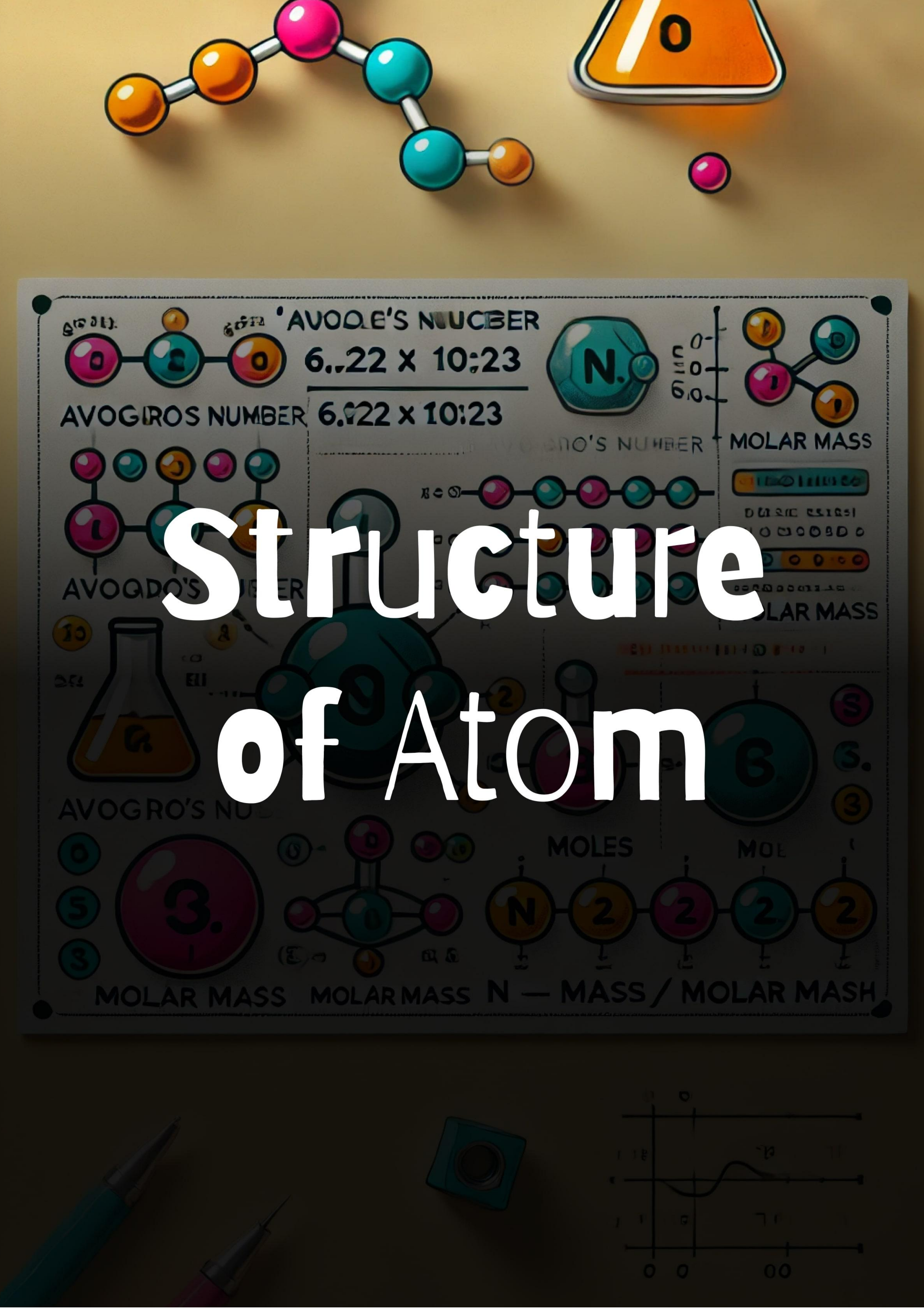
Structure of Atom



Structure of Atom

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1. Atomic number (z) — Tells about $e^{\ominus}$ or No. of p
2. Mass number (A) — Tells about No. of n + p in a nucleus.

