.4 l}$

$= 1.4 g/l$

Q.31 Find the mass of $H_2O$ when it contains 100 mol of H atom

2 mole of H-atom = 1 mole of $H_2O$ at STP

1 mole of H-atom = $\frac{1}{2}$ mole of $H_2O$ at STP

∴ 100 mole of H - atom = $\frac{1}{2} \times 100$ mole of $H_2O$ at STP

= 50 mole of $H_2O$ at STP

∵ $n = \frac{w}{M}$

50 ∴ $w = n \times M$

$= (50 \times 18)\,g$

$= 900\,g$

Q.32 calculate no of chloride ions present in 1.11 gm of $CaCl_2$

∵ mole (n) = $\frac{\text{given mass (g)}}{\text{Molar Mass (g)}}$

$= \frac{1.11}{40+71} = \frac{1.11}{111}$

$= \frac{1}{100}$ mole

no of molecules = $n \times N_A$

$= \frac{1}{100} \times N_A = \frac{N_A}{100}$

∴ no of cl ions = $\frac{N_A}{100} \times 2$

$= \frac{N_A}{50}$

Q.33 Find the no of $PO_4^{3-}$ ion present in 0.5 mol of $Mg_3(PO_4)_2$

$\because n = 0.5$ mol

no. of molecules = $0.5 \times N_A$

$\therefore$ no. of ions ~~of~~ $PO_4^{3-}$ $= 0.5 \times N_A \times 2$

$= 1 \times N_A = N_A$

34 Find the no. of moles of $CaCO_3$ which contains 12 mol of O. atom

$\because$ 3 moles of O - atom = 1 mole of $CaCO_3$

$\therefore$ 1 mol of O - atom = $\frac{1}{3}$ mole of $CaCO_3$

12 mole of O - atom = $\frac{1}{3} \times 12$ mole of $CaCO_3$

= 4 moles of $CaCO_3$

35 Two elements A and B forms ~~same~~ 2 compound
Mass of 0.1 mole of $AB_2$ = 5g and
Mass of 0.1 mole of $A_2B$ = 5.5 g
then find atomic weight of A and B

- $\because n = \frac{w}{M}$

$\therefore M = \frac{w}{n} = \frac{5g}{0.1} = 50\,g$

$A + 2B = 50g$ —①

- $\because n = \frac{w}{M}$

$\therefore M = \frac{w}{n} = \frac{5.5g}{0.1} = 55\,g$

$2A + B =$ ~~50~~ $55g$ —⑪

From eq ① and ⑪ we get,

$A = 50\,g - 2B.$

Putting value of A in eq ⑪

$2(50\,g - 2B) + B = 55\,g$

$= 100\,g - 4B + B = 55\,g$

$= 100\,g - 55\,g = 4B - B.$

$= \frac{45\,g}{3} = B$

$\therefore\ B = 15\,g$

$\therefore\ A = 50\,g - 2 \times 15\,g$

$= 50\,g - 30\,g = 20\,g$

Q. 36 In an experiment, 0.2 gm of volatile liquid on vapourisation gives 56 ml of vapour at STP then find molecular weight of liquid.

$\because$ mol (n) $= \frac{V\,(ml)}{22400\ ml}$

$= \frac{56\ ml}{22400\ ml}$

$= \frac{1}{400}$ mol

$\because \frac{1}{400}$ mol $= 0.2\,g$

$\therefore$ 1 mol $= 400 \times 0.2\,g$

$= 80\,g$

**OR**

56 ml of vapour $= 0.2\,g$

$\therefore$ 1 ml of vapour $= \frac{0.2 \cancel{\times 5}}{56}\,g$

$\therefore$ 22400 ml of vapour $= \frac{0.2}{56} \times 22400$

$= 80\,g$

## * Actual or Absolute weight :

It is the mass of single atom or single molecule represented in gram

eg: 1 H-atom = 1.008 amu [Relative atomic mass]

$$\text{Actual Mass} = 1.008 \times \frac{1}{N_A} \text{ g}$$

$$= 1.008 \times 1.66 \times 10^{-24} \text{ g}$$

$$= 1.67 \times 10^{-24} \text{ g}$$

eg: 1 molecule of $H_2O$ = 18 amu [Relative atomic mass]

$$\text{Actual Mass} = 18 \times \frac{1}{N_A} \text{ g}$$

$$= 18 \times \frac{1}{6.022 \times 10^{23}} \text{ g}$$

$$= 18 \times 1.66 \times 10^{-24} \text{ g}$$

$$= 29.9 \times 10^{-24} \text{ g}$$

## Formula association :

- $n = \frac{\text{no. of particles}}{N_A} = \frac{\text{given mass}}{\text{molar mass}} = \frac{\text{vol}^m (l)}{22.4 \ l}$
- no. of molecules = $n \times N_A$
- no. of atoms = $n \times N_A \times$ no of atoms in a molecule
- no. of $e^-/p^+/n^\circ$/ ions = $n \times N_A \times$ no. of $e^-/p^+/n^\circ$/ions in a molecule
- mole of atom/$e^-/p^+ n^\circ$/ions = $n \times$ atomicity
- $M_{gas} = 2 \times VD$.

## Laws of chemical conservation:

1. Laws of conservation of mass:
It was given by Lavoisier (father of chemistry) and experimentally proved by Landolt.

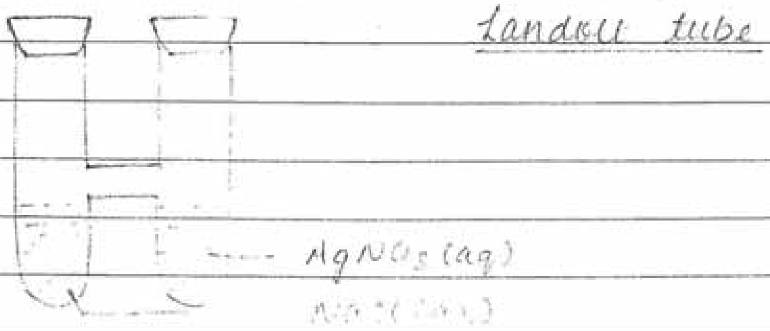
It states that during any physical or chemical change, total mass of the substances remain constant means masses can neither be created nor be destroyed.

- For chemical reactions,
Total mass of reactants = Mass of product

- If substances do not react completely,
Mass of reactant = Mass of product +
Mass of remaining reactants

* This law is not applicable for nuclear reaction.
energy + Mass = constant

Landolt experiment:



initial total mass = x g
final total mass = x g

∴ NaCl (aq) + $AgNO_3$ (aq) ⟶ AlCl(s) ↓ + Na
(white Precipitate)

37 Find the mass of $CO_2$ produced when 50 g of $CaCO_3$ decomposes to give 28 g of CaO

$$\because CaCO_3 \longrightarrow CaO + CO_2$$
$$50g \qquad 28g + xg$$
$$50 g = 28 g + xg$$
$$\therefore x g = 50g - 28 g = 22g$$

2. Law of definite proportion :
It was given by Proust.

It states that composition and chemical compound (by weight) always remain constant whether it is obtained from any source or any method

* It is not applicable for isotops and non-stoichoimetric compound.

- eg : isotops : $^{12}CO_2$ and $^{14}CO_2$
12 : 32 and 14 : 32

$H_2O$ and $D_2O$
2 : 16 and 4 : 16

- eg: Interstitial compound :
  $[Fe_{94} O_{100}]$ or $[Fe_{0.94} O]$
  and
  $[Fe_{96} O_{100}]$ or $[Fe_{0.96} O]$

eg: $CO_2$

12 : 32

3 : 8 by Mass

and

$H_2O$

2 : 16

1 : 8 by Mass.

Q. 38 In an experiment 4g of cu combines with oxygen atom to form 6 g of CuO and in another experiment 3.3 g of CuO decomposes to give 2.2 g of cu. From the above data. Illustrate the law of definite proportion of cu.

Case I : $Cu + O \longrightarrow CuO$

$$4g + xg \longrightarrow 6g.$$

$$\therefore xg = 6g - 4g = 2g$$

$$\therefore \frac{W_{cu}}{W_O} = \frac{4}{2} - \frac{2}{1} = 2:1$$

Case II : $CuO \longrightarrow Cu + O$

$$3.3g \longrightarrow 2.2g + xg$$

$$\therefore xg = 3.3g - 2.2g = 1.1g$$

$$\therefore \frac{W_{cu}}{W_O} = \cancel{3.3}\ \frac{2.2}{1.1} = \frac{2}{1} = 2:1$$

3. Law of Multiple Proportion:

It was given by Dalton

It states that, "If two elements combine to form more than one compound then different masses of one element combine with fixed mass of another element always bears a simple whole no. ratio with one-another."

- eg: H and O

  $H_2O$ = 2 : 16

  $H_2O_2$ = 2 : 32

  ∴ Ratio of mass of O = 1 : 2

- eg: S and O

  $SO_2$ = 32 : 32

  $SO_3$ = 32 : 48

  ∴ Ratio of Mass of O = $\frac{32}{48} = \frac{2}{3}$ = 2 : 3

* This law is not applicable for isotops.

39 Which of the following compounds obeys laws of multiple proportion:

i) $NH_3$ and $PH_3$

ii) $H_2O$ and $H_2S$

iii) $PCl_3$ and $PCl_5$

iv) HCl and HBr

Ans) iii) $PCl_3$ and $PCl_5$

It is because Multiple proportion involves only 2 elements.

Q-40 If two elements x and Y forms two compound in first compound 2g of x combine with 4g Y and in second compoun 4g of x combine with 16g Y.

