

Atomic Structure

→ specific charge = charge/mass

→ s.c. of $e^- = 1.76 \times 10^{11} C/kg$.

→ Order of specific charge:
neutron < α -particle < proton < e^-

→ Radius of nucleus = $10^{-13} cm$ or $10^{-15} m$

$$r_{\text{nucleus}} = 10^{-8} cm = 10^{-10} m$$

$$\rightarrow r_{\text{nucleus}} = r_0 \propto A^{1/3}$$

↓ ↓
const. mass no.

$$r_0 = 1.33 \times 10^{-13} cm$$

$$\{ r_0 = (1.1 - 1.44) \times 10^{-13} cm \}$$

$$\rightarrow Q_T = n e ; \quad n = \text{no. of charge particle}$$

$e = \text{electronic charge}$

$$Q_T = \text{Total charge}$$

$$\rightarrow \text{Mass of } e^- = 9.1 \times 10^{-31} kg$$

$$\text{Mass of } p^+ = 1.67 \times 10^{-27} kg$$

$$\text{charge of } e^- = -1.6 \times 10^{-19} C$$

$$\text{charge of } p^+ = +1.6 \times 10^{-19} C$$

$$\rightarrow 1 C \rightarrow 6.25 \times 10^{18} e^-$$

$$\rightarrow F = \frac{k q_1 q_2}{r^2}, \quad k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 Nm^2/C^2$$

$$\rightarrow P.E = \frac{k q_1 q_2}{r} \quad \{ \text{put } q_1, q_2 \text{ with sign} \}$$

$$\rightarrow W \text{ or } E = F \cdot d = k q_1 q_2 \cdot r$$

$$\rightarrow PE = q \times V$$

$$\checkmark R \text{ or } R_{\text{closest}} = \frac{4kze^2}{mg \cdot Vq^2}$$

$$\rightarrow R_{\text{closest of } Z} ; R_{\text{closest of } \frac{1}{Vq^2}}$$

$$\rightarrow \overline{\nu} = \frac{1}{\lambda} ; \overline{\nu} = \text{wave no.}$$

$\lambda = \text{wavelength}$

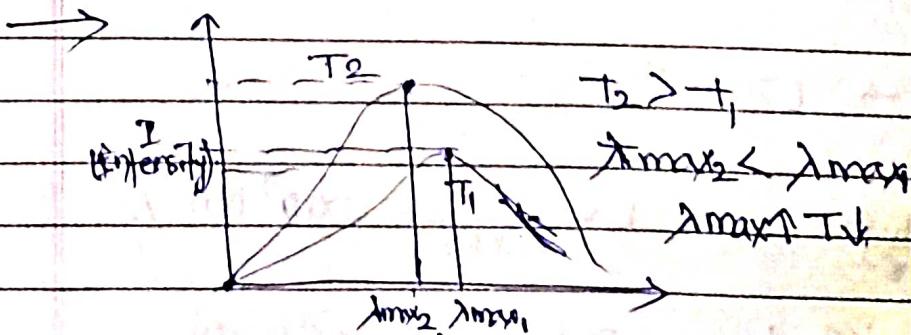
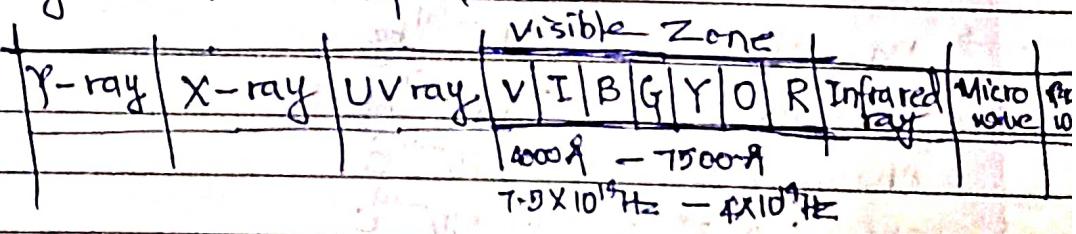
\rightarrow Velocity of all EMR is equal to velocity of light
 $(3 \times 10^8 \text{ m/s})$

\rightarrow for $\nu = \frac{1}{T}$; for $\nu = \text{frequency}$
 $T = \text{Time period}$

$$\rightarrow c = \frac{\lambda}{T}$$

$$\therefore c = \nu \lambda$$

\rightarrow Figure of EMR spectrum :-



\rightarrow particle theory.

$$E = h\nu = \frac{hc}{\lambda}$$

$$\rightarrow E_1 = nh\nu = n\lambda c \quad ; \quad n = \text{no. of photon},$$

$h = \text{Planck's constant} = 6.62 \times 10^{-34} \text{ J}$

$$\rightarrow E_1 = \frac{\lambda_1}{\lambda_2}$$

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

$$\rightarrow E = E_1 + E_2$$

$$\frac{1}{\lambda} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

$$\rightarrow 1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

$$\rightarrow h c = 12400 \text{ eV A}$$

~~Red (1.65 eV) - Violet (3.1 eV)~~

$$\rightarrow h\nu = h\nu_0 + K \cdot E_{\max}$$

$$\frac{hc}{\lambda} = W_0 \text{ or } \phi + K \cdot E_{\max}$$

} $h\nu$ or hc - Energy of incident light
 ν_0 or W_0 or ϕ → threshold
 $K \cdot E_{\max}$ → Max. K.E. of emitted e^- or work function of metal

