

'MODERN PHYSICS'

- ✓ [1] → Atomic Str.
- ✓ [2] → Photoelectric effect. [P.E.E]
- ✓ [3] → Matter Waves
- ✓ [4] → Nuclear Physics
- ✓ [5] → Radioactivity
- ✓ [6] → X-Ray.
- ✓ [7] → Positive Ray
- [8] → Electronics
- [9] → COMMUNICATION SYSTEM.

** (उत्सर्जित इलेक्ट्रॉन) bounded e^- एतत् P.E.E.

2016 AIIMS Photoelectric Effect

→ Emmission of e^- take place from metal surface
 When sufficient high freq light fall upon it. called P.E.E.

- * Discovered by → Hertz (NCERT)
- * Law of P.E.E. → Linard & Milliken
- * Final Explanation → Eienstein.

[1] → A/c to plank quantum theory Radiation transfer its energy in form of small pockets. min energy pockets called photon.
 * photon transfer 100% energy to single electron (e^-). If it is sufficient to remove the e^- come out from metal surface otherwise photon is absorbed.

properties of photon.

[1] → Photon move in straight line with velocity of light.
 $c_0 = 3 \times 10^8 \text{ m/sec}$

$$c_m = \frac{c_0}{\mu_m}$$

$$(c_m \leq c_0)$$

$$(\mu_m \geq 1)$$

$$v \propto d$$

* Frequency of photon remain unchange with medium.

* [2] → It is a neutral particle ($q_{ph} = 0$).

** [3] → Mass of photon →

- * Rest mass = 0 (m_0) ph.
- Relative mass = $m_r = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{0}{0} \Rightarrow$ NOT define
- Effective mass = $m_{eff} = \frac{h}{c\lambda} \propto \frac{1}{\lambda}$

[a] → $E \rightarrow$ max
 \rightarrow VIBRATORY
 \rightarrow min
 $\lambda \uparrow, m_{eff} \downarrow$

[b] → $u \cdot v <$ visible
 $m_{eff} \Rightarrow u \cdot v >$ visible.

14) → Energy of photon →

$$E = h\nu = \frac{hc}{\lambda} = \frac{12400 \text{ eV}}{\lambda(\text{Å})}$$

$$\lambda_{ph} = \frac{12400 \text{ Å}}{E_{ph}(\text{eV})}$$

NOTE → * In a reflection freq, velo, Wavelength & energy of one photon Remains same but total energy may change.

* Penetration power (P.P)

$$\lambda \uparrow, \nu \downarrow, E_{ph} \downarrow, P.P \downarrow$$

JIPMEK 2016

	Y-ray	X-ray	U.V RAYS	VISIBLE	I.R	M.W	R.W
→ Wavelength	$< 0.01 \text{ Å}$	$0.01 \text{ Å} - 100 \text{ Å}$	$100 \text{ Å} - 3800 \text{ Å}$	$3800 \text{ Å} - 7800 \text{ Å}$	$7800 \text{ Å} - 10^6 \text{ Å}$	$> 10^6 \text{ Å}$	
Energy Ranges	$> 1.24 \text{ MeV}$	$1.24 \text{ eV} - 124 \text{ KeV}$	$3.1 \text{ eV} - 124 \text{ KeV}$	$13 \text{ eV} - 3.2 \text{ eV}$	$0.012 \text{ eV} - 1.8 \text{ eV}$	$< 0.124 \text{ eV}$	
	mega e-volt order	kilo e-volt order		eV order			

NOTE → * Left to Right mass of photon ↓
* P.E.E not possible from Infra, Radio Wave, microwave.

15) → Momentum of photon → Momentum = mass × velocity

$$p = \frac{h}{\lambda} = \frac{E_{ph}}{c}$$

16) → Intensity [I] → Energy transferred per unit time, per unit area.
Energy of Radiation = $N_{ph}(h\nu)$
 $I = \frac{E}{A \cdot t} = \frac{P}{A}$
→ Power of Radiation source
→ Area in which radiation distributed

NOTE → Intensity of Radiation only depend on power of Radiation source & distance from radiation source. It is independent from color of radiation, Freq & Wavelength of radiation.

1a) → point source / spherical source → $I = \frac{P}{A} = \frac{P}{4\pi r^2} \propto \frac{1}{r^2}$

1b) → Linear / cylindrical source → $I = \frac{P}{A} = \frac{P}{2\pi rL} \propto \frac{1}{r}$

NOTE → If nature of source is not define consider point source.

17) → No. of photon incident or, incident per unit time →

$$I = \frac{E}{A \cdot t}, \quad \frac{N_{ph}}{t} = n_{ph}$$

$$n_{ph} = \frac{IA}{h\nu} = \frac{IA}{hc} = \frac{PA}{hc}$$

* $\eta_{ph} \propto Pd$ — $|h| \rightarrow P = \text{same} \Rightarrow \eta_{ph} \propto d$ Eg \rightarrow VIBGYOR
 $|h| \rightarrow d = \text{same} \Rightarrow \eta_{ph} \propto P$ Eg $\rightarrow (\eta_{ph})_{100} < (\eta_{ph})_{2204}$.

$$\eta_{ph} = 5 \times 10^{24} \frac{W}{m^2} \frac{m^2}{A} = 5 \times 10^{24} d h$$

$$\frac{1}{hc} = 5 \times 10^{24} \text{ (S.I.)}$$

18] \rightarrow Quantum Efficiency (η_c) \rightarrow $\frac{\text{no of emitted per unit time}}{\text{No. of photon incident per unit time}}$

$\eta_c = \frac{\text{output}}{\text{Input}}$ * $\eta = \frac{n e^-}{n_{ph}}$ * $n e = \eta n_{ph} = \eta \left(\frac{Pd}{hc} \right)$

19] \rightarrow Photoelectric current (i) \rightarrow

* $i = \frac{dq}{dt}$

* $i = n e^- (e) = \eta n_{ph} (e) = \eta \left(\frac{I A d}{hc} \right) (e)$

$\frac{1}{hc} = 5 \times 10^{24} \text{ S.I.} = 5 \times 10^{24} \frac{I A d}{\text{sec}}$

[10] \rightarrow Force / pressure exerted on surface \rightarrow

1a] \rightarrow If surface is perfectly Reflected \rightarrow

change in momentum: $\Delta p_{||} = \vec{p}_f - \vec{p}_i = \frac{h}{\lambda} \sin \theta = \frac{h}{\lambda} \sin \theta = 0$
 $\Delta p_{\perp} = \vec{p}_f - \vec{p}_i = -\frac{h}{\lambda} \cos \theta - \frac{h}{\lambda} \cos \theta = -\frac{2h}{\lambda} \cos \theta \neq 0$

1b] \rightarrow Momentum transferred to the surface \rightarrow

$$|\Delta \vec{p}_{||}| = 0$$

$$|\Delta \vec{p}_{\perp}| = \frac{2h}{\lambda} \cos \theta$$

1b] \rightarrow Force \rightarrow

$$\vec{F}_{||} = \frac{\Delta p_{||}}{dt} = 0$$

$$\vec{F}_{\perp} = \frac{dp}{dt} = \frac{2h \cos \theta}{\lambda}$$

1d] \rightarrow Total force \rightarrow

$$F_{\perp} = \frac{2P}{c} \cos \theta = \frac{2IA}{c} \cos \theta = 2uc \cos \theta$$

1d] \rightarrow Pressure \rightarrow

$$\frac{F_{\perp}}{A} = \frac{2P}{Ac} \cos \theta = 2 \left(\frac{I}{c} \right) \cos \theta$$

i) \rightarrow If surface is perfectly absorbing \rightarrow

ii) \rightarrow change in momentum \rightarrow

$$\Delta \vec{p}_{\parallel} = \vec{p}_f - \vec{p}_i = 0, \quad -\frac{h}{\lambda} \sin \theta = -\frac{h}{\lambda} \sin \theta$$

$$\Delta \vec{p}_{\perp} = \vec{p}_f - \vec{p}_i = 0, \quad -\frac{h}{\lambda} \cos \theta = -\frac{h}{\lambda} \cos \theta \neq 0$$

iii) \rightarrow Momentum transfer to the surface \rightarrow

$$\Delta \vec{p}_{\parallel} = \left[\frac{h}{\lambda} \sin \theta \right], \quad \Delta \vec{p}_{\perp} = \left[\frac{h}{\lambda} \cos \theta \right]$$

iiii) \rightarrow Force \rightarrow

$$\vec{F}_{\parallel} = \frac{d\vec{p}_{\parallel}}{dt} = \frac{hI \sin \theta}{c}$$

$$\vec{F}_{\perp} = \frac{d\vec{p}_{\perp}}{dt} = \frac{hI \cos \theta}{c}$$

lv) \rightarrow Total force \rightarrow

$$F_{\parallel} = \frac{P}{c} \sin \theta = \frac{2A}{c} \sin \theta$$

$$F_{\perp} = \frac{P}{c} \cos \theta = \frac{IA}{c} \cos \theta$$

v) \rightarrow Pressure \rightarrow

$$P_r = \frac{F_{\perp}}{A} = \frac{P}{Ac} \cos \theta = \left(\frac{I}{c} \right) \cos \theta = u \cos \theta$$

NOTE \rightarrow ~~PEE~~ ²⁰¹⁵ Pressure exerted by perfectly absorbing surface is half or, perfectly reflecting surface.

$$P_r = 2 \left(\frac{I}{c} \right) \cos \theta \quad P_a = \left(\frac{I}{c} \right) \cos \theta$$

- * If nature of surface is not define consider perfectly reflecting surface.
- * If angle of incident is not define consider radiation incident normally.
- * If surface is perfectly reflecting, partially absorbing net press. on surface is scalar addition of ~~add~~ reflecting & absorbing part.

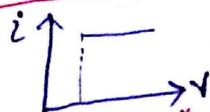
2. Practical Explanation of P.E.E. \rightarrow
or, Linard & Milliken

iii) \rightarrow Effect of Intensity: \rightarrow Photoelectric current \uparrow linearly with Intensity of Incident Radiation. i

$$* I(\nu) \Rightarrow n_{ph}(\nu) = n_{electron}(\nu) = i(\nu)$$

$$i \propto I = \frac{P}{4\pi r^2} \propto \frac{1}{r^2}$$

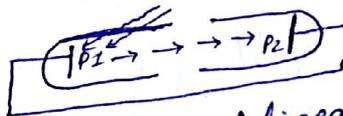
ii) \rightarrow Effect of freq \rightarrow



- * $\nu < \nu_0 \Rightarrow i = 0$
 - * $\nu \geq \nu_0 \Rightarrow i \neq 0$
- $\nu_0 \rightarrow$ Threshold freq

$$i \propto \nu^0$$

****** Pitch of voltage \propto space charge
Intensity \propto no. of photons.



NOTE → P.E.E depend on freq but P.E.E independent from freq

freq
 ↓ on changing freq. no of photon incident per unit time
 Remain unchange. but its energy is change that's why the quantity of e-
 Remain same.