If first compound,

2g x combine with 4g Y

1g x combine with 2g Y

In second compound,

4g x combine with 16g Y

∴ 1g of x combine with 4g Y

Ratio of weight of Y which combine with 1 g of x is $\frac{2}{4}$ i.e 1 : 2

4. Law of gaseous volumes:

It was given by Gay Lussac

It states that 'gases combine with each other in simple ratio of their volume and at similar condition of temperature and pressure'

Q. 41 Find the volume of $O_2$ required for complete combustion of 40 ml of $C_2H_2$ (g) Acetelene gas. Find the volume of $CO_2$ produced at constant temperature and pressure

$$2C_2H_{2(g)} + 5O_{2(g)} \longrightarrow 4CO_{2(g)} + 2H_2O\ (l)$$

$$(2V) \qquad (5V) \qquad\qquad (4V)$$

Ratios of their amount:

$$1V \qquad \frac{5}{2\cancel{V}}\cancel{2}V \qquad \frac{4}{2}V$$

$\because$ 1V combines with $\frac{5}{2}$V of $O_2$ to give $\frac{4V}{2}$

$\therefore$ 40 ml of $C_2H_2$ combine with $\frac{5}{2} \times 40$

i.e. 100 ml of $O_2$ to give $\frac{4}{2} \times 40$

= 80 ml.

## Berzelius Hypothesis :

'equal volume of all gases under similar conditions of temperature and pressure contains equal no of atoms.'

eg: $H_2 + Cl_2 \longrightarrow 2HCl$

1V : 1V 2V

1 atom : 1 atom 2 atom

i.e. $\frac{1}{2}$ atom : $\frac{1}{2}$ atom 1 atom

which is not possible as atoms can't be divided

- Contradictions of Dalton's Atomic theory

## Avogadro's Hypothesis :

'Equal volume of all gases under similar conditions of temperature and pressure contains equal no of molecules' (moles)

$PV = nRT$

$\because PV = nRT$

$$\therefore \frac{PV}{nRT} = \text{constant}$$

For two gases A and B.

$$\left( \frac{P_A V_A}{n_A R T_A} = \frac{P_B V_B}{n_B R T_B} \right) \text{ at constant } T \text{ and } P$$

$$\therefore \frac{PV_A}{n_A RT} = \frac{PV_B}{n_B RT}$$

$$= \therefore \frac{V_A}{n_A} = \frac{V_B}{n_B}$$

If $v_A = v_B$

$$\therefore \frac{1}{n_A} = \frac{1}{n_B}$$

i.e $n_A = n_B$.

Hence proved that it contains equal no of moles i.e equal no of molecules at constant T and P at ~~similar~~ same volume

eg:

Q. 42 If we have four flask of equal capacity containing 4 gases $H_2(g)$, $O_3(g)$, $He(g)$ and $NH_3(g)$ at constant temperature and pressure then find ratio of no. of molecules and no of atoms for different gases. The ratio of four gases at constant T and P.

$H_2(g)$ : $O_3(g)$ : $He(g)$ : $NH_3$.

Ratio of no. of molecules = 1 : 1 : 1 : 1 and

Ratio of no of atoms = 2 : 3 : 1 : 4

(43) Two container of equal capacity at constant temperature and pressure. 0.44 g of $CO_2(g)$ combines with 0.20 g of $X_2(g)$ find Molecular mass

$\because V_1 = V_2$

$\therefore n_1 = n_2$

$CO_2(g)$ : $X_2(g)$

moles of ~~$CO_3$~~ $CO_2$ = $\frac{\text{Given mass}}{\text{molar mass}}$

$= \frac{0.44\,g}{44\,g} = \frac{1}{100}$ mole

$= 0.01$ mole

moles of $\overset{X_2}{\cancel{CO_2}}$ (n) =

$\frac{1}{100} = \frac{0.20\,g}{M_{X_2}}$

$M_{X_2}$ [illegible]

[illegible]

$V.D$ [illegible]

## Percentage composition :

Q. 44 Find the percentage composition of constituent elements of $CaCO_3$.

Mass of $CaCO_3$ = 40g + 12g + 48 g
= 100 g

$\therefore$ Percentage of calcium = $\frac{40\,g}{100\,g} \times 100$
= 40 %.

Percentage of carbon = $\frac{12g}{100g} \times 100$
= 12 %.

Percentage of oxygen = $\frac{48\,g}{100g} \times 100$ = 48 %

* Percentage composition refers mass of various constituents elements present in given compound by 100 parts ~~of mass~~ ~~of~~ by mass of compound.

$$\boxed{\%\text{ of element} = \frac{\text{Mass of element}}{\text{total mass of compound}} \times 100}$$

*** *** $$\boxed{\%\text{ of element} = \frac{\text{no. of atoms} \times \text{atomic mass}}{\text{Molecular Mass}} \times 100}$$

$\because$ Mass of the element = no of atoms × atomic mass

Q. 45 Find the percentage composition of $FeSO_4 \cdot 7H_2O$

Mass of Ferrous sulphate (hydrated) :
56g + 32g + 64 g + (2g + 16 g) 7
= ~~190 g~~ 152 g + 126 g
= 278 g

$\therefore$ % of Fe : $\frac{56g}{278g} \times 100 = 20.14\%$

% of S : $\frac{32g\,g}{278g} \times 100 = 11.5\%$

% of O : $\frac{64\,g}{278\,g} \times 100 = 23\%$

% of $H_2O$ : $\frac{126\,g}{278g} \times 100 = 45.3\%$

46 Find the percentage composition of $Fe_2(SO_4)_3$.

Mass of $Fe_2(SO_4)_3$ :

$$= 56g \times 2 + 3 \times (32g + 64g)$$
$$= 112g + 3 \times (\cancel{8}\,96g)$$
$$112g + 288\,g = 400\,g.$$

$\therefore$ % of Fe $= \frac{56 \times 2}{400} \times 100$

$= 28\%$

% of S $= \frac{3 \times 32}{400} \times 100$

$= 24\%$

% of O $= \frac{4 \times 3 \times 16}{400} \times 100$

$= 48\%$

47 Find the percentage of water crystallisation present in blue vitriol. ($CuSO_4 \cdot 5H_2O$)

Mass of $CuSO_4 \cdot 5H_2O$ :

$$= 63.5g + 32g + 64g + 5(2g + 16g)$$
$$= 159.5g + 5 \times 18g$$
$$= 159.5g + 90g$$
$$= 249.5g$$

$$\therefore \% \text{ of } H_2O = \frac{90g}{249.5g} \times 100$$
$$\simeq \frac{90g}{250g} \times 100$$
$$\simeq 36\%$$

Q. 48 Find the value of $x$ in $Na_2SO_4 \cdot xH_2O$

It contains 50 % of $H_2O$

Mass of $Na_2SO_4 \cdot xH_2O$ :

$$(23 \times 2)g + 32g + (16 \times 4)g + x(2g + 16g)$$
$$= 46g + 32g + 64g + x \times 18g$$
$$= 142g + 18xg$$
$$\because \% \text{ of } H_2O = \frac{(18 \times x)g}{(142 + 18x)g} \times 100 = \frac{50}{\cancel{100}}$$
$$= 2(18x)g = (142 + 18x)g$$
$$= 36xg = 142g + 18xg$$
$$\therefore 36xg - 18xg = 142g$$
$$= 18xg = 142g$$
$$\therefore x = \frac{142g}{18g}$$
$$= 7.9$$
$$\simeq 8 \cancel{\%}$$

Q. 49 In oxalic acid $(COOH)_2 \cdot xH_2O$ when it contains 28.5% of water

Mass of $(COOH)_2 \cdot xH_2O$ :

$2(12+16+16+1) + x(2+16) g$

$= 2(45) + x(18) g$

$= 90 + 18x g$

$\because$ % of $H_2O$ = $\frac{18xg}{90+18x} \times 100 = 28{\cdot}5$

$= 18xg \times 100 = 28{\cdot}5(90+18x) g$

$= 1800xg = 2565 + 513xg$

$= 1800xg - 513xg = 2565$

$= 1287xg = 2565$

$\therefore x = \frac{2565}{1287} = 1{\cdot}99 \simeq 2$

Q.50 Find the percentage of FeO present in ~~$FeSO_4$~~ $Fe_3O_4$

Mass of $Fe_3O_4$ : $(3\times56)g + (16\times4)g$

$= 168 g + 64 g$

$= 232 g$

$\therefore$ % of FeO $= \frac{(56+16)g}{232 g} \times 100$

$= \frac{72 g}{232} \times 100$

$= \frac{7200 g}{232} = 31{\cdot}03 g$

$\simeq 31 g$

51 Find the (1) minimum molecular weight of insulin which contains 3·2% of sulphur by mass.

% of S = $\frac{\text{no of atom} \times \text{atomic mass}}{\text{Molecular Mass}} \times 100$

$$3.2 = \frac{1 \times 32}{M} \times 100$$

$$\therefore M = \frac{3200}{3.2} = 1000 g.$$

* To calculate minimum molecular weight of the compound.

∴ no of atom of given element = 1

Q. 52 Find the minimum molecular weight of haemoglobin which contains 0.25% of Fe by Mass.

$$\because \% \text{ of Fe} = \frac{1 \times \text{no of atom}}{\text{Molecular Mass}} \times 100$$

$$\therefore 0.25 = \frac{1 \times 56}{M} \times 100$$

$$\therefore M = \frac{5600}{0.25} = 22400 g$$

Q. 53 A compound contains 20% of nitrogen by mass. if molecular weight of compound is 140, then find no of ~~Hydrogen present~~ N atoms present in the compound.

$$\because \% \text{ of N} = \frac{\text{no. of atom} \times \text{atomic weight}}{\text{Molecular weight}} \times 100$$

$$20 = \frac{x \times 14}{140} \times 100$$

$$\therefore x = \frac{140 \times 20}{100 \times 14}$$

$$= 2 \text{ atoms.}$$

## Empirical Formula (EF) :

It represents the simplest whole no ratio of atom of different element present in one molecule.