Represent = $^{A}_{Z}X$ No. of neutrons = A − Z

3. Isobars — same atomic number but diff mass number.
4. Isobars — same mass number but diff atomic number.
5. Istones — A & Z = diff but same no. of neutrons.
6. Isoelectronic — species having same no. of electrons.
7. Isodiaphers — A & Z = diff but same $\underbrace{n-p}_{\text{Isotopic number}}$.
8. Isosters — species have same no. of atoms and electrons.

(R) • Electromagnetic waves / Nature of light ⟶ Plancks quantum Theory.

1. Energy transmitted from one body to another body in the form of waves move with speed of light.
2. This waves consist of both EF and MF, which is perpendicula[r] to each other called EMR.
3. EMR or Radiant energy — Don't required medium, can travel in vaccum also.
4. Radiant energy can transfer without medium coming through waves called EMR.

Waves / Radiation
- ↓ Mechanical (medium required) ↓ Sound waves
- ↓ Non-Mechanical (medium not required) ↓ EMR

- Characteristics of waves:

① Wave length (λ) : Distance b/w two crest or Trough.
② Frequency (ν) : The no. of waves which passed through a point in 1 sec.
③ Wave number ($\bar{\nu}$) : The no. of waves spread in a unit length
④ Amplitude : The height of crest or depth of Trough.

• Electromagnetic spectrum:

- The arrangement of various EM values with same velocity called EMS. — Incre: order of wavelength / Decr. order of frequency

(L) ⟶ Wavelength value Increases ⟶ (R)

Cosmic Rays	λ rays	X Rays	UV rays	Visible rays	IR Rays	Micro waves	Radio Waves	T.V waves

$\boxed{\text{V I B G Y O R}}$

(L) ⟶ E, ν, $\bar{\nu}$ values also decreases ⟶ (R)

- Black Body – Perfect absorber and perfect emitter.

• Plank's Quantum theory:

① Black Body emitted or absorbed EMR or Radiant energy
a) discontinuosly.
b) In the form of small packets called quanta.
c) which is propagated in the form of waves.

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Note: If energy source is light → called photon.

② Energy of each small pocket [quantum] ∝ frequency.

$E \propto \nu$

$E = h\nu$

$E = nh\nu$

n = No. of quanta / photons.

n = No. of small energy packets.

↓

So energy emitted or absorbed from one body to another is integral multiple of $h\nu$

i.e $E_{ab/emi} = h\nu, 2h\nu, 3h\nu, 4h\nu \ldots$

- Notes: (According to NCERT)

① Absorption or emission of Radiation due to oscillation or vibration of charge particles in the walls of black body.

② $E, \nu, \bar{\nu}$ and λ values are changed / different for different EMR.

③ Plank suggest that atoms and molecules emit/ab radiation discontinuously in a small packets [quanta].

Note: wavelength of emitted radiation depends on its temp.

Instensity = No. of photons / quanta.

- At a given temp,

① Intensity of emitted radiation increases with increase wavelength, Reached maximum level and then decreases.

② If temp increases, maxima of curve shifts to lower wavelength side.

$$\frac{E_1}{E_2} = \frac{\nu_1}{\nu_2} = \frac{\bar{\nu}_1}{\bar{\nu}_2} = \frac{\lambda_2}{\lambda_1}$$

$\boxed{E = h\nu} \longrightarrow \boxed{E = \frac{hc}{\lambda}} \longrightarrow \boxed{E = hc\bar{\nu}}$

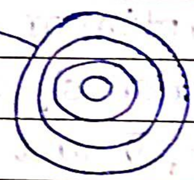
$\left[\nu = \frac{c}{\lambda}\right]$ $\left[\bar{\nu} = \frac{1}{\lambda}\right]$

$E \propto \nu$ $E \propto \frac{1}{\lambda}$ $E \propto \bar{\nu}$

	E/K.E/T.E	h	λ	$\bar{\nu}$	c
SI	J	[redacted] 6.62×10^{-34} J	m	m^{-1}	3×10^{8} m/sec
CGS	Erg	6.62×10^{-27} erg	cm	cm^{-1}	3×10^{10} cm/sec

- Bohr's atomic model :

① orbits / shells / main energy level / stationary level.