Threshold freq. → minimum required freq. for photoelectron emission called threshold freq.

- * $V \geq V_0 \Rightarrow$ P.E.E is possible.
- * $V < V_0 \Rightarrow$ P.E.E is not possible.
- * $\lambda \leq \lambda_0 \Rightarrow$ P.E.E is possible
- * $\lambda > \lambda_0 \Rightarrow$ P.E.E not possible
- * $\frac{c}{\lambda} < \frac{c}{\lambda_0} \Rightarrow \lambda > \lambda_0$ No possible
- * $\frac{c}{\lambda} \geq \frac{c}{\lambda_0} \Rightarrow \lambda \leq \lambda_0 \Rightarrow$ possible.

condition of P.E.E

$$\begin{matrix} V \geq V_0 \\ \lambda \leq \lambda_0 \end{matrix}$$

$\lambda_0 \Rightarrow$ Threshold wavelength
 ↳ Max wavelength above
 which P.E.E is not possible.

iiiii) → Effect of potential →

- la) → on applying zero pot different b/w plates P1 & P2 amount of P.E.C is not equal to zero. If explain self k.E of e- which is provided by photon.
- lb) → on ↑ ⊕ve pot. on plate P2 w.r.t P1 P.E.C ↑ with pot. & become saturated after certain pot.
- lc) → P.E.C ↑ with potential. It means electron corresponding to same metal for same freq. has diff k.E.
- ld) → When no. of e- reached on plate P2 per unit time is equal to no. of e- emitted per unit time from plate P1, P.E.C become saturated.
- le) → on ↑ ⊖ve pot. on plate P2 w.r.t P1 P.E.C ↓ & become zero at certain pot is stopping potential.

Stopping potential (V0) ⇒ Required ⊖ve potential to stop max k.E e-.

$$W = -k \cdot E_{max} = eV_0$$

$$V_0 = -\frac{k \cdot E_{max}}{e}$$

* Required pot. for zero.

$$P.E.C \quad V_0 = -\frac{k \cdot E_{max}}{e}$$

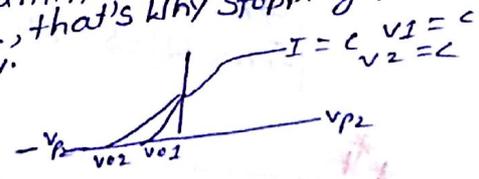
* Stopping pot. ⇒ $|V_0| = \frac{k \cdot E_{max}}{e}$

ALR * At stopping pot. P.E.C becomes zero but emission of photoelectron takes place.

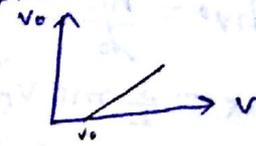
* Stopping pot. depend on nature of emitted plate & Freq. of incident radiation. It is independent from intensity & nature of collector plate.

Reason → on changing intensity quantity of incident photon is change but energy remain same, that's why stopping pot. remain unchange with intensity.

$$\begin{matrix} |V_{02}| > |V_{01}| \\ V_2 > V_1 \\ \lambda_2 < \lambda_1 \end{matrix}$$



* on changing Frequency, Energy of incident photon change that's why Required ⊖ve pot. to stop photo e- is change.



3] → Eienstien explanation →

iii → It explain P.E.E on the basis of partide nature of Radiation.
 * Dual nature of light → $\left\{ \begin{array}{l} \text{partide} \rightarrow \text{P.E.E, crompton Effect, Raman effect} \\ \text{Wave} \rightarrow \text{Reflection, Refraction, Interference, Diffraction, polarisation} \end{array} \right.$

lii → Photon transfer its 100% energy to single e^- or vice-versa (one to one interaction).
 * 10^{-9} sec.

AIEEE

liii → There is no time lag b/w incidend of photon & emmission of e^- provide energy equation of P.E.E.

$$E_{ph} = E_R + K \cdot E_e$$

Require Energy to Remove the e^-
 kinetic energy of e^-

$$K \cdot E_e = E_{ph} - E_R$$

$K \cdot E_{min} = 0$
 $K \cdot E_{max}$
 Max ($E_R = E_{ph}$)
 Min ($E_R = W$)

Range →
 0 to $K \cdot E_{max}$
 0 to V_{min}

* Required energy to Remove the all e^- from metal surface corresponding to same freq. is diff that's why $K \cdot E$ of emmitted e^- possible b/w 0 to max value.

* Same metal →

$$K \cdot E_{e^-} = E_{ph} - E_R$$

max
 min
 $(E_R)_{min} = W$ or ϕ
 Work function.

Work function (W/ϕ) metal surface.

$$E_{ph} = h\nu$$

min min

$$W = h\nu_0 = \frac{hc}{\lambda_0} = \frac{12400}{\lambda_0 (\text{\AA})} \text{ eV}$$

$$V \geq V_0$$

$$h\nu \geq h\nu_0$$

$$\begin{array}{|l} E_{ph} \geq W \\ E_{ph} < W \end{array}$$

⇒ P.E.E possible
 ⇒ not possible

condn of P.E.E

$$\begin{array}{|l} V \geq V_0 \\ \lambda \leq \lambda_0 \\ E_{ph} \geq W \end{array}$$

$$\begin{array}{|l} K \cdot E_{max} = E_{ph} - W \\ K \cdot E_{min} = 0 \end{array}$$

**

$$K \cdot E_{max} = E_{ph} - W$$

$$E_{ph} = h\nu = \frac{hc}{\lambda} = \frac{12400}{\lambda (\text{\AA})} \text{ eV}$$

$$W = h\nu_0 = \frac{hc}{\lambda_0} = \frac{12400}{\lambda_0 (\text{\AA})} \text{ eV}$$

$$K \cdot E_{max} = \frac{1}{2} m_e v_{max}^2 = eV_0$$

$$m_e = 9.1 \times 10^{-31} \text{ kg}$$

NOTE → * Work function depends on nature of surface & it will change with temp. & impurity.

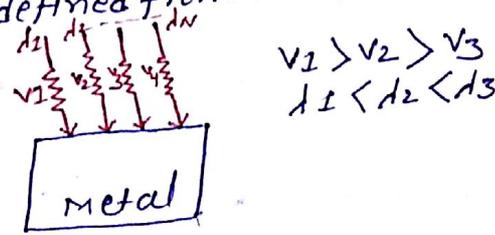
1a) → IA & IIA element ⇒ 2eV to 4eV
 * $W_{min} = Cs$ $W_{max} = Pt (5.65^{\circ})$

1b) → d-block } → 4eV to 10eV
 f-block }

1c) → Temp ↑ ⇒ Work function ↓.

* Freq. same in all medium but wavelength & velocity are changeable medium to medium.

* If polychromatic light incident on same metal then stopping pot. is defined from max freq & min wavelength.



*
$$V_0 = \frac{hc}{e\lambda_{min}} - \frac{W}{e}$$

$$V_0 = \frac{h}{e} \nu_{max} - \frac{W}{e}$$

Points of Expt. Material study of P.E.E

NOTE →

i) → Intensity (I) = const, Frequency (ν) ↑
 no. of photon = const.

$\lambda_{in} \uparrow$ & $\nu_p \downarrow$ & i_s remains same.

ii) → Intensity (I) = ↑, Frequency (ν) = const.

no. of photon ↑
 $\lambda_{in} \Rightarrow \uparrow$, $i_s = \uparrow$, $\nu_p = \uparrow$

'MATTER WAVE'

Wave associated with moving particle.

Wave or, De-broglie wave or, * Probable wave.

De-broglie Hypothesis → Every particle ⊕ nt in nature represents dual nature. (Wave & particle)

⇒ Wavelength of light $\lambda = \frac{h}{p} = \frac{h}{m_{eff}(c)}$

⇒ Wavelength of moving particle

$$\lambda = \frac{h}{p} = \frac{h}{m_{rel}v}$$

$$m_{rel} = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\lambda = \frac{h}{m_0 v \sqrt{1 - \frac{v^2}{c^2}}}$$

Rest mass m_0 → velocity of particle v

Velocity of light c

$v \neq 0$
 $v \neq c$

* $v = 0$ (rest) ⇒ $\lambda = \infty$ (not define) * $v = c$ ⇒ $\lambda = 0$

* $v \ll c$ ⇒ $\left(\frac{v}{c}\right) \ll 1$ ⇒ $\lambda = \frac{h}{m_0 v}$

* 'v' in range of 'c' → $\lambda = \frac{h}{m_{rel}v}$

K.E transfer = $\frac{1}{2} m_0 v^2 = \frac{p^2}{2m_0} \Rightarrow p = \sqrt{2m_0 K.E_{transfer}}$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m_0 K.E_{transfer}}}$$

Work done by pot. on charge particle → * $K.E = q\Delta V$

$$\lambda = \frac{h}{p} = \frac{h}{m_{rel}v} = \frac{h}{\sqrt{2m_0 K.E}} = \frac{h}{\sqrt{2m_0 q\Delta V}}$$

- *** # * If Wavelength of wave (λ) = size of obstacle ⇒ Diffraction take place.
- * If Wavelength of wave (λ) > size of obstacle ⇒ Reflection [in case of light shadow formed]
- * If Wavelength of wave (λ) < size of obstacle ⇒ Rectilinear propagation.

NOTE → De-broglie principle is applicable on micro as well as macro particle but practically it is proved only for micro particle.