## Molecular Formula (MF) :

It represents actual no. of atoms of various elements present in one molecule

| | Molecular formula (M.F) | empirical formula (E.F) | n |
|---|---|---|---|
| i) | $H_2O_2$ | HO | 2 |
| ii) | $C_6H_{12}O_6$ | $CH_2O$ | 6 |
| iii) | $CH_3COOH$<br>$(C_2H_4O_2)$ | $CH_2O$ | 2 |
| (v) | $CH_4$ | $CH_4$ | 1 |

☆ $\therefore$ MF = n × E.F

where n = +ve integer

☆ $\therefore$ $n = \dfrac{\text{M.F. mass}}{\text{E.F mass}}$

## Determination of Empirical formula :

Step 1 : Find the percentage composition of constituent element present in given compound.

Step 2 : Percentage composition of each element is divided by its atomic Mass / weight to obtain relative moles / atomic ratio.

Step 3 : Divide the relative moles of each element by minimum value of relative moles.
(It gives simplest ratio of atoms present in molecule)

Step 4 : If simplest ratio is in fraction, then convert it into whole no by multiplying it with minimum possible integer.

eg: An element contains C, H and O in the composition of 24%, 12% and 64% respectively

| element | % composition | Atomic weight | Relative moles | simplest Ratio |
|---|---|---|---|---|
| C | 24% | 12 | $\frac{24}{12} = 2$ | $\frac{2}{2} = 1$ |
| H | 12% | 1 | $\frac{12}{1} = 12$ | $\frac{12}{2} = 6$ |
| O | 64% | 16 | $\frac{64}{16} = 4$ | $\frac{4}{2} = 2$ |

$\therefore$ E.F = $C_1H_6O_2$

If molecular weight = 100 g

$\therefore\ n = \dfrac{\text{M.F mass}}{\text{E.F mass}}$

$= \dfrac{100\,g}{(12+6+32)\,g}$

$= \dfrac{100\,g}{50\,g} = 2$

$\because$ MF = n × EF

$= 2 \times CH_6O_2$

$\therefore$ M.F = $C_2H_{12}O_4$

Q.54 Find the empirical and molecular formula of the following compounds.

| element | % composition | Atomic weight | Relative moles | simplest ratio |
|---|---|---|---|---|
| C | 57.8 % | 12 | $\frac{57.8}{12} = 4.8$ | $\frac{4.8}{2.4} = 2$ |
| H | 3.6 % | 1 | $\frac{3.6}{1} = 3.6$ | $\frac{3.6}{2.4} = \frac{3}{2}$ |
| O | 38.6 % | 16 | $\frac{38.6}{16} = 2.4$ | $\frac{2.4}{2.4} = 1$ |

~~∴ E.F =~~

$\therefore$ simplest ratio of C, H and O respectively = $2\times2$, $\frac{3}{2}\times2$, $1\times2$

= 4, 3 and 2

$\therefore$ E.F = $C_4H_3O_2$

$\because$ V.D = 83

$\therefore$ $V.D = \frac{Mgas}{2}$

$\therefore$ Mgas = VD × 2

= 83 × 2 = 166

$n = \frac{M.F\ mass}{E.F\ mass}$

$= \frac{166}{83} = 2$

$\because$ MF = n × EF

= 2 × $C_4H_3O_2$

= $C_8H_6O_4$

Q.55. Find the empirical formula of the compound which contains two elements A and B. 50% by mass each. Atomic weight of A = 20 and Atomic weight of B = 10

| element | % composition | Atomic weight | Relative Moles | Simplest Ratio |
|---|---|---|---|---|
| A | 50% | 20 | $\frac{50}{20} = \frac{5}{2}$ | $\frac{5}{2} \times \frac{2}{5} = 1$ |
| B | 50% | 10 | $\frac{50}{10} = 5$ | $5 \times \frac{2}{5} = 2$ |

$\therefore$ EF = $AB_2$

OR

Short trick : For given two elements.

Simplest Ratio = $\frac{50/20}{50/10} = \frac{1}{2}$

$\therefore$ EF = $AB_2$

Q.56 Find the simplest formula of compound which has equal mass of X and Y. Atomic weight of X and Y are 20 and 30 respectively.

| element | % composition | Atomic weight | Relative moles | Simplest Ratio |
|---|---|---|---|---|
| X | 50% | 20 | $\frac{50}{20} = \frac{5}{2}$ | $\frac{5}{2} \times \frac{3}{5} = \frac{3}{2}$ |
| Y | 50% | 30 | $\frac{50}{30} = \frac{5}{3}$ | $\frac{5}{3} \times \frac{3}{5} = 1$ |

$\therefore$ EF = $X_3Y_2$

OR

Simplest ratio = $\frac{50/20}{50/30} = \frac{3}{2}$ $\therefore$ EF = $X_3Y_2$

Q.57 A gaseous compound is found to contain 2.34 g Nitrogen and 5.34 g of oxygen. Find the simplest formula of the compound.

| element | % composition | Atomic weight | Relative moles | Simplest ratio. |
|---|---|---|---|---|
| N | 2.34 g | 14 | $\frac{2.34}{14}$ | ? |
| O | 5.34 g | 16 | $\frac{5.34}{16}$ | |

$\therefore$ EF = $NO_2$

OR

Simplest ratio = $\frac{2.34/14}{5.34/16} = \frac{1}{2}$

$\therefore$ E.F = $NO_2$

Q.58 An iron oxide contains 70 % Fe by Mass. then find its empirical formula.

| element | % composition | Atomic weight | Relative moles | simplest ratio |
|---|---|---|---|---|
| Fe | 70% | 56 | $\frac{70}{56} = 1.25$ | |
| O | 30% | 16 | $\frac{30}{16} = 1.85$ | |

$\therefore$ E.F = $Fe_2O_3$

simplest ratio = $\frac{70/56}{30/16} = \frac{2}{3}$ $\therefore$ EF = $Fe_2O_3$

Q.59 In an organic compound. C, H and N are present in the ratio of 9:1:3.5 by weight. Find empirical formula of the compound as well as molecular formula Mole weight of the compound = 108

| element | % composition | Atomic weight | Relative moles | Simplest ratio |
|---|---|---|---|---|
| C | 9 | 12 | $\frac{9}{12} = \frac{3}{4}$ | $\frac{3}{4} \times 4 = 3$ |
| H | 1 | 1 | $\frac{1}{1} = 1$ | $1 \times 4 = 4$ |
| N | 3.5 | 14 | $\frac{3.5}{14} = \frac{1}{4}$ | $\frac{1}{4} \times 4 = 1$ |

E.F = $C_3H_4N$

$\therefore$ $n = \frac{108}{54} = 2$

$\therefore$ M.F = n x E.F

$2 \times C_3H_4N = C_6H_8N_2$

Simplest ratio : 3 : 4 : 1

∵ MF = n x E.F

$\left[ \begin{array}{l} n = 2 \\ E.F = C_3H_4N \end{array} \right.$

∴ MF = 2X $C_3H_4N$ = $C_6H_8N_2$

60 Calculate the empirical formula of the compound. ~~26.6%~~ which contains 26.6% of K, 35.4% of Cr and 38.1% of O. Find the empirical formula of the compound.

| element | % composition | Atomic weight | Relative Moles | Simplest ratio. |
|---|---|---|---|---|
| K | 26.6 | 39.1 | $\frac{26.6}{39.1} = 0.68$ | 1 |
| Cr | 35.4 | 52 | $\frac{35.4}{52} = 0.68$ | 1 |
| O | 38.1 | 16 | $\frac{38.1}{16} = 2.38$ | 3.5 |

∴ Simplest ratio of K, Cr and O respectively = 1X2, 1X2 and 3.5X2

= 2, 2 and 7

∴ EF = $K_2Cr_2O_7$

61 Find the simplest formula of compound which contains $6 \times 10^{20}$ atoms of P and $15 \times 10^{20}$ atoms of O.

- no. of moles of P $= \frac{6 \times 10^{20}}{N_A}$ and
- no of moles of O $= \frac{15 \times 10^{20}}{N_A}$

$\therefore$ simplest ratio $= \frac{6 \times 10^{20}}{N_A} \times \frac{N_A}{15 \times 10^{20}}$

$= \frac{6}{15} = \frac{2}{5}$

$\therefore$ EF = $P_2O_5$

Q. 62 5 ml of gaseous hydrocarbon of combustion gives 15 ml of $CO_2$ and 20 ml of $H_2O(g)$. Find the molecular formula

* $$\boxed{1C_xH_y + \left(x+\frac{y}{4}\right)O_2 \longrightarrow xCO_2 + \left(\frac{y}{2}\right)H_2O(g)}$$

1V ———— xV $\frac{y}{2}$ V

~~1mo~~

1 mole ———— x mole $\frac{y}{2}$ mole

5 ml ———— 5x ml $5 \times \frac{y}{2}$ ml

- $\because$ 5x ml = 15 ml (given)

  $\therefore x = \frac{15}{5} = 3$ and.