\rightarrow for PEE

$$h\nu \geq h\nu_0 \text{ or } hc \geq hc_0 \text{ or } \nu \geq \nu_0$$

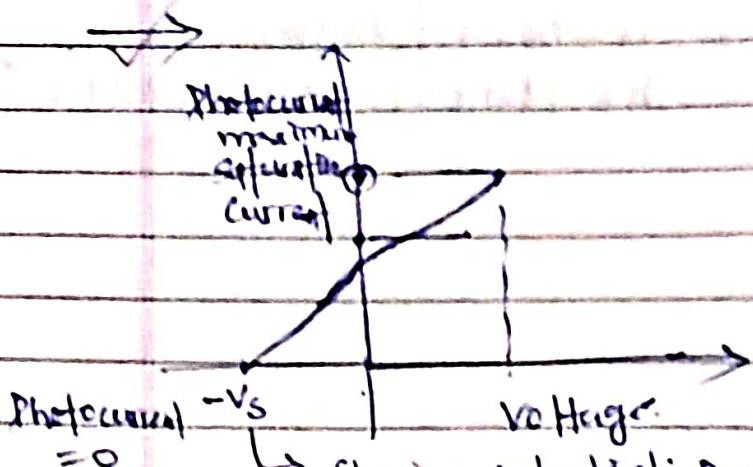
$$h\nu_0 \text{ or } hc_0$$

ν_0 or λ_0 are respectively threshold frequency or wavelength

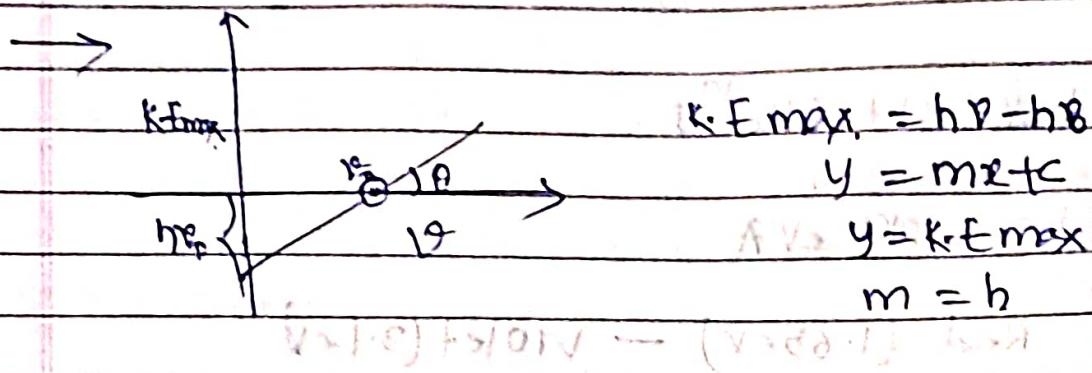
\rightarrow Intensity of no. of photons (or photocurrent)

\rightarrow Frequency of $K \cdot E_{\max}$

$$\rightarrow K \cdot E_{\max} = eVs = h\nu - h\nu_0$$



Stopping potential: applied potential in reverse direction
for $K.E_{max} = 0$



→ Orbital angular momentum of $e^- = nh$

$$\rightarrow \Delta E = E_2 - E_1 = nh\nu - hc\nu$$

$$\rightarrow \frac{m v^2}{r} = \frac{k q_1 q_2}{r^2}$$

$$\rightarrow r = \frac{n^2 h^2}{4\pi^2 m z k e^2}$$

$$\rightarrow r = 0.529 \times \frac{n^2}{z} \text{ Å}$$

• For same z , $r_1 < r_2 < r_3 < r_4$

$$\bullet \quad \frac{r_A}{r_B} = \frac{n_A^2 z_B}{n_B^2 z_A}$$

$$\bullet \quad \frac{r_A}{r_B} = \sqrt{\frac{n_A^2 z_B}{n_B^2 z_A}}$$

$$\rightarrow \cdot v = \frac{2\pi Z e^2}{nh}$$

$$\cdot v = 2.18 \times 10^6 \frac{Z}{n} \text{ m/s}$$

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

$$\cdot \text{For same } Z, \left| \frac{v_A}{v_B} = \frac{n_B}{n_A} \right|$$

$$\cdot \left| \frac{v_A}{v_B} = \frac{Z_A}{Z_B} \cdot \frac{n_B}{n_A} \right|$$

$$\rightarrow E_T = KE + PE$$

$$E_T = \frac{1}{2} m v^2 + \frac{k q_1 q_2}{r}$$

$$\cdot E_T = -KE = PE$$

$$\rightarrow \cdot E_T = \frac{2\pi^2 m z^2 k^2 A}{n^2 h^2}$$

$$\therefore E_T = -2.18 \times 10^{-18} \frac{z^2}{n^2} \text{ J}$$

$$\cdot E_T = -13.6 \frac{z^2}{n^2} \text{ eV}$$

\rightarrow In H-atom,

$$E_1 = -13.6 \text{ eV}$$

$$E_2 = -3.4 \text{ eV}$$

$$E_3 = -1.51 \text{ eV}$$

$$E_4 = -0.85 \text{ eV}$$

$$E_5 = -0.54 \text{ eV}$$

→ For H-atom

$$\cdot E_1 < E_2 < E_3 < E_4 < \dots < E_{\infty}$$

$$\cdot (E_2 - E_1) > (E_3 - E_2) > (E_4 - E_3)$$

10.2 eV

1.89 eV

→ Energy Stability T.