$n=1$ / $n=K$ $\longrightarrow$ 1st shell

$n=2$ / $n=L$ $\longrightarrow$ 2nd shell

$n=3$ / $n=M$ $\longrightarrow$ 3rd shell.

$\Delta E = E_2 - E_1 = nh\nu \longrightarrow$ Energy photon / packet / quanta

② Angular momentum $(mvr) = \frac{nh}{2\pi}$

AM of electrons in 1st shell $= \frac{1h}{2\pi}$ or $\frac{0.5h}{\pi}$

$\frac{h}{2\pi}$ / $\frac{0.5h}{2\pi}$ 2nd shell $= \frac{2h}{2\pi}$ or $\frac{1h}{\pi}$

3rd shell $= \frac{3h}{2\pi}$ or $\frac{1.5h}{\pi}$

4th shell $= \frac{4h}{2\pi}$ or $\frac{2h}{\pi}$

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③ Radius of an orbit : $r_n = \frac{n^2h^2}{4\pi^2 me^2}$

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

- $r_n = 5.29 \times \frac{n^2}{Z}$ nm

$\boxed{r_n = 0.53 \times \frac{n^2}{Z} \text{ A°}}$

④ Energy of an electron : T.E = KE + PE

$E_n = -\frac{2\pi^2 me^4}{n^2h^2}$ $KE = \frac{e^2}{2r}$ $PE = -\frac{e^2}{r}$ $TE = -\frac{e^2}{2r}$

KE = −TE $m = 9.1 \times 10^{-31}$ kg

PE = 2 TE $h = 6.62 \times 10^{-34}$ J

★ ① $E_n = -\frac{2.18 \times 10^{-18}}{n^2} \times Z^2$ J/atom

② $E_n = -\frac{2.18 \times 10^{-11}}{n^2} \times Z^2$ erg/atom

③ $E_n = -\frac{1312}{n^2} \times Z^2$ KJ/mole.

★ ④ $E_n = -\frac{13.6}{n^2} \times Z^2$ eV/atom.

⑤ $E_n = -\frac{313.6}{n^2} \times Z^2$ kcal/mole.

- Energy difference Between two shells

$\Delta E = 2 \times 10^{-18} \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] Z^2$ J

$\Delta E = 13.6 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] Z^2$ eV

①	n = 1	−13.6 eV	④	n = 4	−0.85 eV
②	n = 2	−3.4 eV	⑤	n = 5	−0.53 eV
③	n = 3	−1.51 eV	⑥	n = 6	−0.38 eV.

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- Hydrogen spectrum:

① H_2 gas kept in a discharge tube apply high voltage 10,000 V and low temp and pressure (0.01 atm).
② Radiation coming (energy released)
③ Some energy used to become H_2 molecules to H-atoms.
④ Remaining energy absorbed by electrons in H.

- Note:

① All electrons can't absorb same energy.
② electrons absorb energy and jump to diff excited states but at excited state electrons are unstable so they return to ground state in a single step or multiple steps.

Series	Region	n_1	
Lyman	UV	1	1st line — $H\alpha$
Balmer	visible	2	2nd line — $H\beta$
Paschen	Near IR	3	3rd line — $H\gamma$
Brackett	IR	4	4th line — $H\delta$
Pfund	Far IR	5	∞th line — Limiting line of series.