- $\frac{5y}{2}$ ml = 20 ml (given)

  $\therefore y = \frac{20 \times 2}{5} = 8$

$\therefore$ MF = $C_3H_8$

Q.63 0.2 l of ~~Hydrogen~~ hydrocarbon on combustion gives 1 l of $CO_2$ and 1 l of $H_2O$. Find molecular formula

$$1\,C_xH_y + O_2 \longrightarrow x\,CO_2 + \frac{y}{2}H_2O$$

$$1V \quad - \quad xV \quad \frac{y}{2}V$$

$$0.2\,l \quad - \quad 0.2x\,l \quad 0.2\frac{y}{2}\,l$$

$$1\,l \quad 1\,l$$

- $\because 0.2x\,l = 1\,l.$

$$\therefore x = \frac{1\,l}{0.2\,l} = 5$$

- $\because 0.2\frac{y}{2}\,l = 1\,l$

$$\therefore y = \frac{2\,l}{0.2\,l} = 10$$

$\therefore$ M.F = $C_5H_{10}$

64 Find Molecular formula ~~of com~~ and empirical formula of the compound is $C_2H_4O$ and mass = 176

$$\because n = \frac{\text{M.F. Mass}}{\text{EF Mass}}$$

$$= \frac{176}{2\times12+4+16}$$

$$= \cancel{\frac{176}{32+}} = \frac{176}{24+4+16}$$

$$= \frac{176}{44} = 4$$

$\because$ MF = n× EF

$\therefore$ M.F $= 4 \times C_2H_4O$

$= C_8H_{16}O_4$

Q. 65 Metals and oxygen combines to form two metal oxide. % of metals in 1st oxide is 60% and in the 2nd oxide is 40%. If 1st compound is $M_2O_3$, then find formula of 2nd compound.

| element | % composition | Atomic weight | Relative moles | Simplest Ratio |
|---|---|---|---|---|
| M | 60% | $x$ | $\frac{60}{x}$ | 2 |
| O | 40% | 16 | $\frac{40}{16} = \frac{5}{2}$ | 3. |

~~simp'~~ $\therefore \dfrac{60/x}{5/2} = \dfrac{2}{3}$

$\therefore \dfrac{60}{x} \times \dfrac{2}{5} = \dfrac{2}{3}$

$\therefore x = \dfrac{60 \times 2 \times 3}{5 \times 2} = 36$

| | | | | |
|---|---|---|---|---|
| M | 40% | 36 | $\frac{40}{36} = \frac{10}{9}$ | |
| O | 60% | 16 | $\frac{60}{16} = \frac{15}{4}$ | |

$\therefore$ Simplest ratio $= \dfrac{10/9}{15/4} = \dfrac{8}{27}$

$\therefore$ M.F of 2nd compound $= M_8O_{27}$

66 In a compound 14g X and 8g of Y are present. Find EF if Atomic weight of X is 28 and Y is 32

X → $\frac{14}{28}$

Y → 8 / 32

$$\text{Simplest ratio} = \frac{14}{28} \times \frac{32}{8} = \frac{2}{1}$$

$\therefore$ M.F = $X_2Y$

67 It is found that 16.5g of Metals combine with oxygen to form 35.6 g of Metal oxide. Calculate the % composition of Metals and oxygen present in compound.

$$\% \text{ of Metal} = \frac{16.5}{35.6} \times 100$$

$$= 46.3\%$$

$$\% \text{ of oxygen} = \frac{35.6 - 16.5}{35.6} \times 100$$

$$= \frac{19.1}{35.6} \times 100$$

$$= 53.7\%$$

## Stoichiometry :

- stoichi : element
- metron : measurement

It is the calculation of amount of various reactants and products involved in any chemical reaction.

Stoichiometry co-efficient : The coefficient of reactants and products in any balance chemical reaction is called stoichiometry coefficient.

eg: $②H_2 + ①O_2 \longrightarrow ②H_2O$
here, 2, 1 and 3 represents stoichiometrical coefficient (s.c.)

Balanced reaction:
eg: $aA + bB \longrightarrow cC + dD$
stoichiometrical coefficient - a, b, c, d.

* Stoichiometry always requires balanced chemical reaction.

It tells us about the following:
eg: $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

- S.C ] 1 : 3 : 2
- Molecules ] 1 molecule : 3 molecule : 2 molecules.
- atoms ] 1×NA atoms : 3×NA atoms : 2×NA atoms
- Molar Ratio 1 mole : 3 mole : 2 mole
- constant P and V at S.T.P ] 1V : 3V : 2V
- V-V analysis ] 1×22.4 l : 3×22.4 l : 2×22.4 l

where,
X 1g : 3g : 2g Not possible

- M-M analysis ] 28g of $N_2$ : 6g of $H_2$ : 34g of $NH_3$
- M-V analysis ] 28g : 6g : 2×22.4 l

Mass can't be used directly according to stoichiometric coefficient ! It can be calculated always according to moles.

Some basic Reactions :

i) $CaCO_3 \longrightarrow CaO + H_2O$
(Br, Mg, Ca, Sr, Ba)

ii) $2H_2 + O_2 \longrightarrow 2H_2O$

iii) $2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$

iv) $2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + CO_2 + H_2O$

v) $Li_2O_3 \xrightarrow{\Delta} Li_2O + CO_2$

vi) $Na_2CO_3 \xrightarrow{\Delta} \times$ No reaction
(K, Rb, Cs) except Li

vii) $H_2CO_3 \longrightarrow H_2O + CO_2$

viii) $2H_2O_2 \longrightarrow 2H_2O + O_2$

ix) $NaNO_3 \xrightarrow{\Delta} NaNO_2 + \frac{1}{2}O_2$

x) $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

xi) $3BaCl_2 + 2Na_3PO_4 \longrightarrow Ba_3(PO_4)_2 + 6NaCl$

xii) $NaHCO_3 + HCl \longrightarrow NaCl + CO_2 + H_2O$

How to solve problems related to stoichiometry:

Step I: Write down the balanced chemical reaction.

Step II: Write down the given amounts of reactants and products below their chemical formula.

Step III: Apply unitary method for desired calculation.

1 Type I: Reaction involving only 1 reactants

eg: $A \longrightarrow B + C$ (Balanced)

1 : 1 : 1

10 mole : 10 mole : 10 mole

eg: $A \longrightarrow 2B + 3C$ (Balanced)

1 : 2 : 3

10 mole : 20 mole : 30 mole

eg: $2A \longrightarrow 3B + 4C$ (Balanced

2 : 3 : 4

10 mole : 15 mole : 20 mole

Q.68 Find the mass of CaO and $CO_2$ produced when 50 g of $CaCO_3$ decomposes.

$CaCO_3 \longrightarrow CaO + CO_2$

1 : 1 : 1

Moles] $\frac{50}{100} = \frac{1}{2}$ : $\frac{1}{2}$ : $\frac{1}{2}$

$\therefore$ $\frac{1}{2}$ mole of CaO gives $\frac{1}{2} \times 56\,g = 28g$

and $\frac{1}{2}$ mole of $CO_2$ gives $\frac{1}{2} \times 44 = 22g$

$$\left( \because n = \frac{w}{M} \quad \therefore w = n \times M \right)$$

Q.69 Find the volume of $CO_2$ produced at S.T.P by decomposition of 1000 g of $CaCO_3$.

$$CaCO_3 \longrightarrow CaO + CO_2$$

$1 : 1 : 1$

moles] $\frac{1000}{100} = 10 : 10 : 10$

volume of $CO_2$ produced $= 10 \times 22.4\ l$

$= ~~22.4)~~\ 224\ l$

$$\left( \because n = \frac{V}{22.4\ l} \quad \therefore V = n \times 22.4\ l \right)$$

70 Find the volume of $N_2$ and $H_2$ at S.T.P by decomposition of 50 l of $NH_3$.

$$2NH_3 \longrightarrow N_2 + 3H_2$$

$2 : 1 : 3$

volume] $2V : 1V : 3V$

$50\ l : \frac{50\ l}{2} = 25\ l : 25\ l \times 3 = 75$

~~71~~

$$\left( \because 2V = 50\ l \quad \therefore 1\ V = \frac{50}{2}\ l = 25\ l \text{ and } 3V = 25\ l \times 3 = 75\ l \right)$$

Q.71 Find the moles of $CO_2$ and $O_2$ produced by complete combustion of 5 moles of Butane also find Mass of $H_2O$

$$\because \underset{\underset{x}{\downarrow}}{C_4}\underset{\underset{y}{\downarrow}}{H_{10}} + \left(x + \frac{y}{4}\right) O_2 \longrightarrow x\,CO_2 + \frac{y}{2} H_2O$$

$$C_4H_{10} + \frac{13}{2} O_2 \longrightarrow 4CO_2 + 5H_2O$$

Moles ] 1 mole : $\frac{13}{2}$ mole : 4 mole : 5 mole

5 moles : $\frac{13}{2} \times 5$ mole : $4 \times 5$ mole : $5 \times 5$ mole

5 mole = $\frac{65}{2}$ = 32.5 moles : 20 mole : 25 mole

Hence, Moles of $CO_2$ produced = 32.5 moles

Moles of $O_2$ produced = 20 moles

$\therefore$ Mass of $H_2O$ = $25 \times 18$ = 450 g $\left( \because n = \frac{w}{M} \right.$

$\therefore w = n \times M$.

Q.72 Find the moles of $O_2$ required for complete combustion of 1 mole glucose.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

1 : 6

Moles ] 1 mole : 6 mole

$\therefore$ 6 mole of $O_2$ is required for complete combustion of 1 mole of glucose

Q.73 Find the mass of $H_2O$ produced by 10 g of $H_2$ which reacts with $O_2$.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

2 : 1 : 2

Moles ] 2 moles : 1 mole : 2 mole (= 10g = 5)

2 mole : 1 mole : 2 mole.