$$\rightarrow T_n = 1.51 \times 10^{-16} n^3 \text{ s.}$$

$$\rightarrow f_n = 6.62 \times 10^{15} z \frac{n^3}{s} \text{ s}^{-1}$$

→ For same z,

$$\frac{T_1}{T_2} = \frac{n_1^3}{n_2^3}$$

$$e^{\frac{h\nu}{kT_1}} = \frac{f_1}{f_2} = \frac{T_2}{T_1}$$

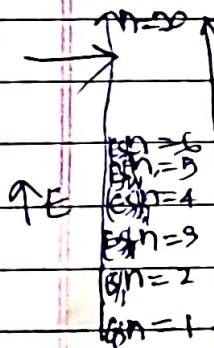
$$e^{\frac{h\nu}{kT_1}} = \frac{T_2}{T_1} = \frac{z^2}{z^3} = \frac{1}{z}$$

$$(E_2 - E_1) > (E_3 - E_2)$$

→ $n \uparrow r \uparrow v \uparrow K.E. \downarrow P.E. \uparrow E_f \uparrow \Delta E_n \downarrow T_n \uparrow f_n \downarrow$
 $(r \propto n^2)$ \downarrow due to $\propto [T_n \propto n^3] f_n \propto \downarrow$
 \downarrow resign

→ Absorbed energy is always positive, whereas emitted energy is always negative

A. E	V ₂ \leftarrow $E_f - E_i + h\nu$
e^- \uparrow H-E $\Delta E = E_f - E_i$	e^- \downarrow $\Delta E = E_f - E_i$



$$\begin{aligned} -0.50 \text{ eV} \\ -0.85 \text{ eV} \\ -1.51 \text{ eV} \\ -3.4 \text{ eV} \\ -13.6 \text{ eV} \end{aligned}$$

→ Ground state: $n=1$

→ Excited state: state of e^- , $n=2, 3, 4, 5, 6, \dots$
 $|E_1\rangle, |E_2\rangle, |E_3\rangle, |E_4\rangle, |E_5\rangle, |E_6\rangle, \dots$

→ Excitation Energy: energy necessary to take the e^- from G-S to E.S

$$-(E.E)_I = n_1=1 \text{ to } n_2=2 \approx 10\text{ eV}$$

$$= \Delta E = E_2 - E_1 = 10.2 \text{ eV}$$

$$-(E.E)_{II} = n_1=1 \text{ to } n_2=3$$

$$= \Delta E = E_3 - E_1 = 12.09 \text{ eV}$$

$$-(E.E)_{III} = n_1=1 \text{ to } n_2=4$$

$$= \Delta E = E_4 - E_1 = 12.75 \text{ eV}$$

- For H-atom - with increasing n , ΔE decreases

$$(E.E)_I < (E.E)_{II} < (E.E)_{III} < \dots$$

$$-\Delta E = E_2 - E_1 = -13.6 \times \frac{z^2}{n_2^2} = -13.6 \frac{z^2}{n_1^2}$$

$$\Delta E = -13.6 z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \text{ eV}$$

→ Ionisation Energy: energy necessary to take the e^- from G-S to ∞

→ In Bohr's model:

$$I.F = 13.6 z^2 \text{ eV}$$

→ |Ionisation energy| \equiv |Ionisation potential|

→ Separation energy (SE) or binding energy (B.E): energy necessary to take e^- from E.S to ∞ .

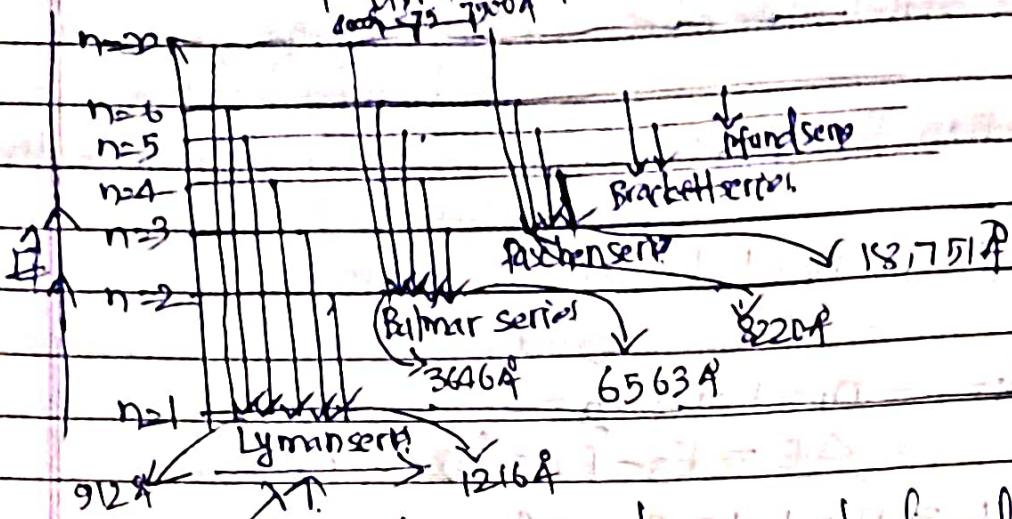
$$-(S.E)_I = n=2 \text{ to } \infty = 13.4 \text{ eV}$$

$$-(S.E)_{II} = n=3 \text{ to } \infty = 1.51 \text{ eV}$$

$$-(S.E)_{III} = n=4 \text{ to } \infty = 0.85 \text{ eV}$$

→ $(S.E)_I > (S.E)_{II} > (S.E)_{III} > \dots$

→ Line spectrum of H



→ Longest transition, shortest wavelength and shortest transition longest wavelength.

$$\rightarrow \text{Total no. of spectrum lines} = \sum_{n_1=1}^{n_2} (n_2 - n_1)$$