- Rydberg's eq: $\bar{\nu} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] Z^2$

$R = 109678\ cm^{-1}$
$R = 1.1 \times 10^5\ cm^{-1}$
$R = 1.1 \times 10^7\ m^{-1}$

- <u>Trick</u>: No. of spectral lines : $\Sigma n = \Sigma n_2 - n_1$

- λ longest = λ maxi = λ High $\Rightarrow$ E mini ν mini $\bar{\nu}$ mini
λ shortest = λ mini = λ Low $\Rightarrow$ E max ν max $\bar{\nu}$ max

- Maximum energy — Minimum energy

Maximum energy	Minimum energy
$n_1 = 1 \longrightarrow n_2 = \infty$	$n_1 = 1 \longrightarrow n_2 = 2$
$n_2 = 2 \longrightarrow n_2 = \infty$	$n_1 = 2 \longrightarrow n_2 = 3$
$n_1 = 3 \longrightarrow n_2 = \infty$	$n_1 = 3 \longrightarrow n_2 = 4$

- Notes :

① P.q.n $\longrightarrow$ AM of an $e^{\ominus}$ $mvr = nh/2\pi$
A.q.n $\longrightarrow$ AM of an orbital $mvr = \sqrt{l(l+1)}\,\frac{h}{2\pi}$

② Maximum no. of electrons in a shell = $2n^2$

③ $l = 0 \longrightarrow$ s-subshell (spherically symmetrical)
$l = 1 \longrightarrow$ p-subshell (Dumb-bell)
$l = 2 \longrightarrow$ d-subshell (Double dumb-bell)
$l = 3 \longrightarrow$ f-subshell (complex)

④ No. of subshells in a shell = n. — $n \rightarrow$ size of orbit

⑤ l values from 0 to $(n-1)$ — $l \rightarrow$ shape of subshell
$n = 1 \longrightarrow l = 0 \longrightarrow$ 1s
$n = 2 \longrightarrow l = 0, 1 \longrightarrow$ 2s, 2p
$n = 3 \longrightarrow l = 0, 1, 2 \longrightarrow$ 3s, 3p, 3d.
$n = 4 \longrightarrow l = 0, 1, 2, 3 \longrightarrow$ 4s, 4p, 4d, 4f

⑥ No. of orbitals in a subshell = $(2l+1)$ $\longrightarrow$ s = 1 ($2e^{\ominus}$)

⑦ No of orbitals in a shell = n^2. — p = 3 ($6e^{\ominus}$)

⑧ m values = $-l$ ---- 0 ---- $+l$ — d = 5 ($10e^{\ominus}$)
$l = 0 \longrightarrow m = 0$ — f = 7 ($14e^{\ominus}$)
$l = 1 \longrightarrow m = -1, 0, +1$
$l = 2 \longrightarrow m = -2, -1, 0, +1, +2$
$l = 3 \longrightarrow m = -3, -2, -1, 0, +1, +2, +3$

$s\,(l=0) \longrightarrow m = 0$

$p\,(l=1) \longrightarrow$ p_x p_y p_z
-1 +1 0

$d\,(l=2) \longrightarrow$ $d_{x^2-y^2}$ d_{z^2}
+2 0

$d\,(l=2) \longrightarrow$ d_{xy} d_{yz} d_{zx}
-2 -1 +1

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- Trick: 1s → 2s
2p 3s → 3p 4s
3d 4p 5s → 4d 5p 6s
4f 5d 6p 7s → 5f 6d 7p 8s

I. AfBau – electrons must enter into lower energy – Higher energy.
- Energy of orbitals calculate by $(n+l)$ value.

① Lower $(n+l)$ value – lower energy
② Higher $(n+l)$ value – Higher energy
③ If $(n+l)$ value is same — lower n value — lower energy
Higher n value – Higher energy.

II. Hund's rule: In de-generated orbitals, orbitals first filled with single $e^{\ominus}$ with same spin and then pairing will takes place.

III. Pauli's Exclusion principle: Each orbital filled with 2 electrons with opposite spin. These $2e^{\ominus}$ have different 4 quantum number.

- According to hund's rule, Half-filled or Full-filled degenerated orbitals are stable.
p^3/p^6 d^5/d^{10} f^7/f^{14}

- According to A, H, P rules, anamalous E.C of Cr and Cu

Cr [Z = 24] ⟶ (Ar) $4s^1 3d^5$
Cu [Z = 29] ⟶ (Ar) $4s^1 3d^{10}$

- Orbital - where maximum propobility of finding electrons (95%)

Node - The point where P.F $e^{\ominus} = 0$ [n-1]

Spherical / Radial node : The spherical space around nucleus where P.F. $e^{\ominus} = 0$ [n-l-1].