Moles ] $\frac{10}{2} = 5$ mole : $\frac{5}{2}$ mole : 5 mole

∴ Mass of $H_2O$ produced = $5 \times 18 = 90g$

$\left( \because n = \frac{w}{M} \quad \therefore w = n \times M \right)$

OR

M-M analysis ] 2 mole : 1 mole : 2 mole

4g : 16g : 36g

∴ 1g ———— $\frac{36}{4}$

∴ 10g ———— $\frac{36}{4} \times 10 = 90g$

$\left( \because n = \frac{w}{M} \quad \therefore w = n \times M \right)$

74 Find the volume of $CO_2$ produced by combustion of 10 l of ethene gas at constant Pressure and Temperature.

$C_2H_6 + \frac{7}{2} O_2 \longrightarrow 2CO_2 + 3H_2O$

$1 : \frac{7}{2} : 2 : 3$

V-V analysis ] 1V ———— 2V

10 l ———— $10 \times 2 = 20$ l.

2 Type II : Reactants involving more than 1 reactant but amount of only one reactant is given then other reactant are present in excess. (sufficient amount)

Q.75 Find the mass of $NH_3$ produced when 56g of N reacts with hydrogen.

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

1 : 3 : 2

mole] 1 mole : 3 mole (excess) : 2 mole

$\frac{56}{28} = 2$ mole —————— $2 \times 2 = 4$ mole

$= 4 \times 17$ g

$= 68$g

$$\left( \because n = \frac{w}{M} \quad \therefore w = n \times M \right)$$

OR

M-M analysis] ~~2 mole~~ —————— ~~4 mole~~

1 mole —————— 2 mole

28g —————— 34g

1g —————— $\frac{34}{28}$

$\therefore$ 56g —————— $\frac{34}{28} \times 56 = 68$g

Q.76 Calculate the following:

i) Mass of $CO_2$

ii) Vol$^m$ of $CO_2$ at STP

iii) Mass of MgO produced by decomposition of 8.4 g of $MgCO_3$.

$$MgCO_3 \xrightarrow{\Delta} MgO + CO_2$$

1 : 1 : 1

M-M analysis] 84g : 40g : 44g

1g : $\frac{40}{84}$ g : $\frac{44}{84}$ g

8.4 g : $\frac{40}{84} \times 8.4 = 4$g : $\frac{44}{84} \times 8.4 = 4.4$g

8.4g : 4g : 4.4g

i) Mass of $CO_2$ produced = 4.4g

ii) vol$^m$ of $CO_2$ produced:

$$\because n = \frac{\text{given Mass}}{\text{Molar Mass}} = \frac{4.4g}{44g} = \frac{1}{10}$$

$$\because n = \frac{V}{22.4 l} \quad \therefore V = n \times 22.4 l$$

$$\therefore V = \frac{1}{10} \times 22.4 l$$

$$= 2.24 l$$

iii Mass of MgO produced = 4g

17 8l mixture of $CH_4$ and $C_3H_8$ on complete combustion gives 14l of $CO_2$. Find the volume of $CH_4$ and $C_3H_4$ present in the mixture.

let the mixture of $CH_4$ be x l

$\therefore$ the mixture of $C_3H_8$ = (8−x) l.

- $$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

v−v analysis] 1L ——— 1L

xl ——— xl

- $$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$$

1L ——— 3L

(8−x)l ——— ~~3x~~ 3(8−x)

acc to que,

$$x + 3(8-x) = 14$$

$$x + 24 - 3x = 14$$

$$24 - 14 = 3x - x$$

$$2x = 10$$

$$x = 5$$

$\therefore$ volume of $CH_4$ = x l = 5 l

$\therefore$ volume of $C_3H_8$ = (8−x) l = 8−5 l = 3 l

OR

let the mixture of $CH_4$ be $x$ l and
the mixture of $C_3H_8$ be $y$ l.

- $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

V-V analysis] 1L ——— 1L

$x$ l ——— $x$ l

- $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

V-V analysis] 1L ——— 3L

$y$ l ——— $3y$ l

acc to que,

$$x + y = 8$$
$$x + 3y = 14$$
$$(-)\quad(-)\qquad(-)$$
$$-2y = -6$$
$$\therefore y = 3$$
$$x = 8 - y = 8 - 3 = 5$$

OR

Short trick :

C①$H_4$ and C③$H_8$

$x$ l      $3(8-x)$ l

$\therefore\ x + 3(8-x) = 14$ l (given)

$x + 24 - 3x = 14$

$\therefore\ -2x = -10$

$\therefore\ x = 5$ l and $(8-x)$

~~y~~ $= 8 - 5 = 3$ l

Q.78 10 l mixture of $C_2H_6$ and $C_3H_8$ gives 22 l of $CO_2$ on complete combustion. Find the volume using short trick :

C②$H_6$ and C③$H_8$

$2x$ l      $3(10-x)$ l

$\therefore\ 2x + 3(10-x) = 22$ l (given)

$2x + 30 - 3x = 22$ l

$-x = 22 - 30$

$\therefore x = 8\,l$ and $(10 - x)$

$= (10 - 8) = 2\,l$

79 Calculate the volume of air required for complete combustion of 10 l of $CH_4$

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

$$1 : 2 : 1 : 2$$

V-V analysis] $1l : 2l : 1l : 2l$

$10\,l : 20\,l : 10\,l : 20\,l$

$\because$ Air contains $O_2$ by 20% by volume.

$$\therefore V_{air} \times \frac{20}{100} = V(O_2)$$

$$\therefore V_{air} \times \frac{1}{5} = V(O_2)$$

$$\therefore V_{air} = 5 \times V(O_2)$$

$$\therefore V_{air} = 5 \times 20\,l = 100\,l$$

Q.80 Calculate the volume of air required for complete combustion of 5l of propane

$$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + H_2O$$

$$1 : 5 : 3 : 1$$

V-V analysis] $1l : 5l : 3l : 1l$

$5l : 5 \times 5\,l : 5 \times 3\,l : 5l$

$= 25\,l \quad = 15\,l$

$\because V_{air} = 5 \times Vol(O_2)$

$= 5 \times 25\,l = 125\,l.$

☆ Volume (air) $= 5 \times$ volume $(O_2)$

2. Type II : Reaction involved in more than 1 reactants and amount of all other reactants are given.

* Special case of type 2, (limiting reagent)

Limiting reagent : The reaction which is completely consumed (finished earlier) in chemical reaction is called limiting reagent. It always limit the amount of product form.

Method to find LR.

Mole ratio: $\frac{\text{Moles of Reactant}}{\text{Stoichiometric coefficient}}$

The reactant which have minimum least mole ratio is limiting reagent

eg: $\overset{L.R}{\boxed{N_2}} + 3H_2 \longrightarrow 2NH_3$

1 : 3

5l : 20l (given)

then, 5l will reacts with 15 l.

Remaining volume = 20l − 15l = 5l

L.R = $N_2$

eg: $\overset{L.R}{\boxed{2H_2}} + O_2 \longrightarrow 2H_2O$

10 mole : 7 mole : 10 mole (given).

L.R $\frac{10}{2} : \frac{7}{1}$

$5 < 7$

∴ $H_2$ is L.R.

81 Find L.R. ?

$N_2 + \overset{L.R.}{\boxed{3H_2}} \longrightarrow NH_3$

10 mole 15 mole

$\therefore LR = \frac{10}{1} : \frac{15}{3}$

$10 > 5$

$\therefore$ LR is $H_2$

- Reactants which do not consume completely is reaction is called excess reagent.

82 $2A + 3B \longrightarrow C + D$

20 mole 30 mole

Find L.R.

$\therefore LR = \frac{20}{2} : \frac{30}{3}$

$10 = 10$

$\therefore$ Both A and B are limiting reagent.

83. $2A + B + 3C \longrightarrow 4D + E$

Find LR. and final composition of reaction mixture.

$2A + B + \boxed{3C}_{LR} \longrightarrow 4D + E$

5 mole 6 mole 6 mole

$\therefore L.R. = \frac{5}{2} : \frac{6}{1} : \frac{6}{3}$

$2.5 < 6 > \boxed{2}$

$\therefore$ 3C is the limiting reagent.

For final composition,

4D ⇒ ∵ 3 mole —— 4 mole

1 mole —— $\frac{4}{3}$ mole

$\therefore$ 6 mole —— $\frac{4}{3} \times 6$ mole

$= 4 \times 2 = 8$ mole

E ⇒ $\because$ 3 mole = 1 mole

$\therefore$ 1 mole = $\frac{1}{3}$ mole

$\therefore$ 6 mole = $\frac{1}{3} \times 6 = 2$ mole.

Q. 84 Calculate the moles of $H_2$ obtained when 0.3 mole of Zn reacts with 0.5 mole of HCl.

$$Zn + \boxed{2HCl}_{L.R} \longrightarrow ZnCl_2 + H_2$$

1 mole : 2 mole : 1 mole : 1 mole

0.3 mole : 0.5 mole :

$\therefore$ L.R = $\frac{0.3}{1} = 0.3$ : $\frac{0.5}{2} = 0.25$

$0.3 > 0.25$

$\therefore$ LR = HCl

$\because$ 2 mole —— 1 mole

$\therefore$ 1 mole —— $\frac{1}{2}$ mole

0.5 mole —— $\frac{1}{2} \times 0.5$

$= 0.25$ moles

Q. 85. Find the moles of C produced in the reaction.

$$\overset{}{L.R}\ \boxed{3A} + 5B \longrightarrow 4C$$

15 moles 35 moles

$LR = \frac{15}{3} = 5 < \frac{35}{5} = 7$

∵ 3 mole ——— 4moles

1 mole ——— $\frac{4}{3}$ moles

∴ 15 moles ——— $\frac{4}{3} \times 15 = 4 \times 5$

$= 20$ moles.

86 calculate volume of $NH_3$ at STP. when 100 ml of $N_2$ is mixed with 500 ml of $H_2$

$$\overset{L.R}{\boxed{N_2(g)}} + 3H_2(g) \longrightarrow 2NH_3(g)$$

v-v analysis ] 1V : 3V : 2V

100 ml : 500 ml.

moles ] $\frac{100}{22400} : \frac{500}{22400}$

$\frac{1}{224} < \frac{5}{224}$

∴ LR = $N_2$

∵ 1V ——— 2V

∴ 100 ml ——— 200 ml.