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

$$\rightarrow \sum (m_2 - n_1) = (n_2 - n_1)(n_2 - n_1 + 1)$$

$$\therefore \sum (\Delta n) = (n_2 - n_1)^2$$

$$\rightarrow \frac{1}{\lambda} = R = R \cdot Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \quad \left. \begin{array}{l} R = 2.02 \times 10^2 \text{ m} \\ \text{or Rydberg} \end{array} \right\}$$

$$\text{Rydberg constant} = 1.097 \times 10^7 \text{ cm}^{-1}$$

n_1	$n_2 (n_2 > n_1)$	corresponding zone
Lyman	(1, 2, 3, ..., 20)	UV zone
Balmer	(2, 3, 4, ..., 20)	Visible zone
Paschen	(3, 4, 5, ..., 20)	IR zone
Brackett	(4, 5, 6, ..., 20)	"
Pfund	(5, 6, 7, ..., 20)	"
Humphrey	(6, 7, 8, ..., 20)	"

→ For any series, last line or terminal line is border line of each

$$[n_2 = \infty]$$

$$\rightarrow h_2 = n_1 + \text{line no.}$$

$$\rightarrow \nu_{\text{minimum}} = n_2 \text{ minimum.}$$

$$\nu_{\text{maximum}} = n_2 \text{ maximum.}$$

\rightarrow In spectrum of H, only first four lines of Balmer series are in visible zone, rest lines are in UV zone

$$1.86 \text{ eV} < \text{Balmer} \leq 3.4 \text{ eV}$$

First line α last line γ

hence visible ($1.65 \text{ eV} - 3.1 \text{ eV}$)

$$\rightarrow \lambda = \frac{h}{p} = \frac{h}{mv}, \quad m: \text{mass of particle.}$$

$p: \text{momentum of particle}$

$h: \text{Planck's constant}$ $v: \text{velocity of particle}$

$$\rightarrow \Delta \lambda = \frac{\Delta h}{m \Delta v}; \text{ no significance}$$

$$\bullet \Delta \lambda = \frac{h}{m \Delta v}; \text{ significance}$$

$$\rightarrow 2\pi c \Delta \lambda = n \lambda$$

$$\rightarrow \lambda = \frac{h}{\sqrt{2mKE}}$$

$$\rightarrow \lambda = \frac{h}{\sqrt{2mQV}}$$

$$\rightarrow \lambda_{\text{evidence}} = \sqrt{\frac{150}{\nu}} \approx \frac{1027}{\sqrt{\nu}} \approx \frac{12.3}{\sqrt{\nu}}$$

$$\rightarrow (\Delta x)(\Delta p) \geq \frac{h}{4\pi}, \quad \Delta x: \text{Uncertainty in position.}$$

$$\bullet (\Delta x)(\Delta p) = \frac{h}{4\pi}, \quad h: \text{Planck's constant}$$

$$\text{or, } (\Delta X)(m_i \Delta O) = \frac{h}{2\pi} \rightarrow \Delta V = \text{Uncertainty in } h$$

\rightarrow value:	Q.No.	Represent:	gives information about
$1 - \infty$	n	orbit or shell	size
$0 - (n-1)$	l	subshell or subshell	stage
$-6 \text{ to } +6$	m_i	orbital or orbital	orientation

\rightarrow orbit or shell	K	L	M	N	O	P
n	1	2	3	4	5	6

\rightarrow subshell or Subshell	S	P	D	F
starting location	1	2	3	4

\rightarrow In a shell, total no. of subshell is equal to
i.e., for any n , $l \rightarrow 0 \text{ to } (n-1)$ = total n value

- \rightarrow For any subshell, $n > l$
- \rightarrow S subshell starts from $1s$
- \rightarrow P subshell starts from $2p$
- \rightarrow D subshell starts from $3d$
- \rightarrow F subshell starts from $4f$

\rightarrow Energy of subshell & orbital is given by formula.

\rightarrow In a subshell total no. of e⁻ = $2(2l+1)$ or $(4l+2)$

\rightarrow In a subshell total no. of orbitals = $2(l+1)$.

Subshell	Total no. of orbitals	Total no. of e ⁻
S	1	2
P	3	6
D	5	10
F	7	14

partition # sub = 8

$$1 \cdot 1 = (2 \cdot 1)(2 \cdot 2) \cdot 2$$

P	3	6
D	5	10
F	7	14

s -subshell, $l=0, m_l = 0$

$\rightarrow s$ -subshell is also known as s -orbital.

$\rightarrow p$ -subshell, $l=1, m_l = -1, 0, +1$

$\rightarrow d$ -subshell, $l=2, m_l = -2, -1, 0, +1, +2$

\rightarrow In a shell or orbit, maximum no. of orbital = n^2

\rightarrow In view of energy all orbitals of same subshell are identical which are known as degenerate orbitals

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

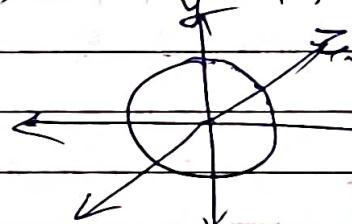
$$\rightarrow \frac{h}{2\pi} = \hbar$$

\rightarrow Clock wise or $+1/2$ or 1.