*** # Standard Result: → $\lambda = \frac{h}{p} = \frac{h}{m_{rel}v} = \frac{h}{\sqrt{2m_0 K.E}} = \frac{h}{\sqrt{2m_0 q\Delta V}}$

I → Electron → $\lambda_e = \frac{12.27}{\sqrt{\Delta V(\text{volt})}} \text{ \AA} = \frac{12.27}{\sqrt{K.E(\text{ev})}}$

$$\Delta V = \frac{(12.27)^2}{\lambda_e^2} = \frac{150}{\lambda_e^2}$$

$$\Delta V = \frac{150}{\lambda_e^2} \text{ volt}$$

$$K.E_e = \frac{150}{\lambda_e^2} \text{ ev}$$

II → Proton → $\lambda_p = \frac{0.286}{\sqrt{\Delta V(\text{volt})}} \text{ \AA} = \frac{0.286}{\sqrt{K.E(\text{ev})}}$

III → Deuteron → $\lambda_D = \frac{0.202}{\sqrt{\Delta V(\text{volt})}} \text{ \AA} = \frac{0.202}{\sqrt{K.E(\text{ev})}}$

IV) α -particle $\rightarrow \lambda_\alpha = \frac{0.101 \text{ \AA}}{\sqrt{\Delta V(\text{volt})}} = \frac{0.101}{\sqrt{\frac{k \cdot E(\text{ev})}{2}}}$

#	particle	charge	Mass $m_e = \frac{m_p}{1836}$
	e^-	$-e$	$m_e = \frac{m_p}{1836}$
	p	$+e$	m_p
	d	$+e$	$2m_p$
	α	$+2e$	$4m_p$

Ratio of de-broglie Wavelength associated with e^- , H^+ , deuteron & α -particle
When it is move with:

i) \rightarrow Same momentum $\lambda \propto \frac{1}{p} \Rightarrow \lambda_e : \lambda_p : \lambda_d : \lambda_\alpha = 1 : 1 : 1 : 1$
 ii) $\rightarrow d = \frac{h}{p} = \text{same} \Rightarrow \lambda_e : \lambda_p : \lambda_d : \lambda_\alpha = \frac{1}{m_e} : \frac{1}{m_p} : \frac{1}{m_d} : \frac{1}{m_\alpha}$
 iii) $\rightarrow \lambda = \frac{h}{mv} \propto \frac{1}{m} \Rightarrow \lambda_e : \lambda_p : \lambda_d : \lambda_\alpha = 1840 : 1 : \frac{1}{2} : \frac{1}{4}$

iv) $\rightarrow k \cdot E \text{ same} \Rightarrow \lambda = \frac{h}{\sqrt{2mkE}} \propto \frac{1}{\sqrt{m}}$
 $\lambda_e : \lambda_p : \lambda_d : \lambda_\alpha = \sqrt{1840 \times 4} : \sqrt{4} : \sqrt{2} : \sqrt{2}$

v) $\rightarrow \Delta V \Rightarrow \text{same} \Rightarrow \lambda = \frac{h}{\sqrt{2m_0 e \Delta V}} \propto \frac{1}{\sqrt{m}}$

NOTE \rightarrow In same condition de-broglie Wavelength of moving e^- is max & in a neutral particle max for photon.

Standard Result for Neutral particle

I) \rightarrow Neutron: $\lambda_n = \frac{h}{p} = \frac{h}{m_p v} = \frac{h}{\sqrt{2m_0 kE}} = \frac{0.286 \text{ \AA}}{\sqrt{k \cdot E(\text{ev})}}$

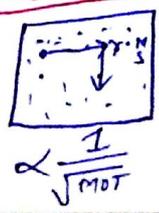
II) \rightarrow Thermal neutron: \rightarrow In a fusion rxn energy of the neutron is very high that's why Moderator is required for fission, moderated neutron.
 * It behave as a gas molecule. $\rightarrow k \cdot E = \frac{f}{2} kT$

$f=3$ $k \cdot E = \frac{3}{2} kT \Rightarrow \lambda = \frac{h}{\sqrt{2m(\frac{3}{2}kT)}}$
 $\lambda = \frac{h}{\sqrt{3mkT}} = \frac{28.2}{\sqrt{T(K)}} \text{ \AA}$

* $k = \frac{R}{N_A} = 1.38 \times 10^{-23} \text{ J/K}$
 Boltzmann const.

III) \rightarrow Photon $\rightarrow \lambda = \frac{h}{p} = \frac{h}{2m_e v(c)} = \frac{hc}{E_{ph}} = \frac{12400 \text{ \AA}}{E_{ph}(\text{ev})}$

IV) \rightarrow Gas molecule \rightarrow



$\lambda = \frac{h}{\sqrt{3kT}}$
 $\lambda = \frac{h}{\sqrt{3(\frac{M_w}{N_A})kT}}$

$\lambda = \sqrt{\frac{h}{3mkT}}$
 $V_{RMS} = \sqrt{\frac{3kT}{m}}$

comparison of electron & photon

	electron	photon
I → Rest mass	$m_0 = 9.1 \times 10^{-31} \text{ kg} = \frac{m_p}{1840}$	$(m_0)_{ph} = 0$
II → R.M.S	$E_0 = m_0 c^2 = 0.51 \text{ MeV}$	$(E_0)_{ph} = 0$
III → K.E	$K.E = \frac{1}{2} m v^2 \quad (v \ll c)$ $K.E = \frac{h\nu}{2de}$	
IV → T.E	$T.E = \frac{hc^2}{d\lambda}$	$T.E_{ph} = K.E_{ph} = \frac{hc}{d}$

I → condition 1st → Electron & photon move with same de-broglie wavelength.

$d_e = d_{ph} = d$ $K.E_{ph} = \frac{hc}{d_{ph}}$ $K.E_{e^-} = \frac{hc}{2d_{e^-}}$ $\frac{K.E_{e^-}}{K.E_{ph}} = \frac{h\nu/2d}{hc/d} = \frac{v}{2c}$

$v \ll c \Rightarrow K.E_{e^-} \ll K.E_{ph}$

II → condition 2nd → compare its total energy.

$d_{e^-} = d_{ph} \Rightarrow$

$T.E_{ph} = \frac{hc}{d_{ph}}$ $T.E_{e^-} = \frac{hc^2}{d_{e^-}}$ $\frac{T.E_{e^-}}{T.E_{ph}} = \frac{hc^2/h\nu}{hc/d} = \frac{c}{v} > 1$

$T.E_{e^-} > T.E_{ph}$

III → condition 3rd → Electron & photon move with same K.E compare its de-broglie wavelength.

$K.E_{ph} = \frac{hc}{d_{ph}}$ $K.E_{e^-} = \frac{h^2}{2md^2}$ $d_{e^-} = \frac{h}{\sqrt{2mK.E_{e^-}}}$ $\frac{d_{e^-}}{d_{ph}} = \frac{h/\sqrt{2mK.E_{e^-}}}{hc/E}$

$\frac{hc}{d_{ph}} = \frac{h^2}{2md^2}$ $\frac{hc}{d_{ph}} = \frac{1}{c} \sqrt{\frac{E}{2m_0}}$

* $\sqrt{E} = c\sqrt{2m_0} \Rightarrow d_{e^-} = d_{ph}$
 * $\sqrt{E} = c\sqrt{2m_0} \Rightarrow d_{e^-} > d_{ph}$
 * $\sqrt{E} = c\sqrt{2m_0} \Rightarrow d_{e^-} < d_{ph}$

$\sqrt{E} = c\sqrt{2m_0}$
 $E = 2(m_0 c^2) = 2 \times 0.51$
 $E = 1.02 \text{ MeV}$

* $E = 1.02 \text{ MeV} \Rightarrow d_{e^-} = d_{ph}$
 * $E > 1.02 \text{ MeV} \Rightarrow d_{e^-} > d_{ph}$
 * $E < 1.02 \text{ MeV} \Rightarrow d_{e^-} < d_{ph}$

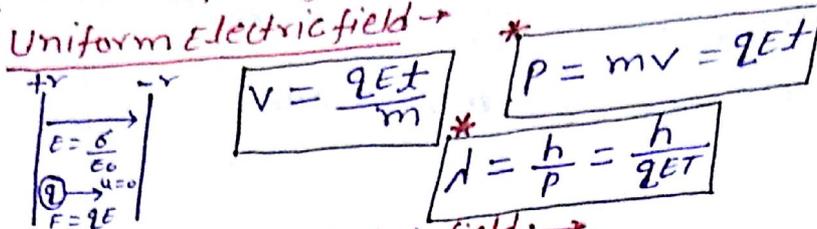
NOTE → * If e^- & photon move with same de-broglie wavelength then $K.E_{ph} > K.E_{e^-}$ but total energy of photon is less than from e^-

* If e^- & photon move with same K.E then de-broglie wavelength depend on magnitude of energy.

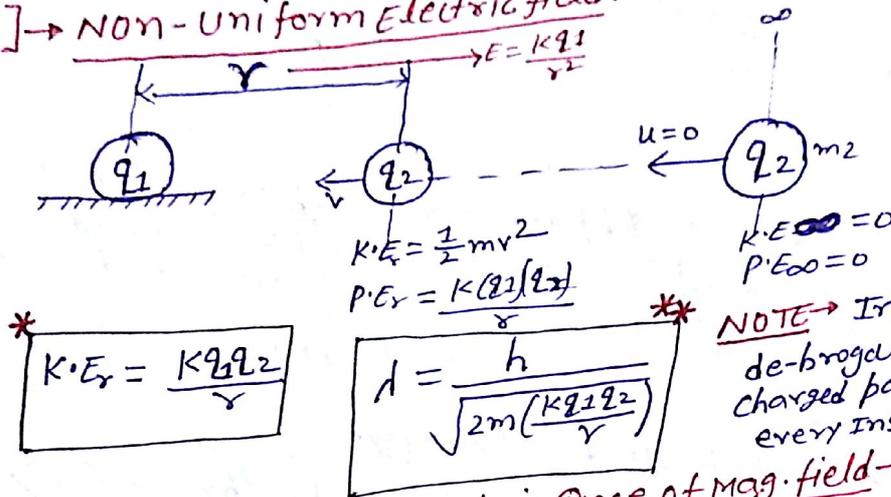
*** # Special case \rightarrow

Case I \rightarrow Motion of charged particle in presence of electric field.

[A] \rightarrow Uniform electric field \rightarrow



[B] \rightarrow Non-Uniform electric field \rightarrow

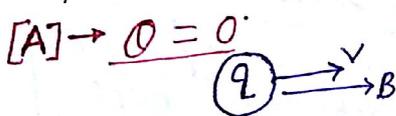


NOTE \rightarrow In presence of electric field, de-broglie wavelength of charged particle is change at every instant.