87 Find the mass of HCl produced when 10g of $H_2$ combines with 142 g of Cl.

$$H_2 + \boxed{Cl_2}\ L.R \longrightarrow 2HCl$$

10gm 142gm

moles ] $\frac{10}{2} : \frac{142}{71}$

5mole : 2mole

∴ LR = $\frac{5}{1} > \frac{2}{1}$

1 ~~2~~mole ——— 2 mole

2 mole ——— 4 mole

∴ mass of 4 mole HCl = $4 \times (1+35.5)$

$= 4 \times 36.5 = 146$ gm

Q.88 Find the mass of $H_2O$ produced when 2g of $H_2$ reacts with 8g of $O_2$

$$2H_2 + [O_2]_{L\cdot R} \longrightarrow 2H_2O$$

$$2 : 1 : 2$$

$$2gm \quad 8gm$$

mole] $\frac{2}{2} : \frac{8}{32}$

$$1 \text{ mole} : \frac{1}{4} \text{ mole}$$

$L\cdot R = \frac{1}{2} > \frac{1}{4}$

$\because$ 1 mole —— 2 mole

$\therefore$ $\frac{1}{4}$ mole —— $\frac{1}{4} \times 2 = \frac{1}{2}$ mole

Mass of $\frac{1}{2}$ mole of $H_2O$ $= n \times 18$

$= \frac{1}{2} \times 18 = 9g$

OR

~~Q.89~~ m-M analysis] $\because$ 32 g —— 36 g

1 g —— $\frac{36}{32}$ g

$\therefore$ 8g —— $\frac{36}{32} \times 8 = 9g$

Q.89 Find the final composition of reaction mixture when 30 l of $N_2$ reacts with 30 l of $H_2$

$$N_2 + [3H_2]_{L\cdot R} \longrightarrow 2NH_3$$

$$1 : 3 : 2$$

$$30\,l : 30\,l$$

$\therefore L.R = \frac{30}{1} > \frac{30}{3} = 10$

∵ 3 mole —— 2 mol

3 L —— 2 L

1 L —— $\frac{2}{3}$ L

∴ 30 L —— $\frac{2}{3} \times 30$

= 20 L

∴ For remaining volume : Ininial volume − reactant volume

$$\begin{array}{r} 30\text{ L} \\ -\ 10\text{ L} \\ \hline 20\text{ L} \end{array} \qquad \begin{array}{r} 30\text{ L} \\ 30\text{ L} \\ \hline \end{array}$$

Hence, 20 L of $N_2$ is left unreactant.

Q. 90 Find the mass of $SO_3$ produced when 64 g of $SO_2$ combines with 32 g of $O_2$

$$\text{L.R}\ \boxed{2SO_2} + O_2 \longrightarrow 2SO_3$$

2 : 1 : 2

64 g : 32 g

moles] $\frac{64}{64}$ : $\frac{32}{32}$

1 mole : 1 mole

∴ LR = $\frac{1}{2} < 1$

2 mole —— 2 mole

1 mole —— 1 mole

~~$\frac{1}{2}$ mole~~ —— ~~$\frac{1}{2}$ mole~~

∴ Mass of 1 mole of $SO_3$ = n × [48 + 32]

= 1 × 80

= 80 g

Q.91 calculate the volume of $NH_3$ produced at STP when $3\times10^{23}$ .molecules of $N_2$ combined with 6g of $H_2$

L.R $[N_2] + 3H_2 \longrightarrow 2NH_3$

$1 : 3 : 2$

$3\times10^{23}$ molecules : 6g

moles] $\frac{3\times10^{23}}{6\times10^{23}} : \frac{6}{2}$

$\frac{1}{2}$ mole : 3 mole

$\therefore$ LR $= \frac{1}{2} < \frac{3}{3} = 1$

1 mole ——— 2 mole

$\frac{1}{2}$ mole ——— $\frac{1}{2}\times 2$ mole

$= 1$ mole

$\therefore$ volume of ~~of~~ 1 mole of $NH_3 = n\times22.4\,l$

$= 1\times22.4\,l$

$= 22.4\,l$

Q.92 Calculate the moles of $Ba_3(PO_4)_2$ when 9 moles of $BaCl_2$ reacts with 8 moles of $Na_3PO_4$

L.R $[3BaCl_2] + 2Na_3PO_4 \longrightarrow Ba_3(PO_4)_2 + 6NaCl$

$3 : 2 : 1 : 6$

9 moles : 8 moles

L.R $= \frac{9}{3} = 3 : \frac{8}{2} = 4$

$3 < 4$

3 moles ——— 1 moles

1 mole ——— $\frac{1}{3}$ mole

$\therefore$ 9 mole ———— $\frac{1}{3} \times 9 = 3$ mole

93 40 ml of $SO_2$ reacts with $O_2$ after reaction 80 ml of $O_2$ remained unreactant then calculate original volume of $O_2$

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

2 : 1 : 2

2V : 1V : 2V

(40 ml) : 20 ml

$\because$ ( 2 mole = 40 ml
$\therefore$ 1 mole = 20 ml )

$\therefore$ Initial volume = remaining volume + ~~un~~reactant volume
= 80 ml + 20 ml = 100 ml

94 Find the mass of iron which gives $Fe_3O_4$ on reaction with 18 g of steam

$$3Fe + 4H_2O \longrightarrow Fe_3O_4 \cdot 4H_2$$

3 : 4 : 1

Moles ] $\dfrac{\text{given mass}}{\text{Molar mass}} = \dfrac{18\,g}{18}$

[illegible] 1 mole

$\because$ 3 mole ———— 4 mole

$\frac{3}{4}$ mole ———— 1 mole

$\therefore$ Mass of $\frac{3}{4}$ mole of Fe $= n \times 56$

$= \frac{3}{4} \times 56$

$= 3 \times 14 = 42\,g$

Concentration Terms ( Application of mole concept in solutions)

It represent the amount of solute present in given amount of solvent or solution

Solution : It is a homogenous mixture of two or more non- reacting substances.

* Classification ~~of~~ on the basis of Physical State :

i) Solid solution : Alloys
ii) Liquid solution : Aqueous solution
(eg : $H_2SO_4$ , NaCl etc)
iii) Gaseous solution : Air

Solution : Solute + solvent

* Classification on the basis of number of solute :

i) 2 compound : 1 solute + 1 solvent
(Binary solution)

ii) 3 compound : 2 solute + 1 solvent
(Terhary solution)

Generally, the component which is present in comparatively small amount is called solute and components which are present in larger amount is called solvent

eg: 10 g NaCl (s) + 50 g $H_2O$ (l)
(Solute) ( solvent)

eg: 20 ml of alcohol(l)+ 50 ml of $H_2O$ (l)
( solute) ( solvent)

eg: 60 g sugar (s) + 50 g $H_2O$ (l)
(solute) (Solvent)

- If solutions have more than one physical state of their components, than, physical state of solvent and solution remain same

1 Percentage :

i) Percentage by mass ( by weight) ( % mass) :
It represents mass of solute in gram present in 100 g of solution.

$$\therefore \% \frac{w}{w} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

$$W_{solution} = W_{solute} + W_{solvent}$$

eg: 15 g of urea present in 100 g of solution
∴ Mass of solvent ($H_2O$) = (100 - 15 ) g
= 85 g

eg: x g of solute present in 100 g of solution
∴ mass of solvent ~~($H_2O$)~~ = (100 - x) g

95 Find % by mass of solution when 50 g solute ~~in~~ present in 250 g.

$$\% \text{ by mass} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

$$= \frac{50}{250} \times 100 = 20\%$$

96 Find % by weight when 5g HCl dissolves in 50g $H_2O$

$$\% \text{ by mass} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

$$= \frac{5}{50+5} \times 100$$

$$= \frac{5}{55} \times 100 = 9.1\%$$

ii) Percentage by volume:

- $\% \frac{w}{v}$ = It gives mass of solute present in 100 ml of solution

$$\therefore \% \frac{w}{v} = \frac{\text{Mass of solute (g)}}{\text{volume of solution (ml)}} \times 100$$

97 Find % by volume when 20g of NaCl is present is 500 ml of solution

$$\therefore \% \frac{w}{v} = \frac{\text{Mass of solute (g)}}{\text{volume of solution (ml)}} \times 100$$

$$= \frac{20}{500} \times 100$$

$$= 4\%$$

- $\% \frac{V}{V}$ = It gives volume of solute (ml) present in 100 ml of solution (ml)

$\therefore \% \frac{V}{V} = \frac{\text{volume of solute (ml)}}{\text{volume of solution (ml)}} \times 100$

98 Find % by volume ~~when 50 weight by~~ volume when 50 ml of $C_2H_5OH$ present in 400 ml of $H_2O$

$$\% \frac{V}{V} = \frac{\text{vol}^m \text{ of solute (ml)}}{\text{vol}^m \text{ of solution (ml)}} \times 100$$

$$= \frac{50}{400+50} \times 100$$

$$= \frac{50}{450} \times 100 = \frac{100}{9} = 11.1\ \%$$

2. Mole Fraction (x) :

It is the ratio of no. of moles of one component to total no of moles of all the components present in solution

eg: Let A = solute and B = solvent

$\therefore$ moles of A = $n_A$ and B = $n_B$

$$\therefore X_A = \frac{n_A}{n_A + n_B}$$

$$X_B = \frac{n_B}{n_A + n_B}$$

* Some of ~~all the~~ mole fraction of all the components present in solution is equal to one. $\therefore X_{solute} + X_{solvent} = 1$

$X_1 + X_2 + X_3 \ldots\ldots\ldots\ldots + X_n = 1$

Q.99 If two moles of solute is present in 3 moles of solvent, then find the mole fraction.

$$X_{solute} = \frac{2}{2+3} = \frac{2}{5} \text{ and}$$

$$X_{solvent} = \frac{3}{2+3} = \frac{3}{5}$$

Q-100 In a closed container, 10 g of $H_2$, 56 g of $N_2$ and 4g of He is present, then find mole fraction of each component.