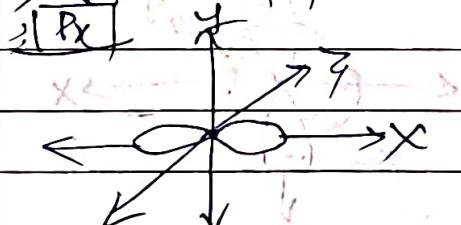
\rightarrow Anticlockwise or $-1/2$ or 1

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

\rightarrow s -orbital does not have any orbital angular momentum



\rightarrow p -orbital



$|P_x|$

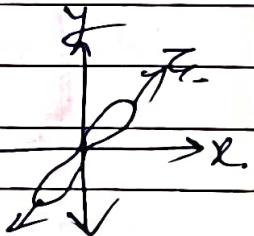
$|P_y|$

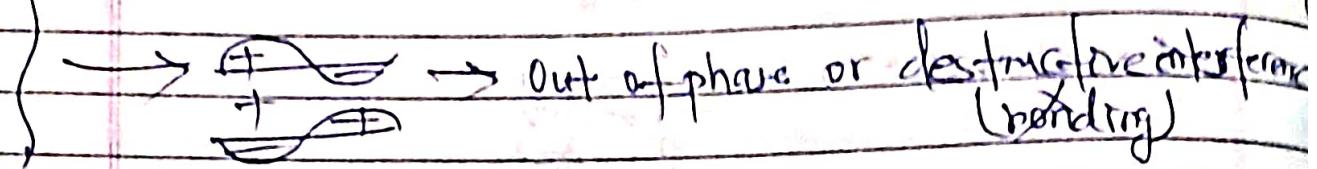
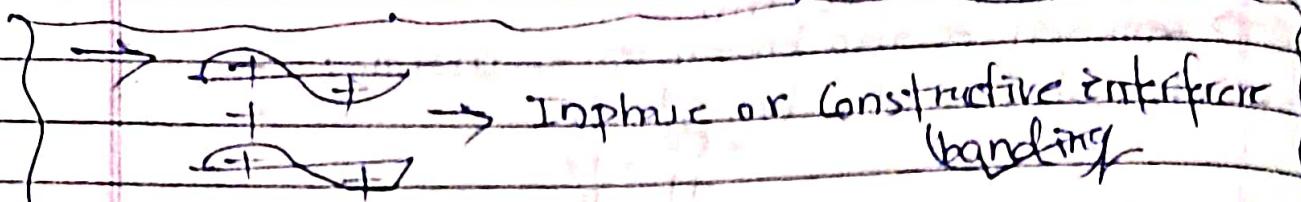
$|P_z|$

$|P_z|$

$|P_z|$

$|P_z|$





Nodal plane : probability of finding e^- is minimum in orbital nodal plane

p_x orbital at (yz)

p_y orbital at (zx)

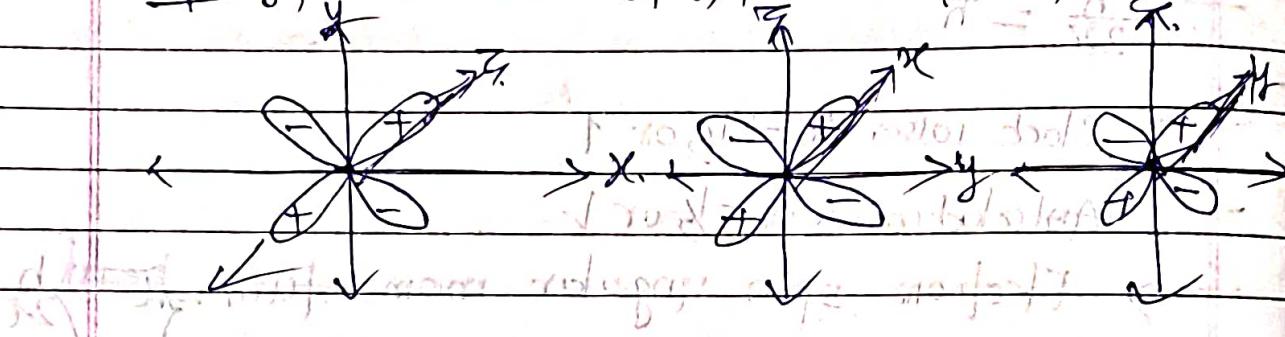
p_z orbital at (xy)

→ complex d-orbital (planar)

$|d_{xy}|$

$|d_{yz}|$

$|d_{zx}|$

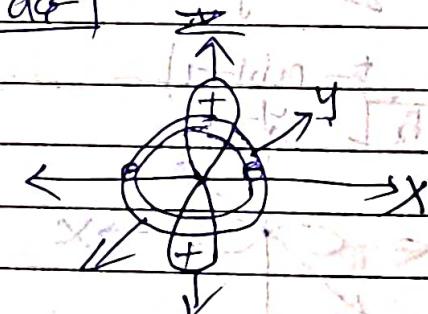
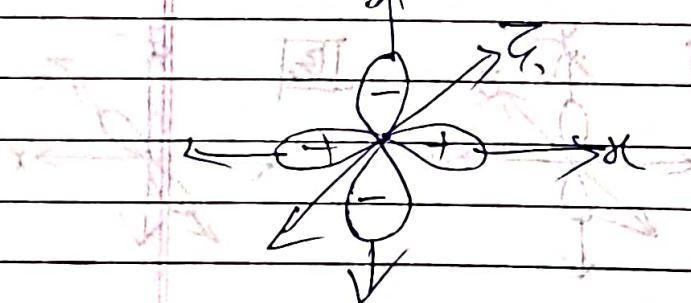


→ In d_{xy} orbital at 45° angle probability of finding e^- maximum in xy plane.