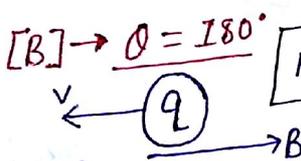
Case II \rightarrow Motion of charge particle in presence of Mag. field \rightarrow

Lorentz force \rightarrow $F = qvB \sin \theta$

* $v=0 \Rightarrow F=0 \Rightarrow$ Rest $\Rightarrow \lambda = \infty$

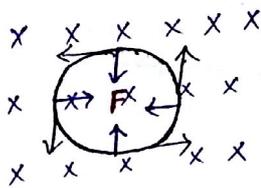


$F=0 \Rightarrow a=0 \Rightarrow v=const \Rightarrow \lambda = \frac{h}{mv} = const.$



$F=0, a=0, v=const, \lambda = \frac{h}{mv} = const$

[C] $\theta = 90^\circ$

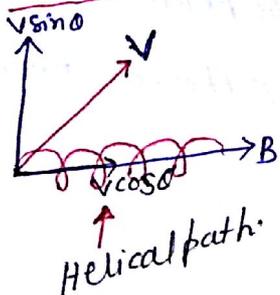


$\vec{F} \perp \vec{v} \Rightarrow W = 0 = \Delta K \cdot E$
* $K \cdot E = const$, * Speed = const.

$F = qvB \sin 90^\circ = \frac{mv^2}{r}$

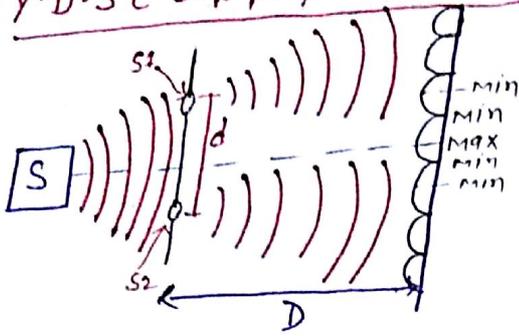
$P = mv = qBr$
* $\lambda = \frac{h}{p} = \frac{h}{qBr} = const.$

[D] $\rightarrow \theta \neq 90^\circ, 0^\circ, 180^\circ$



* $\lambda_{||} = \frac{h}{mv \cos \theta} = const.$
* $\lambda_{\perp} = \frac{h}{mv \sin \theta} = const.$
* $\lambda = \frac{h}{mv} = const.$

Case III → y.D.S.C Exp perform with Matter Wave



$$B = \frac{\Delta D}{d} = \frac{h}{\sqrt{2m_0 e \Delta V}} \frac{D}{d} \propto \frac{1}{\sqrt{\Delta V}}$$

$$\Delta V \uparrow \Rightarrow B \downarrow$$

$$\Delta V \downarrow \Rightarrow B \uparrow$$

AIR AFIMS 2011 BHU AMU

Explanation of Rutherford Drawback & Bohr quantisation condⁿ →

* i → Electron rotate around the nucleus in a stable path that's why its matter waves is also move in a same circular orbit. When wave are bounded it produce standing wave that's why energy of rotating e⁻ remain same & e⁻ rotate in stable circular orbit.

ii → Length of its path is complete multiple of wavelength.

$$2\pi r = n\lambda$$

* n=1 ⇒ 2πr₁ = 1(λ)

* n=2 ⇒ 2πr₂ = 2(λ)

* n=3 ⇒ 2πr₃ = 3(λ)

$$2\pi r = n\lambda$$

$$2\pi r = n \left(\frac{h}{mv} \right)$$

$$* J = mvr = \frac{nh}{2\pi}$$

Devison - Germer Exp → practically prove wave nature of particle.

- * Construction & Working → Electron gun based on thermionic emission principle. Electron beam incident on Ni² crystal & scattered it is collected by ionising chamber & practically calculate max. intensity condition.
- * Thermionic emission → Emission of e⁻ takes place ~~with~~ by the thermal energy.
- * Photoelectric emission → Electron emission takes place with energy of photon.
- * Field emission → Electron emission take place with external electric field. (10⁸ V m⁻¹)

Exp. Result →

ii → Max intensity is formed at 50° deviation & at 54 volt electron gun pot.

$$\Delta V = 54 \text{ Volt}$$

$$\theta = 50^\circ \Rightarrow \phi = 90^\circ - \frac{50}{2} = 65^\circ$$

AIEEE/AIPMT

$$* D \sin \theta = n\lambda$$

$$* 2d \sin \theta = n\lambda$$

λ = Wavelength, n = order of diffraction = 1, 2, 3, ...

$$D \sin \theta = n\lambda$$

$$* D \sin \theta = 2.15 \text{ \AA}$$

$$\lambda_{\text{max}} = \frac{D \sin \theta}{n_{\text{min}}} = 1$$

$$\lambda_{\text{max}} = D \sin \theta = 2.15 \sin 50^\circ$$

$$* \lambda_{\text{max}} = 1.66 \text{ \AA}$$

$$* \lambda_{\text{DB}} = \frac{12.27}{\sqrt{\Delta V (\text{volt})}} \text{ \AA}$$

$$= \frac{12.27}{\sqrt{54}}$$

$$* \lambda_{\text{DB}} = 1.65 \text{ \AA}$$

$$\lambda_{\text{practical}} \approx \lambda_{\text{DB value}}$$

'NUCLEAR PHYSICS'

I I → Nucleus

[A] → Nucleon = Proton + Neutron

* Mass = $M_p = 1.67 \times 10^{-27} \text{ kg}$ * $M_n = 1.68 \times 10^{-27} \text{ kg}$
 $\approx 1.007 \text{ amu}$ $\approx 1.008 \text{ amu}$

* Largest unit of charge → Farady
 * S.I. → Cb
 * C.G.S. → S/cb/esu/franklin
 * Practical unit → abcb
 Farady

* $q_p = +e = 1.6 \times 10^{-19} \text{ C}$
 $= 4.8 \times 10^{-10} \text{ esu}$

* $q_n = 0$

* Spin quantum no = $\pm \frac{1}{2}$
 * Spin angular momentum = $\pm \frac{1}{2} \left(\frac{h}{2\pi} \right)$

* Formation of proton & neutron in nucleus is explain by quark particle.

* Quark particle → up quark = $q_{up} = \pm \frac{2e}{3}$
 down quark = $q_{down} = \pm \frac{e}{3}$ → $m_{down} > m_{up}$

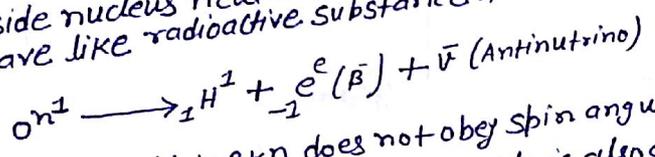
* Proton = 2 (up quark) + 1 (down quark)
 $= 2 \left(+\frac{2e}{3} \right) + 1 \left(-\frac{e}{3} \right) = +e$

* Neutron = 1 (up quark) + 2 (down quark)
 $= 1 \left(+\frac{2e}{3} \right) + 2 \left(-\frac{e}{3} \right) = 0$

NOTE → Quark particle does not exist in free state that's why quanta of charge still $[e]$.

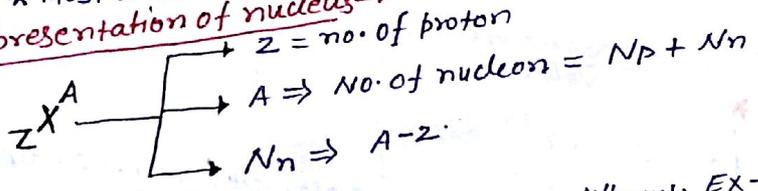
Imp *
NOTE → In a stable nucleus proton & neutron both are stable particle but in a unstable nucleus both are unstable particle. & outside nucleus proton is stable particle & neutron is unstable.

AIMS
 * outside nucleus neutron convert in H^+ & emit β -particle & Antineutrino & behave like radioactive substance of half life 12.5 min.



this RKN does not obey spin angular momentum conservation that's why pauli assume another particle is also emitted with β -particle whose spin quantum no. $\pm 1/2$, charge & mass no = 0, than particle is called neutrino & Antineutrino.
 * most unstable particle is → Neutron

12) → Representation of nucleus →

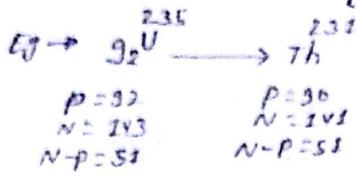


13) → Types of nucleus →

- 1a) → Isotopic nucleus → $Z = N_p = \text{same}, A = \text{different}$. EX → ${}^1H^1, {}^2H^2, {}^3H^3$
- 1b) → Isobaric nucleus → No. of nucleon same = A , No. of proton different
 EX → ${}^6C^{24}, {}^7N^{24}$
- 1c) → Isotonic/Isoneutronic → Same no. of neutron = same = $A - Z$
 EX → ${}^6C^{13}, {}^7N^{24}$ $N = 13 - 6 = 7$ $N = 24 - 7 = 17$] same (N)

**
 1d) → Mirror nucleus → If no. of proton & neutron is opposite.
 ${}^Z_1 X^A \leftrightarrow {}^Z_2 Y^A$ **NOTE** → Those isobar which has opposite & neutron. called mirror nucleus.

1e) → Isodiapher nucleus → difference of Neutron & proton is same.
 $[N - Z = \text{same}]$



**
 1f) → Isostex nucleus → Having same no. of atom & same no. of electron.
 eg → $\text{N}_2(24) \& \text{Co}(24) \& \text{Co}^{2+}(22) \& \text{N}_2\text{O}(22)$

Accessories

1g) → Isoelectronic → Same no. of e^- .
 eg → $\text{O}^{2-}, \text{F}^-, \text{Ne}, \text{Na}^+, \text{Mg}^{2+}, \text{Al}^{3+} (10e^-)$

1h) → Size of nucleus →

1a) → Radius → Radius of nucleus \propto to cube root of mass no.

* $r_{nu} \propto (A)^{1/3}$ * $r_{nu} = r_0 (A)^{1/3}$

$r_0 = \text{Rutherford nuclear const}$
 $= 1.2 \times 10^{-15} \text{ m}$
 $= 1.2 \text{ fermi}$

1b) → Volume → Nucleus behave as non-conducting solid sphere.