~~$X_{He} = \frac{10}{10+5}$~~

Moles of $H_2 = \frac{10}{2} = 5$ moles,

Moles of $N_2 = \frac{56}{28} = 2$ moles

moles of $He = \frac{4}{4} = 1$ moles

$$\therefore X_{H_2} = \frac{5}{5+2+1} = \frac{5}{8}$$

$$X_{N_2} = \frac{2}{5+2+\cancel{8}1} = \frac{2}{8} = \frac{1}{4}$$

$$X_{He} = \frac{1}{5+2+1} = \frac{1}{8}$$

For verification: sum of mole fraction = 1

$$\frac{5}{8} + \frac{1}{4} + \frac{1}{8} = \frac{5+2+1}{8}$$

$$= \frac{8}{8} = 1 \text{ , Hence, verified.}$$

Mole percent = Mole fraction x 100

$\therefore$ Mole % = $\frac{\text{Moles of component}}{\text{Total moles}} \times 100$

101 100 g of aqueous solution of $C_2H_5OH$ contains 46g of $C_2H_5OH$. calculate mole % of both solute and solvent.

$\because$ 46 g of $C_2H_5OH$ is present in 100 g of aqueous solution.

Moles of solute = $\frac{46}{24+5+16+1} = \frac{46}{46} = 1$ mole

$\therefore$ ~~moles~~ amount of solvent = 100 − 46 = 54 g

$\therefore$ moles of solvent ($H_2O$) = $\frac{56}{18}$ = 3 mole

Mole % of $C_2H_5OH$ = $\frac{1}{1+3} \times 100$

= $\frac{1}{4} \times 100$ = 25%

Mole % of $H_2O$ = $\frac{3}{1+3} \times 100$

= $\frac{3}{4} \times 100$ = 75%

3. Molarity / Molar concentration (M) :

It is defined as no of moles of solute present in 1 L solution.

Unit : Mole/ litre

= $\frac{\text{mol}}{L}$

$$M = \frac{\text{no of moles of solute}}{\text{volume of solution (L)}}$$

eg: 0.5 Mole aqueous solution of $HNO_3$
∴ 0.5 mole $HNO_3$ present in 1 L solution

1.2 Mole solution

Q. 102 If 20 g NaOH is present in 2L of solution then find molarity

$$M = \frac{\text{no of moles of solute}}{\text{volume of solution (L)}}$$

$$= \frac{\frac{20g}{40g}}{2l} = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$$

$$= 0.25 \ M/L$$

Q.103 4.9 gm of $H_2SO_4$ is dissolve in water and volume of solution is melt upto 500 ml, find molarity.

$$M = \frac{\text{no. of moles of solute}}{\text{volume of solution (L)}}$$

$$= \frac{\frac{4.9\,g}{98\,g}}{500 \times 10^{-3}\ L} = \frac{49}{980} \times \frac{10^3}{500}$$

$$= \frac{1}{20} \times 2 = \frac{1}{10}\ M/L$$

Q.104 5.6 gm of KOH is present in 200 ml of solution. Find molarity.

$$M = \frac{\text{no of moles of solute}}{\text{volume of solution (L)}}$$

$$= \frac{\frac{5.6\ g}{56\ g}}{200 \times 10^{-3}\ L} = \frac{56}{560} \times \frac{10^{3}}{200}$$

$$= \frac{1}{10} \times 5 = \frac{1}{2} = 0.5\ M/L$$

* No. of moles of solute = $M \times V(L)$

* No of millimoles = $M \times V(ml)$

Q.105 Find the no. of moles of solute present in 100 ml of 0.1 Molar HCl solution.

$$\because\ M = \frac{\text{no of moles of solute}}{\text{volume of solution (L)}}$$

$$\therefore \text{no of moles} = M \times V(L)$$

$$= 0.1 \times \frac{100}{1000}$$

$$= \frac{1}{10} \times \frac{100}{1000} = \frac{1}{100} = 0.01\ M/L$$

Q.106 How many moles and gram of Nacl are present in 250 ml of 0.5 Molar of Nacl solution

$$\text{no of moles} = M \times V(L)$$

$$= 0.5 \times \frac{250}{1000}$$

$$= \frac{5}{10} \times \frac{1}{4} = \frac{1}{8}$$

$$= 0.125\ \text{moles}$$

$\because \quad n = \frac{w}{M} \quad \therefore \quad w = n \times M.$

$= 0.125 \times 58.5$

$= 7.3g$

Q.107 How many grams of NaOH should be dissolved to make 100 ml of 0.15 Molar NaOH solution

no of Moles = M x V(L)

$= 0.15 \times \frac{100}{1000}$

$= \frac{15}{100} \times \frac{1}{10} = \frac{3}{200}$ moles

$\because \; n = \frac{w}{M} \quad \therefore \; w = n \times M$

$= \frac{3}{200} \times (23+16+1)$

$= \frac{3}{200} \times 40 = 0.6g$

Q.108 4g of caustic soda present in 100 cc solution Find Molarity

caustic soda : NaOH

no of Moles = M x V(L)

$\therefore \quad M = \frac{\text{no. of Moles}}{\text{volume (L)}}$

$= \frac{\frac{4g}{40g}}{100 \times 10^{-3} L}$

$= \frac{1000}{10 \times 100} = 1$

Q.109 40% w/V NaOH solution.

∵ 40 g NaOH is present in 100 ml.

$$\therefore M = \frac{\text{no of moles of solute}}{\text{volume of solution (L)}}$$

$$= \frac{\frac{40\,g}{40\,g}}{100 \times 10^{-3}\,L} = \frac{1 \times 10^{3}}{100}$$

$$= \frac{1000}{100} = 10$$

Q.110 Find molarity when ~~5.6 0~~ 5.6% w/v KOH solution

∴ 5.6 g of ~~10~~ KOH is present in 100 ml

$$\therefore M = \frac{\text{no of moles of solute}}{\text{volume of solution (L)}}$$

$$= \frac{\frac{5.6\,g}{56\,g}}{100 \times 10^{-3}} = \frac{56}{560} \times \frac{10^{3}}{100}$$

$$= \frac{1}{10} \times 10 = 1$$

4. Molality / Molal concentration (m)

It is defined as no. of moles of solute present in 1 kg (1000 g) **solvent**

unit : $\frac{\text{moles}}{\text{kg}}$

$$m = \frac{\text{no. of moles of solute}}{\text{mass of solvent (kg)}}$$

* $m = \frac{W_{solute}}{M_w} \times \frac{1}{W_{solvent}}$

eg: 0.2 m aqueous solution $C_6H_6$
∴ 0.2 mole of solute present in 1 kg of solvent.

Q.111 5.8 g of NaCl is present in 500 g of $H_2O$. Find molality

$$\because m = \frac{\text{no. of moles of solute}}{\text{Mass of solvent (Kg)}}$$

$$= \frac{\frac{5.85g}{58.5g}}{500 \times 10^{-3} \text{ kg}}$$

$$= \frac{10^3}{10 \times 500} = \frac{1}{5} = 0.2 \text{ moles/kg}$$

Q.112 98 g of $H_2SO_4$ is present in 198 g of its aqueous solution. calculate molality

$$m = \frac{\text{no of moles of solute}}{\text{Mass of solvent (kg)}}$$

$$= \frac{\frac{98g}{98g}}{100 \, \cancel{198} \times 10^{-3}} \qquad \frac{1 \times 10^3}{100}$$

( ∵ Mass of solution = 198 g
∴ Mass of solvent = 198 g − 98 g = 100 g )

$$= \frac{1000}{100} = 10 \text{ moles/ kg}$$

Q.113 250 g $CaCO_3$ is present in 1000 g of its aqueous solution. calculate molality

$$m = \frac{\text{no of moles of solute}}{\text{mass of the solvent (kg)}}$$

Mass of solvent = Mass of solution - mass of solute

∴ Mass of solvent = 1000g - 250g = 750g

$$= \frac{\frac{250\,g}{100\,g}}{750 \times 10^{-3}\,kg} = \frac{2.5 \times 1000}{750}$$

$$= \frac{25}{7500} \times 1000 = \frac{10}{3} = 3.33 \text{ moles/kg}$$

Q.114 10g NaOH is dissolved in 500 g of water. Find molality

$$m = \frac{\text{no. of moles of solute}}{\text{mass } \sout{\text{volume}} \text{ of solvent (kg)}}$$

$$= \frac{\frac{10g}{40g}}{500 \times 10^{-3}\,kg} = \frac{1}{4} \times \frac{1000}{500}$$

$$= \frac{2}{4} = \frac{1}{2} = 0.5 \text{ moles/kg}$$

Q.115 Find molality of 40% w/w NaOH solution

∴ 40 g of NaOH is present in 100 g solution.

Mass of solvent = Mass of solution - Mass of solute

= 100g - 40g = 60g

$$\therefore m = \frac{\text{no of } \sout{\text{sol}} \text{ moles of solute}}{\text{mass of the solvent (kg)}}$$

$$= \frac{\frac{40g}{40g}}{60 \times 10^{-3}\,kg} = \frac{1000}{60} = 16.67 \frac{\text{moles}}{\text{kg}}$$

5. Parts per million (PPM):

It represents parts of solute present in 1 million ($10^6$) by part solution.