→ Axial d-orbital

$|d_{z^2}|$

$|d_{z^2}|$



\rightarrow	$s_{\text{ orbital}}$	<u>nodal plane</u>
	d_{xy}	$2(xz, yz)$
	d_{yz}	$2(xy, zx)$
	d_{zx}	$2(xy, yz)$
	$d_{x^2-y^2}$	2
	d_{z^2}	0

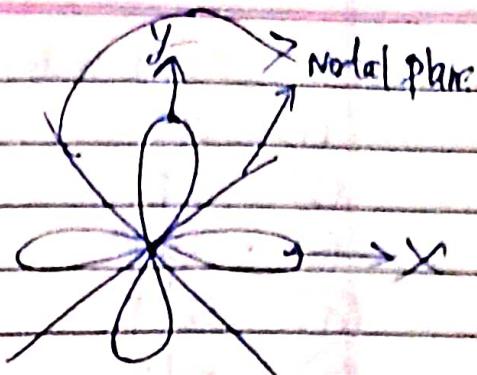
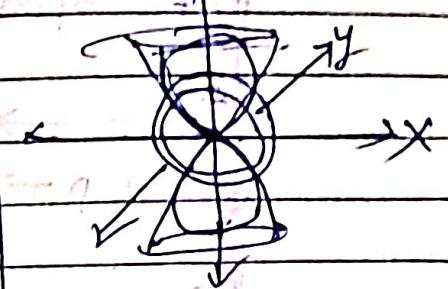


Fig. Two physical wave infor.



\rightarrow Total no. of nodes = $(n-1)$
or Total no. of nodal surfaces

\rightarrow Total no. of angular node = l

\rightarrow Total no. of radial node = $(n-l-1)$
or spherical nodes

\rightarrow Pauli's Exclusion Principle

- different set of all four quantum no. of different effects
- An orbital if two e^- have opposite or a parallel spin

\rightarrow Hund's rule of maximum multiplicity.

- In degenerate orbital, pairing of electron does not occur until every orbital is filled is singly occupied by by electron with parallel spin

\rightarrow s-subshell do not require Hund's rule.

\rightarrow No. of unpaired electrons:

\rightarrow Aufbau principle

- electrons firstly enter in that subshell for which $(n+l)$ is less
- $(n+l) \downarrow$ Energy \downarrow Stability \uparrow
- For same value of $(n+l)$, the electron enter firstly in the subshell for which n is less.

→ Seven codes

- | | |
|----------|--|
| (1) S | |
| (2) SP | |
| (3) SdP | |
| (4) SdP | |
| (5) SdP | |
| (6) SfdP | |
| (7) SfdP | |

$$\begin{aligned} S, P &\rightarrow n \\ d &\rightarrow (n-1) \\ f &\rightarrow (n-2) \end{aligned}$$

n^{th} shell \rightarrow D.H. shell

$(n-1)$ shell \rightarrow inner or penultimate

$(n-2)$ shell \rightarrow outer or fully penultimate

- | | |
|--------------------------|----|
| (1) $S \rightarrow 1s$ | |
| (2) $SP \rightarrow 2s$ | 2p |
| (3) $SdP \rightarrow 3s$ | 3p |

- | | |
|--------------------------|----|
| (4) $SdP \rightarrow 4s$ | 3d |
| | 4p |

- | | |
|--------------------------|----|
| (5) $SdP \rightarrow 5s$ | 4f |
| | 5p |

- | | |
|---------------------------|----|
| (6) $SfdP \rightarrow 6s$ | 4f |
| | 5p |
| | 6p |

- | | |
|---------------------------|----|
| (7) $SfdP \rightarrow 7s$ | 4f |
| | 5p |
| | 6d |
| | 7p |

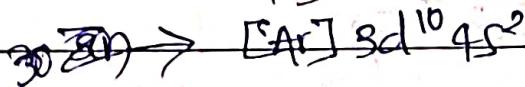
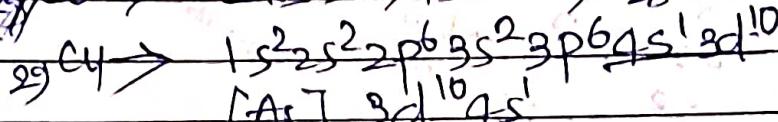
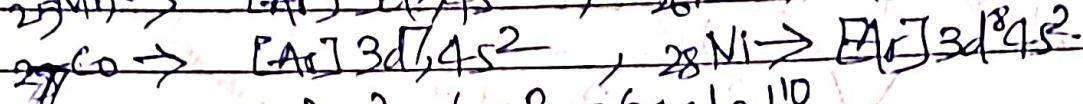
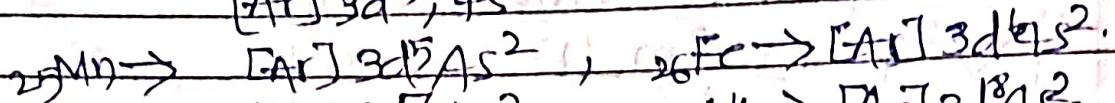
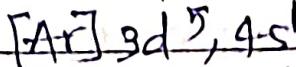
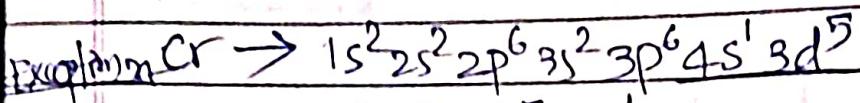
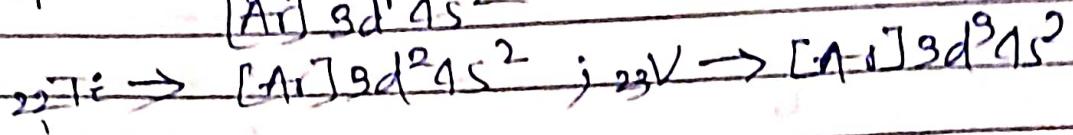
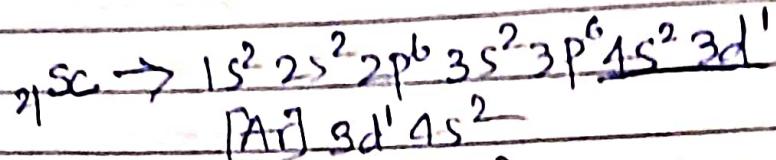
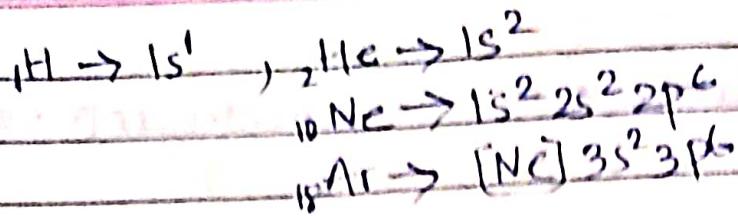
Subshell filling order