$V_{nu} = \frac{4}{3} \pi r_{nu}^3$
 $= \frac{4}{3} \pi (r_0 A)^3$
 $V_{nu} = \frac{4}{3} \pi r_0^3 A \propto A$

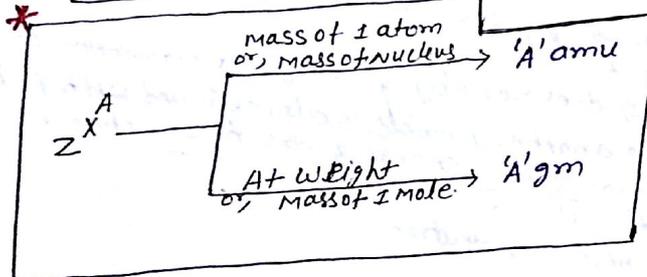
* $A \uparrow, r_{nu} \uparrow, V_{nu} \uparrow$ (size \uparrow)
 * Exp. it has been observed that volume of nucleus \propto mass no.

$\frac{4}{3} \pi r^3 \propto A$

1c) → Mass →

$M_{nucleus} = M_{nucleon}$
 $= \sum m_p + \sum m_n$

$M_{nu} = Z m_p + (A-Z) m_n$
 * $m_p \approx m_n = 1 \text{ amu}$
 $M_{nu} = A m_p = A \text{ amu}$



* 1d) → Density →

density (d) = $\frac{\text{mass of nucleus}}{\text{volume of nucleus}} = \frac{(1.67 \times 10^{-27}) A}{\frac{4}{3} \pi r_0^3 A}$

* $d = 2.3 \times 10^{17} \text{ kg/m}^3$

**
NOTE → Density of nucleus is same for all nuclei. (Independent from mass no.)
 * AS nuclei do not have sharp boundary, the volume of r_0 or r_0 may also have slight deviation from the given volume.

* Density of nucleus is very high while that of atom is very small, as most of the part of atom is empty.

ALP Nuclear spin →

similar to e^- nucleon also rotate about their own axis & they possess a permanent angular momentum & hence the complete nucleus has some angular momentum.

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Mass Energy Relation

$E = mc^2$ — velo. of light
 Energy corresponding to mass — part of mass which is convert into energy.

NOTE → A/c to Einstein system release energy its mass decrease & system absorb energy its mass increase.

Energy corresponding to mass —
 * 1 kg → $E = 9 \times 10^{16} \text{ J}$
 * → 1 amu → $E = 931 \text{ MeV}$
 $E = mc^2 = m(931) \text{ MeV} = m(9 \times 10^{16}) \text{ J}$

|a| → Rest Mass Energy → $[R.M.E] (E_0)$

R.M.E →
 → proton, $m_{op} = 1 \text{ amu} \Rightarrow E_{op} \Rightarrow 931 \text{ MeV}$
 → neutron, $m_{on} = m_{op} = 1 \text{ amu} \Rightarrow E_{on} \Rightarrow 931 \text{ MeV}$
 → electron, $m_{oe} = 9.1 \times 10^{-31} = \frac{m_p}{1836} = \frac{1}{1836} \text{ amu} \Rightarrow E_{oe} \Rightarrow 0.51 \text{ MeV}$
 → positron, $m_{pe} = m_{oe} = R.M.E_{pe} = R.M.E_{oe} \Rightarrow 0.51 \text{ MeV}$
 → photon, $m_{oph} = 0 \Rightarrow R.M.E_{ph} = 0$

|b| → Relative Energy (E_R) → Total energy.

$E_R = mc^2$
 $m_R > m_0$
 $E_R > E_0$

$E_R = mc^2 (1 - \frac{v^2}{c^2})^{1/2}$
 $E_R = mc^2 + \frac{1}{2} m_0 v^2$
 $E_R = R.M.E + K.E$
 $E_R > R.M.E$

K.E of Formula $E = mc^2$
 Rest mass m_0 & Aux $K.V$
 A Relativity theory $\Rightarrow E = mc^2$

Basic process/Defination

iii) → pair production → High energy photon is absorb by nucleus & configuration* of nucleus remain unchange & nucleus emit pair of electron & positron.
 * only done by photon not by neutron, proton etc.

* $E_{ph} = E_{e^-} + E_{e^+}$
 $= R.M.E_{e^-} + K.E_{e^-} + R.M.E_{e^+} + K.E_{e^+}$
 * $E_{ph} = 1.02 \text{ MeV} + K.E_{e^-} + K.E_{e^+}$

*** NOTE → * pair production energy convert in mass but mass energy equivalent is conserved.
 * Minimum required energy photon for pair production is 1.02 MeV
 * In a nuclear R.K. or, nuclear event charge, mass no, linear momentum, angular momentum, spin quantum no, spin angular momentum & mass energy remain conserved means, Phys all conservation law is followed.
 * $K.E_{e^-} = K.E_{e^+} = 0 \Rightarrow (E_{ph})_{min} = 1.02 \text{ MeV}$ (photon)
 * $E_{ph} < 1.02 \text{ MeV} \Rightarrow$ * pair production not possible.
 * P.E.E
 * Compton effect] → possible
 * $E_{ph} > 1.02 \text{ MeV} \Rightarrow$ * P.P
 * P.E.E
 * C.E] → possible.
 * P.E.E & C.E atomic event but pair production is nuclear event.

iii) → Pair Anihilation → Electron & positron come closer & annihilate each other release energy in form of radiation.

- * In pair annihilation two γ -photon are emitted & move in a opposite direction (follow linear momentum conservation).
- * In pair annihilation mass convert into Energy.
- * It is reverse process of pair production.

$$E_e^- + E_{e^+} = 2E_{ph} \Rightarrow 0.51 + KE_{e^-} + 0.51 + KE_{e^+} = 2E_{ph}$$

$$* E_{ph} = 0.51 \text{ MeV} + \left(\frac{K \cdot E_e^- + K \cdot E_{e^+}}{2} \right)$$

$$\# K \cdot E_e^- = KE_{ph} \Rightarrow (E_{ph})_{\min} = 0.51 \text{ MeV}$$

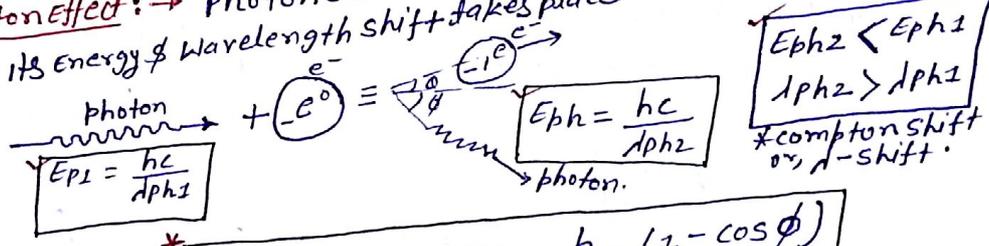
↑
For single For two $\Rightarrow 1.02 \text{ MeV}$

$$* (\lambda_{ph})_{\max} = \frac{12400}{0.51 \times 10^6} \text{ \AA}$$

* Min release of single photon in pair annihilation is 0.51 MeV & Min release energy 1.02 MeV.

iiiii) → P.E.E → Photon transfer its 100% energy to single e^- (perfectly inelastic collision) If it is sufficient to remove the electron than e^- come from metal surface effect is called PEE.

iiii) → Compton effect: → Photon collide elastically with e^- & transferred sum part of its energy & wavelength shift takes place.



$$\begin{aligned} E_{ph2} &< E_{ph1} \\ \lambda_{p2} &> \lambda_{p1} \end{aligned}$$

* Compton shift or λ -shift.

$$* \Delta \lambda = \lambda_{p2} - \lambda_{p1} = \frac{h}{m_0 c} (1 - \cos \phi)$$

iv) → Mass defect (Δm) → Mass of nucleus is slightly less than from mass of nucleon.

$$\Delta m = M_{\text{nucleon}} - M_{\text{nucleus}}$$

$$* \Delta m = Zm_p + (A-Z)m_n - M_{\text{nu}}$$

v) → Binding Energy (B.E) → Required energy to bound the nucleon in nucleus or Remove the nucleon from nucleus. (Energy corresponding to mass defect.)

$$* B.E = \Delta m c^2 \approx \frac{\Delta m}{a.m.u} (931) \text{ MeV}$$

$$* B.E = [Zm_p + (A-Z)m_n - M_{\text{nu}}] c^2$$

NOTE → B.E of free nucleon & Hydrogen nucleus is zero.

viii) → Binding Energy per nucleon (B.E/A) → Average energy required to remove the single nucleon from nucleus.

$$* \frac{B.E}{A} = \frac{\Delta m c^2}{A} = \frac{[Zm_p + (A-Z)m_n - M_{\text{nu}}] c^2}{A}$$

Case-III → If $B \cdot E$ is given → $B \cdot E = -R \cdot M \cdot E$

$$E = B \cdot E_p - B \cdot E_r$$

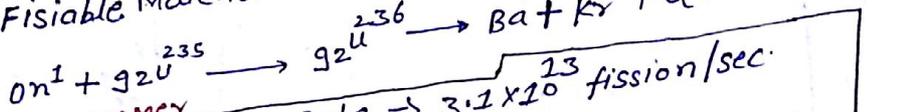
- * $B \cdot E_p > B \cdot E_r \Rightarrow E = \oplus VE$ (Release)
- * $B \cdot E_p < B \cdot E_r \Rightarrow E = \ominus VE$ (absorb)
- * $B \cdot E_p = B \cdot E_r \Rightarrow E = 0$

$$1 \text{ day} = 8.64 \times 10^4 \text{ sec}$$

$$1 \text{ yr} = \pi \times 10^7 \text{ sec}$$

Nuclear Reaction

- 111 → Fission Reaction → * Release energy per fission 200 MeV.
- * Release Energy per nucleon per fission = $\frac{200}{235} = 0.8 \frac{\text{MeV}}{\text{nucleon}}$
 - * Approx 1% of mass convert in energy remaining 99.9% part
 - * Fissile material → $U^{235}, U^{238}, Pu^{239}, Th^{232}$



Per fission → 200 MeV (Release energy)

$P = 1 \text{ KW}$ → Fission Rate $\Rightarrow 3.1 \times 10^{23}$ fission/sec.