OR

Mass of solute in gram present in 1 million ($10^6$) gram solution.

$$PPM = \frac{\text{Mass of solute (g)} \times 10^6}{\text{Mass of solution (g) / (solvent)}}$$

∴ Mass of solution ≃ Mass of solvent.

It is generally used for the concentration of very dilute solution like air pollution, hardness of water.

eg: 10g of $CaCO_3$ present in 5000 g of $H_2O$

$$= \frac{10}{5000} \times 10^6$$

$$= 2 \times 10^3 = 2000 \text{ ppm}$$

Q.116 Find the concentration in ppm by 40% w/w solution.

∴ 40 g of solute present in 100 g solution

$$= \frac{40 g}{100 g} \times 10^6$$

$$= 4 \times 10^5$$

✳ $PPM = \% \frac{w}{w} \times 10^4$

Q.117 60 g of $H_2SO_4$ is dissolved in water and volume of solution is ~~2 L~~ $\overset{500\,ml}{\wedge}$ and density of solution 1.2 g/ml. Find:

- % w/v
- % w/w

$\because$ density = $\frac{\text{Mass}}{\text{vol}^m}$

$\therefore$ M = $\rho V$

= 1.2 × 500 = 600 g

$\therefore$ % w/v = $\frac{\text{Mass of solute (g)}}{\text{volume of solution (ml)}} \times 100$

= $\frac{60}{500} \times 100$

= 12%

$\therefore$ % w/w = $\frac{\text{mass of solute (g)}}{\text{Mass of solution (g)}} \times 100$

= $\frac{60}{600} \times 100$ = 10%

~~Law of~~

* Temperature dependent:

- % by volume
- Molarity (M)
- Normality (N)

It is due to change in volume because of temperature.

* Temperature Independent:

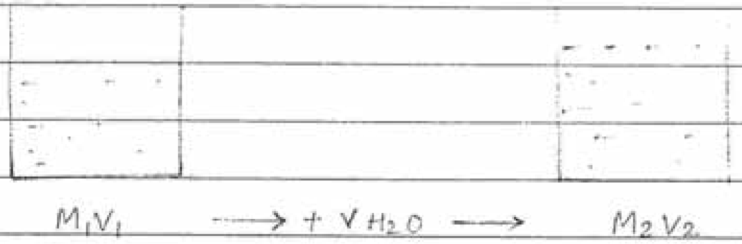
- Mole fraction (X)
- Molality (m)
- PPM

It is because mole doesn't change with time

## Law of Dilution :

~~It~~ Dilution means addition of solvent (~~H2~~ usually $H_2O$ (water)

- In the dilution, no of moles of solute remain unchanged because only solvent is added.



- Before dilution,
  $n_{solute} = M_1V_1$

- After dilution,
  $n_{solute} = M_2V_2$
  where $V_2 = V + V_1$

$\therefore$ Molarity equation : $M_1V_1 = M_2V_2$

$$\therefore M_2 = \frac{M_1V_1}{V_2}$$

$$M_{final} = \frac{\text{no. of moles of solute}}{\text{Total volume of solution}}$$

eg : 5 mole of $H_2SO_4$ in 2 L + 8L of $H_2O$

$$\because M_2 = \frac{M_1V_1}{V_2}$$

$$= \frac{5 \times 2}{2+8} = \frac{10}{10} = 1 \text{ mole}$$

118 200 ml ~~of~~ solution of HCl of 1 molarity is diluted and final molarity becomes 0.5 moles, then find volume of $H_2O$ added.

$$\because V_2 = \frac{M_1 V_1}{M_2}$$

$$= \frac{1 \times 200}{0.5} = 400 \text{ ml}$$

$$\therefore \text{volume of } H_2O = V_2 - V_1$$

$$= 400 \text{ ml} - 200 \text{ ml} = 200 \text{ ml}$$

119 Find the resultant molarity of solution if in 200 ml of 1 molarity (M) HCl in 800 ml of $H_2O$

$$\because M_2 = \frac{M_1 V_1}{V_2}$$

$$= \frac{1 \times 200}{800} = \frac{1}{4}$$

120 calculate the molarity of 2M solution if it is diluated to 100 times.

$$\because M_2 = \frac{M_1 V_1}{V_2}$$

$$= \frac{2 \times V}{100 V} = 0.02$$

* Molarity ~~is~~ $\propto \frac{1}{\text{Volume}}$

It means when volume increases therefore molarity decreases.

Q.121 Calculate the volume of water required to make centimolar (M/100) solution from 100 ml of semimolar (M/2) solution

$$\because \quad V_2 = \frac{M_1V_1}{M_2}$$

$$= \frac{\frac{M}{2} \times 100}{\frac{M}{100}} = 5000 \text{ ml}$$

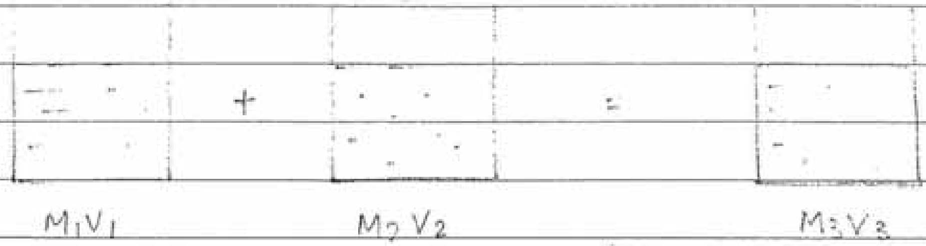
$$\therefore \text{ Volume of } H_2O = V_2 - V_1$$

$$= (5000 - 100) \text{ ml}$$

$$= 4900 \text{ ml}$$

## Molarity for mixture of solutions :

Case I : Mixing of same type of solution (Non - reacting).

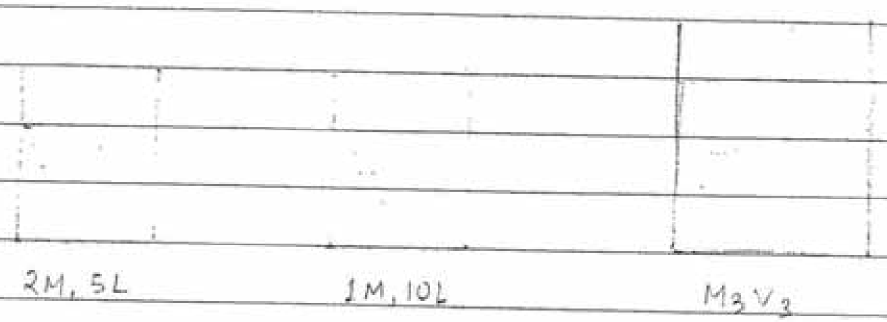


$$\therefore M_1V_1 + M_2V_2 = M_3V_3$$

$M_3V_3$ is final moles of solute.

$$\therefore M_3 = \frac{M_1V_1 + M_2V_2}{V_1 + V_2} \quad \text{(final molarity)}$$

$\therefore$ ~~Rea~~ Resultant molarity = $\frac{\text{Total moles of solute}}{\text{Total vol}^m \text{ of solution}}$



$$\therefore M_3 = \frac{M_1V_1 + M_2V_2}{V_1 + V_2}$$

$$= \frac{2\times5 + 1\times10}{5+10}$$

$$= \frac{10+10}{15} = \frac{4}{3}$$

.122 200ml of 0.1 M of NaOH is mixed with 800 ml of 0.5 M of NaOH. Find $M_f$

$$\therefore M_f = \frac{M_1V_1 + M_2V_2}{V_1+V_2}$$

$$= \frac{\cancel{200\times} 200\times0.1 + 800\times0.5}{200+800}$$

$$= \frac{20+400}{1000} = \frac{420}{1000} = 0.42\ M$$

Molarity of ions :

~~(solid acid~~

(strong acid, strong base and salts)

eg: 0.5 M $H_2SO_4$ solution $[H^+] = M$

$$\because H_2SO_4(aq) \longrightarrow 2H^+ + SO_4^{-2}$$

1 : 2 : 1

0.5 M = 0.5×2 and 0.5 M

= 1 M

Q.123 Find the molarity of ions of $Ba(OH)_2$ of 0.2 M

$\because$ $Ba(OH)_2 \longrightarrow Ba^{2+} + 2OH^-$

[illegible] : 1 : 2

0.2 [illegible] $0.2\ M$ $= 0.2 \times 2$

$= 0.4\ M$

Q.124 Find the Molarity of ions of $Al_2(SO_4)_3$ of 1.5 M

$\because$ $Al_2(SO_4)_3 \longrightarrow 2Al^{+3} +$ ~~or~~ $3SO_4^{-2}$

: 2 : 3

$= 2 \times 1.5$ : $= 3 \times 1.5$

$= 3\ M$ and $4.5\ M$

## Case II : Mixing of reacting solution

eg: $HCl + NaOH \longrightarrow NaCl$

$\begin{pmatrix} 1M \\ 50\ ml \end{pmatrix}$ $\begin{pmatrix} 1M \\ 50\ ml \end{pmatrix}$ 100 ml

$\therefore$ Molarity = 1 M

Millimoles: $1 \times 50$ + $1 \times 50$ = 50 mmoles

= 50 mmoles =50 mmoles

where mmoles = millimoles

eg: $M_1$ (molarity of NaCl) = $\dfrac{\text{moles of solute}}{\text{Total volume of solution}}$

$= \dfrac{50\ mMoles}{100\ ml} = \dfrac{1}{2}\ M$

OR

$\dfrac{0.05\ moles}{0.1} = \dfrac{1}{2}\ M.$

$\therefore$ (Molarity) final i.e. $M_f = \dfrac{\text{Moles of solute}}{\text{Total volume}}$