Angular node / nodal plane : The plane where P.F $e^{\ominus} = 0$ [l]

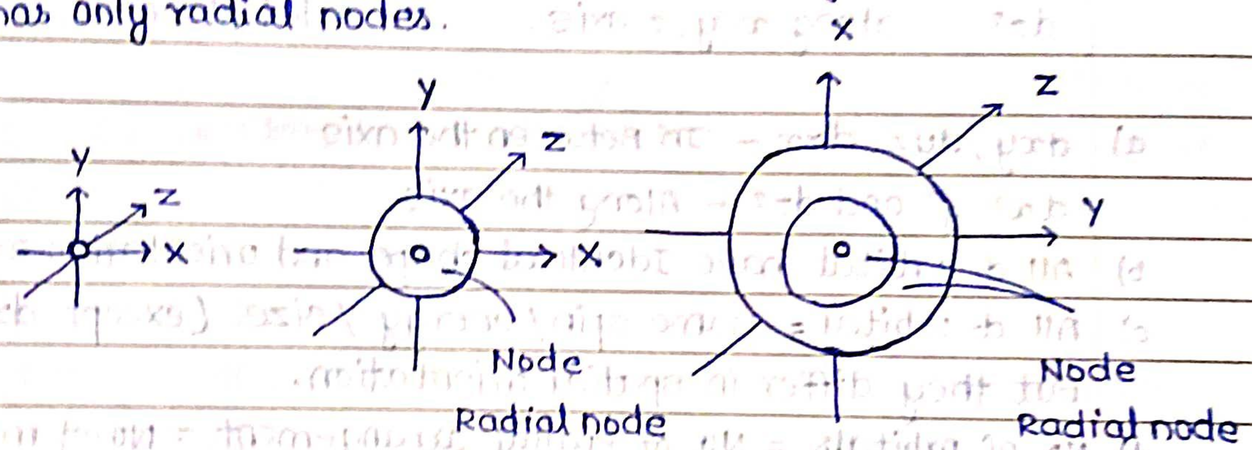
- s-orbital

① For s-orbitals $l = 0$ $n = 1, 2, 3, 4, \ldots$ $m = 0$

② s-orbital = spherically symmetrical and non-directional

③ P.F $e^{\ominus}$ symmetrically distributed along x, y, z-axis.

④ It has only radial nodes.



- P-orbital :

① For p-orbital $l = 1$, $n = 2, 3, 4 \ldots$ $m = -1, 0, +1$

② P-orbital = dumb-bell shape / Directional nature.

③

Orbital	Maximum $e^{\ominus}$ density	Nodal plane
Px	x-axis	yz
Py	y-axis	xz
Pz	z-axis	xy

④ 2Px, 2Py, 2Pz orbitals ⟶ same shape, same size, same energy, same spin } differ in spatial arrangement.

⑤ No. of orbitals = No. of spatial arrangement = no. of m values = 3

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- d-orbitals:

① For d-orbitals $l = 2$ $n = 3, 4, 5$ $m = -2, -1, 0, +1, +2$
② Each d-subshell having 5 degenerated orbitals.
③ Each d-orbital = 4 lobes / double dumb-bell except dz^2

Orbital	Maximum PF electrons	Nodal planes
d_{xy}	45° to x and y axis	xy, yz
d_{yz}	45° to y and z axis.	xy, xz
d_{xz}	45° to x and z axis	xy, zy
$d_{x^2-y^2}$	Along x and y axis	xz, yz
d_{z^2}	along x, y, z axis.	No nodal plane

a) d_{xy}, d_{yz}, d_{zx} – In Between the axis
$d_{x^2-y^2}$ and d_{z^2} – Along the axis.
b) All d-orbital have Identical shape and orientation except dz^2
c) All d-orbital = same spin / energy / size (except dz^2)
But they differ in spatial orientation.
d) No. of orbitals = No. of spatial arrangement = No. of m values = 5