Mass consumption Rate = $12 \times 10^{-12} \text{ kgm/sec}$

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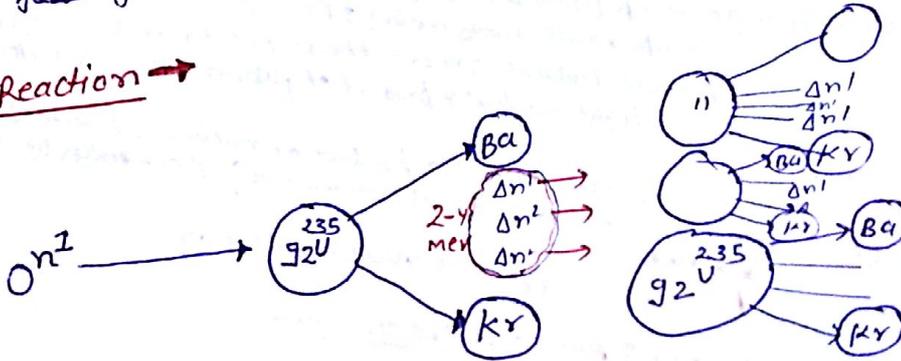
NOTE →

Fragment formed are of unequal masses bcoz the heavy nuclei have a greater $\frac{n}{p}$ ratio as compared to light nuclei, thus the fragment formed will have more neutron to maintain this ratio. Generally fragment form one belongs to family with higher $\frac{n}{p}$ value & another belong to moderate $\frac{n}{p}$ value, few extra neutron are emitted as soon as fragment are formed.

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Chain Reaction

Chain Reaction →



Difficulty in chain reaction

- 111 → In a natural uranium ratio of uranium isotopes $U^{233} : U^{235} : U^{238}$ is $0.3 : 0.7 : 99$ & Required energy for fission of U^{238} & U^{235} Resp. 7 - 8 MeV & less than 1 eV but energy of secondary neutron is 2 - 4 MeV.

Probability of neutron absorption is 99% & due to high K.E of neutron move with very high velocity (10^6 m/sec) & leakout from fissile material.

Removal Action →

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1a) → To increase probability of collision with ^{235}U nucleus is increase. (In rich process). (concentration of ^{235}U in enrich uranium is 3% (max)).

1b) → To decrease energy of neutron, substance moderator are used. D_2O (Best moderator), H_2O , BaO , Paraffin Wax (Hydrocarbon).

Why? → When comparable masses body collide elastically Max energy transfer takes place, mass of deuteron is in order of mass of neutron that's why it absorb max energy of neutron.

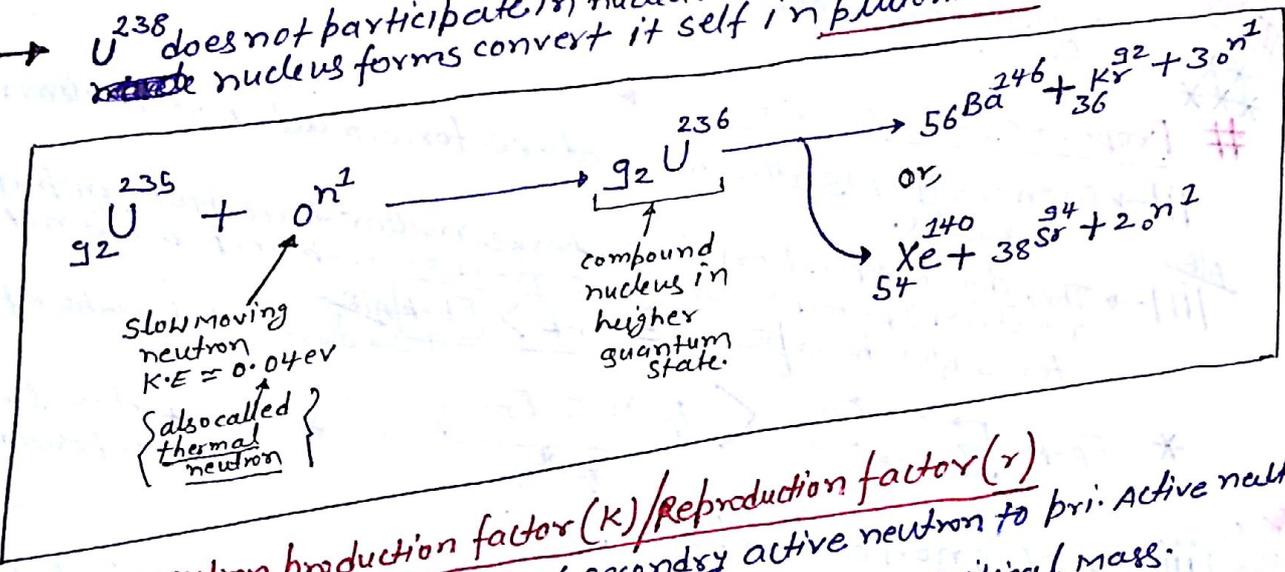
But, H_2O is best moderator??!!

Neutron (m)	Moderator (m_2)	$\frac{\Delta K \cdot E_1}{K \cdot E_1}$	Remain Energy
1 a.m.u	$1 \text{ H}^1 = 2 \text{ a.m.u}$	$\rightarrow 100\%$	0 ✓
1 a.m.u	$1 \text{ H}^2 = 2 \text{ a.m.u}$	$\rightarrow \frac{4(1)(2)}{(1+2)^2} = \frac{8}{9}$	$\frac{1}{9}$ ✓

that's why H_2O is not a best moderator!!

1c) → To maintain minimum 1 neutron in a fissible material size of fissible fuel is design as a critical size & critical mass (20kg).

AIR → ^{238}U does not participate in nuclear chain reaction bcoz compound ~~nucleus~~ nucleus forms convert it self in plutonium.



Neutron production factor (K) / reproduction factor (r)

Ratio of secondary active neutron to pri. Active neutron.

Nuclear bomb or atom bomb
Nuclear Reactor

- * If $K > 1 \Rightarrow$ uncontrolled chain reaction $\Rightarrow m >$ critical mass.
 - * If $K = 1 \Rightarrow$ controlled chain reaction $\Rightarrow m =$ critical mass.
 - * If $K < 1 \Rightarrow$ Rate of chain reaction decrease $\Rightarrow m <$ critical mass.
- Imp NOTE → * If all neutron are active than chain reaction is C.R.P.
* Number of neutron produce after 'n' heat = $N^{\text{th}} = 3^N$
* Neutron production Rate & absorption rate & volume of fissible material.
* Neutron leakout Rate & surface.

Controlled chain reaction

Eg → Nuclear Reactor.

- * Control Rod → cadmium, graphite.
- * Moderator → D₂O, H₂O, B₂, Paraffin.
- * Fusible material → U²³⁵, U²³³, Pu²³⁹, Th.
- * Pb → Best radiation absorber.

Uncontrolled chain reaction

Eg → Nuclear bomb

- * Fusible material → H₂, He, Be, B, C, N.

Breeder Reactor → Fast neutron generate fuel as well as energy.

Fusion Reaction → Presence of High temp. & High pressure light nucleus come closer & form comparable mass nucleus.

Destructive use → Nuclear bomb

- iii → Release Energy per fusion ⇒ 28 MeV
- * iii → per nucleon → Fission ⇒ 0.8 MeV/nucleon
- iii → Fusion ⇒ 7 MeV/nucleon.
- iii → condition of fusion reaction.

* $T \cdot E \gg E \cdot P \cdot E$

** $T \gg \frac{1}{3k} \left[\frac{2122e^2}{4\pi\epsilon_0 r} \right]$

or, stability of nucleus.

Unstability of nucleus : → A/c to nuclear force In a nucleus electrostatic repulsion force b/w proton & proton is 10³⁴ times more than gravitational attractive force but all nucleus are not unstable it means another attractive force is also present b/w nucleon called nuclear force. (which are 50-60 times stronger than electrostatic forces.

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Properties of nuclear force →

- iii → Generally it is attractive nature force & act b/w nucleon inside a nucleus.
- iii → They don't depend on charge, hence nuclear force b/w any pair of neutron & proton is same i.e n-n or, n-p or, p-p but net force b/w them $F_{n-n} = F_{n-p} > F_{p-p}$ due to electrostatic repulsion.

* $F_{p-p} \begin{cases} F_C \rightarrow \ominus ve \\ F_N \rightarrow \oplus ve \end{cases} < \begin{cases} F_{p-n} \approx F_{n-n} \\ F_C, F_N \\ \oplus ve. \end{cases}$

* do not obey law of superposition

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iii → It is non central force.

iv → It is non-conservative force.

v → Nuclear force depend on distance b/w nucleon but it does not obey Inverse square law or, Exponential law.

vi → It is strongest force in a natural forces but its Range is very short. (Range = 10⁻¹⁴ m)

vii → Unlike gravitational or, electrostatic force they do not have any formula for calculation.

viii → When the distance b/w nucleons is less than 0.5 fermi, they become strongly repulsive.

ix → Net force b/w proton-proton in stable nucleus (inside) is attractive & outside nucleus is repulsive.

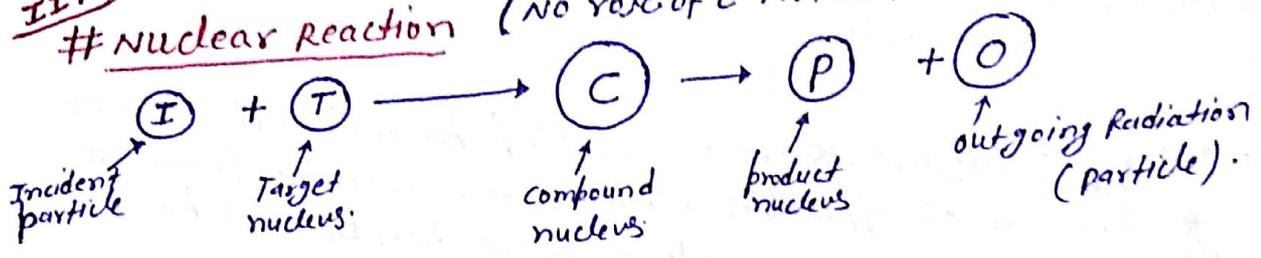
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A/C to neutron p proton ratio

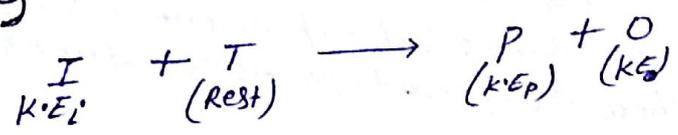
$N \geq Z \Rightarrow$ nucleus stable
 $N < Z \Rightarrow$ nucleus unstable.