v. i. Eo of subshell

v. ii. Order of filling

Subshell top to bottom

Subshell filling order



→ Diamagnetic \Rightarrow paired
- colourless

→ Paramagnetic \Rightarrow unpaired
- coloured

→ Paramagnetic moment or magnetic moment of
spin only magnetic moment

→ Total spin = Total no. of unpaired electrons $\times \left(\frac{+1}{2}\right)$ or $\left(\frac{-1}{2}\right)$

→ Spin multiplicity = $2^{\text{Total spin}}$

Technique

no. of unpaired electrons

paramagnetic moment

1

1. —

2

2. —

3

3. —

4

4. —

5

5. —

6

6. —

→ First form of schrodinger eqn

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

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$$

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$$

position and energy

 → Ψ_{NCM}

 → IInd form of schrodinger wave equation

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

 → IIIrd form

$$\boxed{E\psi = A\psi}$$

A = mathematical operators (not)

(Helmholtzian operator)

$$W = R\lambda\psi$$

 → R or ψ_r = radial part of wave function

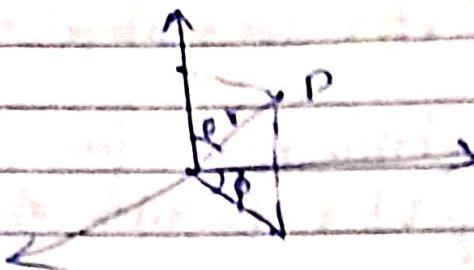
or radial wave function

— depends upon Q. no. (h, c.)

 $\Psi_{\theta, \phi}$ = Angular part of the wave function

— depends upon Q. no. (g)

→ polar coordinates (r, θ, ϕ)



→ 1) node

$$\text{II-1} \quad U_P = 0$$

$$\text{II-1} \quad U_P^2 = 0$$

(Probability density) or radial PD

P: $\rho = \frac{\text{Probability}}{\text{Volume}}$

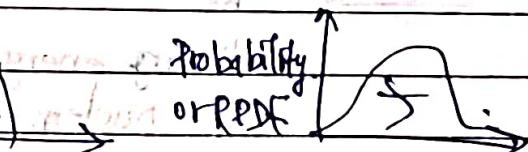
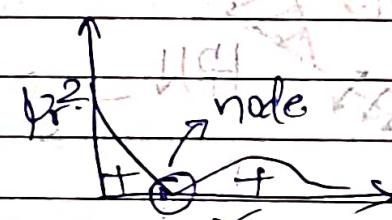
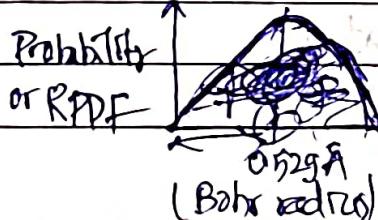
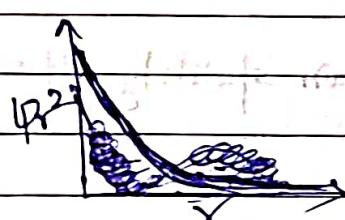
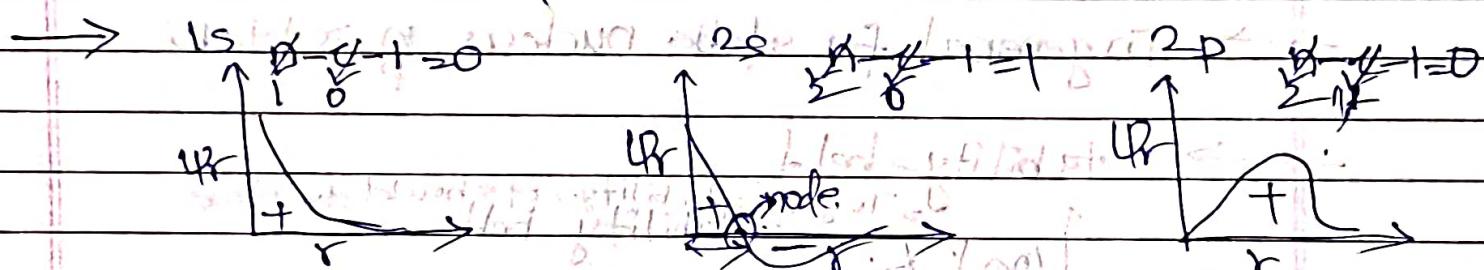
III-1 Probability

or RPDF or $U_P^2 \cdot 4\pi r^2 dr = 0$

RPDF: Radial Probability distribution function

$$\rightarrow U_P = R = k \cdot e^{-r/k'} \times r^n \times \{ \text{polynomial of order } (n-l-1) \}$$