- De-Broglie's wave nature concept:

① Like EMR, All micro or macroscopic particles also having dual nature
② Means just like photons → microscopic particle also having wave and particle nature.
③ The wave associated with particle called De-Broglie's wave or matter waves.
④ Every object in motion have wave nature — observed / seen in microscopic particles
— Not seen in macroscopic particles

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⑤ Any moving matter particles has λ and $P \rightarrow \lambda = \frac{h}{P}$

$\downarrow P = mV$

$\lambda_{de} \propto \frac{1}{m \text{ and } v} \longleftarrow \lambda_{de} = \frac{h}{mv}$

- $\lambda = \frac{h}{P}$ $\quad \lambda = \frac{h}{mv}$ $\quad$ • $V = \sqrt{\frac{2KE}{m}}$

$\frac{\lambda_1}{\lambda_2} = \frac{m_2 V_2}{m_1 V_1}$ $\quad \lambda = \frac{h}{\sqrt{2m K \cdot E}}$

- $\lambda = \frac{h}{\sqrt{2meV}}$ $\quad \lambda \propto \frac{1}{\sqrt{KE}}$ $\quad \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{m_2 \cdot KE_2}{m_1 \cdot KE_1}}$

(I) For $e^{\ominus} = \lambda = \frac{12.26}{\sqrt{V}} A^{\circ}$

(II) For $p = \lambda = \frac{0.286}{\sqrt{V}} A^{\circ}$

(III) For $\alpha = \lambda = \frac{0.101}{\sqrt{V}} A^{\circ}$

- Constructive Interference

$2\pi r = n\lambda$

Destructive Interference

$2\pi r \neq n\lambda$

- No. of waves made by the $e^{\ominus}$ in a shell $= n$.

- Heisenberg Uncertainty principle:

① It is impossible to determine both position and momentum of $e^{\ominus}$ simultaneously and accurately.

② H.U.P — Rules out existance of definite path / Trajectories of $e^{\ominus}$ and other similar particles.

③ H.U.P — Only meant for microscopic particles like $e^{\ominus}, p, n, \alpha$..

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$$\Delta x \cdot \Delta p \geq \frac{h}{4\pi} \qquad \frac{h}{4\pi} = 0.52 \times 10^{-34}\ J$$
$$0.52 \times 10^{-27}\ erg$$

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

$$\Delta x \cdot m \Delta v = \frac{h}{4\pi} \rightarrow \frac{\Delta x_1 \cdot m_1 \Delta v_1}{\Delta x_2 \cdot m_2 \Delta v_2} = \frac{1}{1}$$

$$\frac{\Delta x_1}{\Delta x_2} = \frac{m_2 \Delta v_2}{m_1 \Delta v_1}$$

$$\frac{\Delta v_1}{\Delta v_2} = \frac{m_2 \Delta x_2}{m_1 \Delta x_1}$$

① Δx = Uncertainty in position

Δx = radius × error / accuracy.

② Δv = Uncertainty in velocity

Δv = Actual velocity × error / accuracy

• Note : $\Delta x \cdot \Delta p = \frac{h}{4\pi}$

If $\Delta x = \Delta p$

$$(\Delta x)^2 = \frac{h}{4\pi}$$

$$\Delta x = \sqrt{\frac{h}{4\pi}}$$

$$\Delta x = \frac{1}{2}\sqrt{\frac{h}{\pi}}$$

$$\Delta p = \frac{1}{2}\sqrt{\frac{h}{\pi}}$$

$$(\Delta p)^2 = \frac{h}{4\pi}$$

$$(m\Delta v)^2 = \frac{h}{4\pi}$$

$$\Delta v^2 = \frac{h}{4\pi m^2}$$

$$\Delta v = \sqrt{\frac{h}{4 \cdot m^2 \cdot \pi}}$$

$$\Delta v = \frac{1}{2m}\sqrt{\frac{h}{\pi}}$$