A/C to stability
 Even-Even > even-odd > odd-odd

IIT
 # Nuclear Reaction (No role of e^- in this reaction)



Q - value of a nuclear Reaction -



$$Q = K \cdot E_p + K E_o - K E_i$$

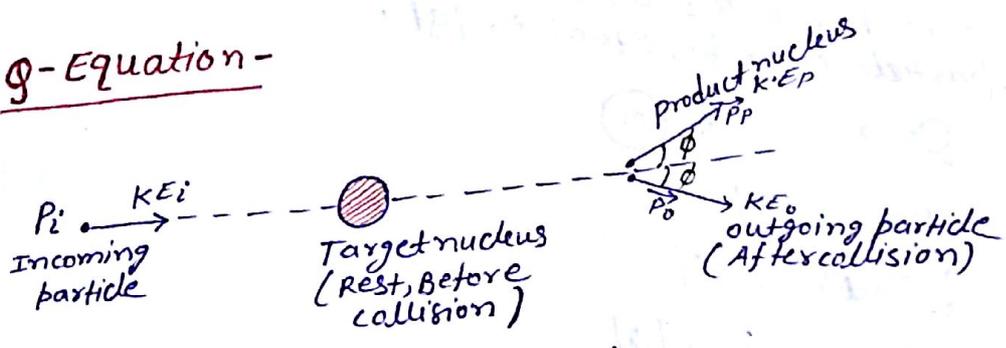
If mass of I, T, P, & O are m_i, m_t, m_p, m_o , then from conservation of Energy.

$$Q = (\Delta m) c^2$$

Imp

- * If $m_i + m_t > m_p + m_o \Rightarrow Q > 0 \Rightarrow$ Exergonic Reaction
- * If $m_i + m_t < m_p + m_o \Rightarrow Q < 0 \Rightarrow$ Endergonic Reaction.

Q-Equation -



From Momentum conservation

$$\vec{P}_i = \vec{P}_p + \vec{P}_o$$

$$\vec{P}_p = \vec{P}_i - \vec{P}_o$$

$$P_p^2 = P_i^2 + P_o^2 - 2P_i P_o \cos \theta$$

$$P_p^2 = P_i^2 + P_o^2 - 2P_i P_o \cos \phi$$

$$\therefore K \cdot E = P^2 / 2m$$

$$\left. \begin{aligned} P_i^2 &= 2m_i (K \cdot E_i) \\ P_p^2 &= 2m_p (K \cdot E_p) \\ P_o^2 &= 2m_o (K E_o) \end{aligned} \right\}$$

$$Q = K \cdot E_p + K \cdot E_o - K E_i$$

$$Q = \left(1 + \frac{m_o}{m_p}\right) K \cdot E_o - \left(1 - \frac{m_i}{m_p}\right) K \cdot E_i - \frac{2}{m_p} \sqrt{m_i m_o K E_i K E_o \cos \theta}$$

If outgoing particle is scattered at angle $\pi/2$.

$$Q = \left(1 - \frac{m_o}{m_p}\right) K E_o - \left(1 - \frac{m_i}{m_p}\right) K \cdot E_i$$

A body of mass 'M' at rest, it explodes in two particles m_1 & m_2 , calculate energy of fragments of the body in terms of 'Q'.

$$Q = \frac{P_1^2}{2} \left[\frac{m_1 + m_2}{m_1 m_2} \right]$$

$$K.E_2 = \frac{P_2^2}{2m_2} = \frac{Q m_1}{m_1 + m_2}$$

$$K.E_1 = \frac{P_1^2}{2m_1} = \frac{Q m_2}{m_1 + m_2}$$

NOTE → * K.E of fragments are inversally proportional to their masses.

* This analysis applicable in nuclear fission in two fragments.
*** * If nucleus is converted in three parts then we will have 2 equation & three unknowns.

This was the reason of birth of neutrino & antineutrino particle during such experiment missing energy & momentum were assigned to particles neutrino & antineutrino.

Threshold Energy of an Endoergic Reaction -

To initiate an endoergic reaction the K.E of incoming particle must be greater than a threshold value. The K.E should overcome the \ominus ve Q value as -

Some part of it also used to provide K.E to the product nuclei & outgoing particle.

In centre of mass from total momentum of particle is zero, hence K.E with respect to centre of mass of incoming particle must be equal to |Q|.



$$K.E' \geq |Q|$$

$$\frac{1}{2} M v_{rel}^2 \geq |Q|$$

$$\frac{1}{2} \left(\frac{mM}{m+M} \right) v^2 \geq |Q|$$

$$\frac{1}{2} m v^2 \geq \left(\frac{m+M}{M} \right) |Q|$$

$$K.E_{particle} \geq \left(1 + \frac{m}{M} \right) |Q|$$

RADIOACTIVITY

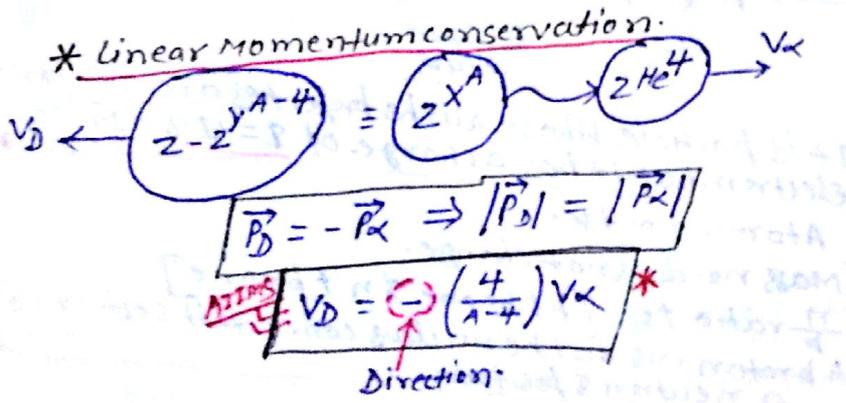
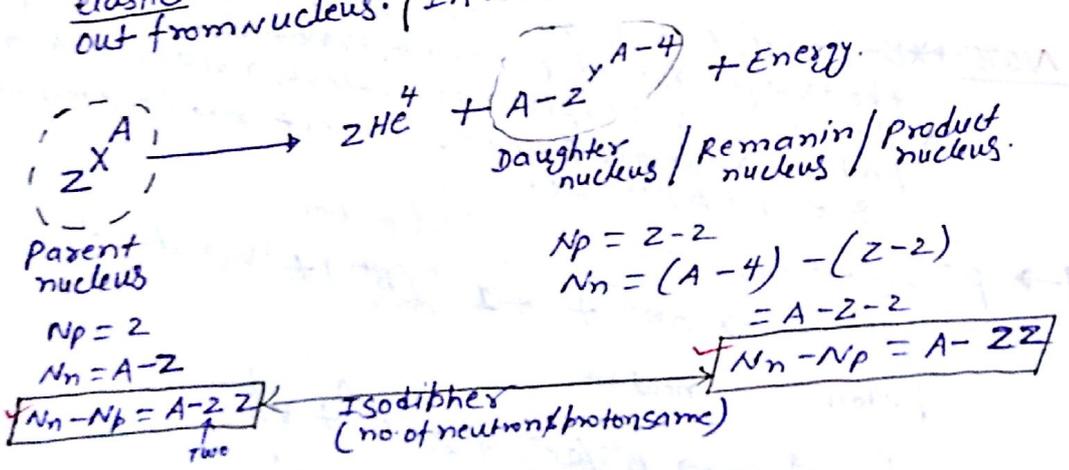
- * Exothermic reaction (Energy Release).
- Property or process by which disintegration or decay of unstable nucleus takes place with emission of α , β or γ rays.
- !! * It is nuclear event not atomic & remain unchange with pressure, temp. or any other physical or chemical change.
- * * 1st order reaction but 1st order ~~kinetics~~ concept apply (Mind ~~for~~ After study chemical kinetics).
- * Random process.
- * * Nuclear configuration in Radio active emission change, but atomic configuration remain same.

- AIMS * Proton never emitted by radioactive substance during decay.
- Decay to maintain $\frac{n}{p}$ ratio -
- 1) \rightarrow If $\frac{n}{p}$ ratio is greater than the required value for stability, β^- emission takes place.
 - 2) \rightarrow If $\frac{n}{p}$ ratio is less than the required value for stability α -decay or β^+ decay or e^- capture takes place.
 - 3) \rightarrow During radioactive reaction or nuclear reaction a nucleus in higher quantum state emit γ -ray & comes in lower quantum state.

* * * [A] \rightarrow α -emission \rightarrow In a unstable nucleus 2 proton & 2 neutron make one particle. K.E of α -particle is 7-8 MeV but required to cross the barrier of nucleus is 28 MeV. It means α -particle not come out from nucleus.

Its emission explain with 'Tunnel Effect' \downarrow

In a nucleus α -particle collide with nucleus wall & another particle, collision is perfectly elastic. When it arrange energy more than 28 MeV it come out from nucleus. (In a nucleus α -particle perform 10^{21} collision/sec)



* Neutron remain inside the nucleus & positron is emitted.
 * Neutrino is a particle whose properties are similar to antineutrino but it has opposite spin, It is always emitted with a positron.

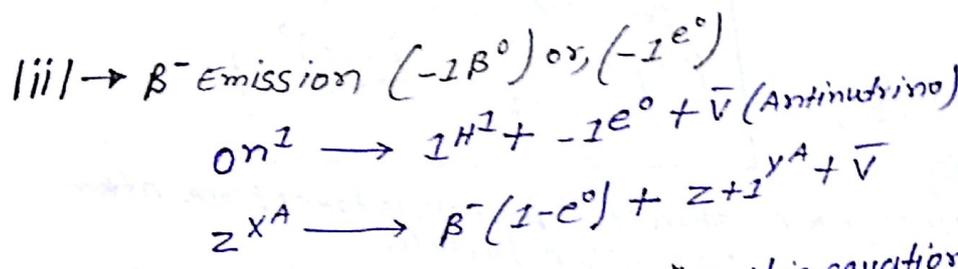
$$Q = (m_x - m_y - m_e) c^2$$

mass of nuclei

$$Q = (M_x - M_y - 2m_e) c^2$$

$$Z^A X \rightarrow Z-1^{A} Y^A + +1\beta^0 + \bar{\nu}$$

$m_x =$ Mass of $Z^A X$ atom
 $m_y =$ Mass of $Z-1^{A} Y^A$ atom
 $m_e =$ Mass of e^-



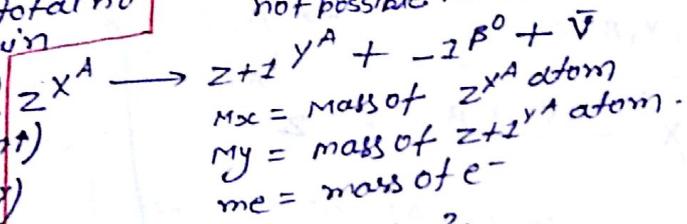
* Z \rightarrow	0	0
* A \rightarrow	0	0
* m \rightarrow	negligible	
* spin \rightarrow	$\pm \frac{1}{2}$	+1

NOTE \rightarrow * In this equation spin quantum conservation is not applicable, that's why Pauli assume another particle, is also emitted with β^- particle whose charge & mass no. is zero, but spin quantum no. $\pm 1/2$ & particle is called neutrino & Antineutrino.