Here, k & k' are constant



Characteristics of graphs :-

i) Graph of $1/r^2$ vs r & $1/r^2$ vs r^2 for s-orbital starts from some q-reading.

ii) Graphs of p, d & f orbitals starts from origin.

iii) Graphs of probability vs r of s-orbitals also starts from origin.

iv) Graphs of $2p, 3d, 4f$ will be same nature of radial node.

v) Similarly, Graphs of $3p, 4d$ & $5f$ will be of same nature & all will have 1 radial node.

$$\rightarrow E = mc^2$$

$$\rightarrow BE = \Delta m \times c^2 ; \Delta m \rightarrow \text{mass defect}$$

$$\rightarrow \Delta m = z \times m_p + (A - z) \times m_n - \text{actual mass of nucleus}$$

Inherent mass of nucleons

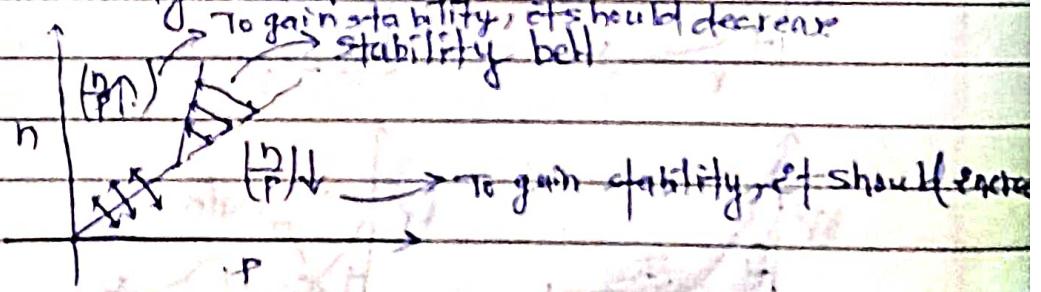
m_p, m_n : mass of proton & neutron

$$\rightarrow 1 \text{ amu} = 931.5 \text{ MeV}$$

	mass no. nucleus	charge

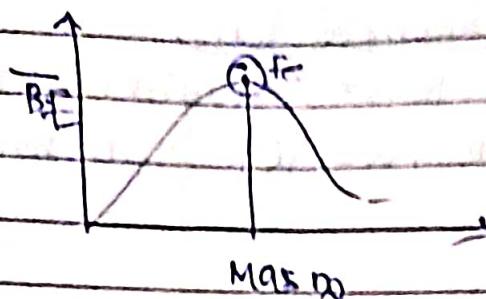
→ In general for stable nucleus, n/p is 1 to 1.5

→ Stability belt



$$\rightarrow \frac{BE}{\text{binding energy per nucleon}} = \frac{BE}{\text{total no. of nucleons}}$$

binding energy
per nucleon

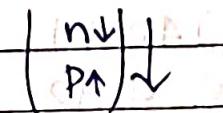
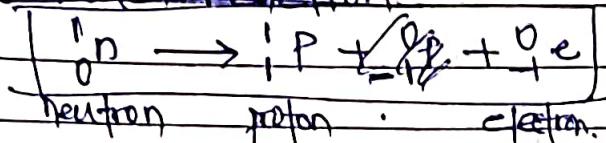


* If η_p ratio is high,
Then to decrease it

| | Technique
| | H.B.

η_p High β -emission
To make η_p low

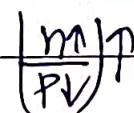
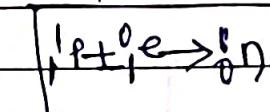
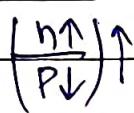
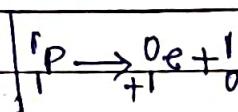
- β -particles are electrons emitted from nucleus
nuclear recombination



* If η_p ratio is low,
Then to make it high

| | Technique

| | P.K.
| i) position emission ii) K-electron capture



* Magritm theory :-

→ Nucleus having 2, 8, 20, 50, 82 protons or 2, 8, 20, 28, 56, 82, 126 neutrons are more stable.

→ If both no. of P & no. of n are even, then also nucleus is more stable

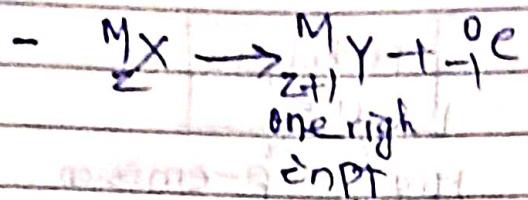
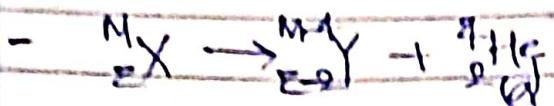
→ velocity : $\alpha < \beta < \gamma$

→ Ionisation Power : $\alpha > \beta > \gamma$

→ Penetration Power : $\alpha < \beta < \gamma$

Soddy-Fajan's group displacement law

- By emission of an α-particle, daughter element produced has position two left in the periodic table



Radioactive series

$$\textcircled{1} 4n+0$$

$$\textcircled{2} 4n+1$$

$$\textcircled{3} 4n+2$$

$$\textcircled{4} 4n+3$$