NOTE \rightarrow * parent nucleus & daughter nucleus is isobar of each other.
 * In β^- emission total no of nucleon remain same but neutron & proton ratio change.

****** properties of Antineutrino -
 * It is a chargeless, massless particle like photon.
 * It is not deflected by electric or magnetic field.
 * Due to very less interaction with matter it is not possible to detect it.

****** $\left(\frac{N}{P}\right) \rightarrow \beta^+(\frac{N}{P} \uparrow)$ (stability \uparrow)
 $\rightarrow \beta^-(\frac{N}{P} \downarrow)$ (stability \downarrow)



* In α^- emission neutron & proton ratio must \uparrow but in β^- emission It may be \uparrow/\downarrow .

$$Q = (m_x - m_y - m_e) c^2$$

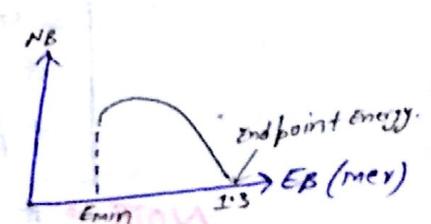
mass of nuclei

$$Q = [M_x - M_y] c^2$$

****** \rightarrow Atomic no. increase by 1.
****** \rightarrow Mass no. doesn't change.
****** \rightarrow $\frac{n}{p}$ ratio \downarrow (It is by 1 & $n \downarrow$ by 1)

2026 AILMS

Energy spectrum of β^- particle \rightarrow
 Diff energy of β^- particle which is emitted from same radioactive substance is explain with linear momentum conservation.



AIIMS 2026

A \rightarrow β^- particle Energy spectrum is continuous.
 R \rightarrow β^- decay is a spontaneous statistical process.
 Ans \rightarrow #

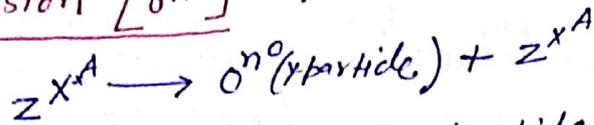
$Z+1^{A} Y^A \equiv Z^A X \rightarrow \beta^+/\beta^-$

$$P_f = -(\vec{P}_D) + \vec{P}_{\nu/\bar{\nu}}$$

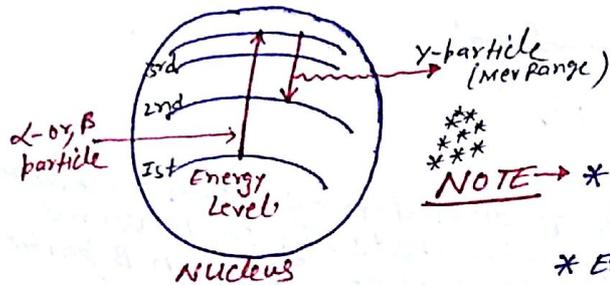
$$K \cdot E_{\beta} = \frac{P_{\beta}^2}{2m_{\beta}} = f(Q)$$

NOTE \rightarrow A/c to Pauli $\nu/\bar{\nu}$ hypothesis we explain -
 * spin angular momentum conservation
 * Diff. energy of β^- particle.

[C] α, γ Emission $[0^{00}] \rightarrow$



Emission of γ -particle is explain with energy level of nucleus when nucleus emit α -or, β -particle. It become excited & comes in high energy level when it again comes in low energy level release energy in form of radiation which is called γ -particle.



Recoil K.E Daughter nucleus

$$K.E_D = \frac{P_D^2}{2m_D} = \frac{(h\nu/c)^2}{2m_D}$$

- NOTE** \rightarrow
- * Emission of γ -particle, is takes place after emitting α or, β -particle.
 - * Emission of α - β -particle not takes place simultaneously.
 - * Emission of 2 particle simultaneously not possible from same nucleus.

EX \rightarrow Identify correct order of α, β & γ emission.

- $\rightarrow \gamma, \alpha$ X
- $\rightarrow \gamma, \beta$ X
- $\rightarrow \alpha, \beta, \gamma$ X
- $\rightarrow \beta, \alpha, \gamma$ X
- $\rightarrow \alpha, \gamma, \beta, \gamma$ ✓
- $\rightarrow \beta, \gamma, \alpha, \gamma$ ✓
- $\rightarrow \alpha, \beta, \gamma$ X
- $\rightarrow \alpha, \beta, \gamma, \gamma$ X
- $\rightarrow \beta, \gamma, \gamma$ X

$Z_1^X A_1 \xrightarrow{n\alpha, n\beta} Z_2^Y A_2$

$$n\alpha = \frac{A_1 - A_2}{4}$$

$$n\beta = 2n\alpha - Z_1 + Z_2$$

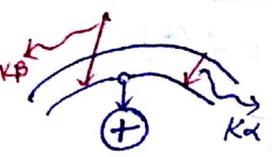
IIT 2016

Electron Kepture or, K-eppture \rightarrow nucleus pulls an e^- from k-shell, inside the nucleus & a proton combined with this e^- to $\uparrow \frac{n}{p}$ ratio.

- * Atomic no. \downarrow by 1.
- * Mass no. does not change.
- * $\frac{n}{p}$ ratio \uparrow .
- * $p \uparrow$ by 1 & $n \uparrow$ by 1.

NOTE \rightarrow * To fill the vacancy created in K-shell, K_α or, K_β line X-rays can be emitted.

* nucleus can only pull e^- from K-shell.

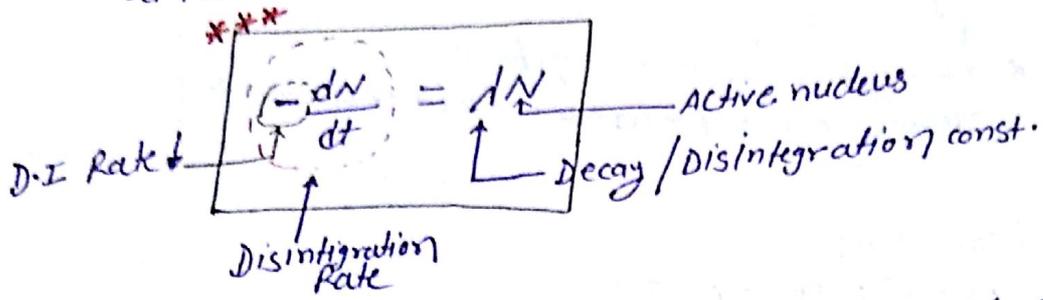


$$Q = (m_x + m_e - m_y) c^2$$

Mass of nuclei

$$Q = [m_x - m_y] c^2$$

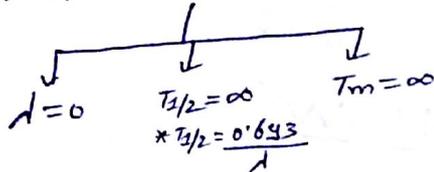
Rutherford - Sodi Law or, Disintegration Law →
 Disintegration rate \propto to active nucleus (N) at that instant.



$$\lambda = \frac{1}{N} \left(-\frac{dN}{dt} \right) \quad \text{Unit} \rightarrow \text{sec}^{-1}, \text{min}^{-1}, \text{hour}^{-1}, \text{day}^{-1}, \text{month}^{-1}$$

*** NOTE → Decay const, half life, mean life depend on nature of substance it is independent from quantity, temp, press, time or, any other physical or, chemical change.

* For stable nucleus



Relation b/w Active nucleus & Time →

$$\log(M) - \log(N) = \log \frac{M}{N}$$

$$N = N_0 e^{-\lambda t}$$

Active nucleus at time 't' initial Active nucleus

* Active nucleus at time 't' ⇒ $N = N_0 e^{-\lambda t}$

* " " " " " " t=0 ⇒ N_0

* Disactive nucleus at time 't' ⇒ $N' = N_0 - N = N_0 (1 - e^{-\lambda t})$

* Active mass at t=0 ⇒ M_0

* " " " " " " t ⇒ $M = M_0 e^{-\lambda t}$

* Disactive mass at time 't' ⇒ $M' = M_0 - M = M_0 (1 - e^{-\lambda t})$

- *** NOTE →
- * Active nucleus & Active mass ↓ Exponential w.r.t time.
 - * Disactive nucleus & Disactive mass Exponentially ↑ w.r.t time.
 - * Total no. of nucleus & mass of sample remain unchange w.r.t time.
 - * Rutherford sodi law is applicable on large no. of nucleus.
 - * More the value of decay const 'lambda', faster is the decay of Radioactive sample.

Packing fraction (f) →

$$f = \frac{M-A}{A}$$

- * It may be ⊕ve, ⊖ve, maybe zero
- * Its ⊖ve value explain more stability of nucleus

Special condition

$$\lambda \ll 1 \text{ (short range)}$$

$$e^x = 1 + \frac{x^1}{L^1} + \frac{x^2}{L^2} + \frac{x^3}{L^3} \dots$$

$$L^1 = 1$$

$$L^2 = 2 \times 1$$

$$L^3 = 3 \times 2 \times 1$$

$$\vdots$$
$$L^n = n(n-1)(n-2) \dots 1$$

BASIC DEFINITION

- ii) → Half life ($T_{1/2}$ or $t_{1/2}$)
- iii) → Mean life (T_m)
- iiii) → Activity (R)
- iv) → Specific Activity (R_{gm})

ii) → Half life → Time in which active nucleus remain 50% or half of initial value.

$$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

NOTE → If half life of sample is given as $t_{1/2}$
at $t = 0$, $N = N_0$
at $t = t$, $N = N$

$$\text{no. of half lives} = \frac{t}{t_{1/2}} = n$$

$$N = N_0 (2)^{-n}$$

$$A = A_0 (2)^{-n}$$

iii) → Mean life → Time in which active nucleus remain 37% of Initial value or, disintegrate 63% call mean life.

$$T_{\text{mean}} = \frac{\text{Sum of lives of all nuclei}}{\text{Total no. of nuclei}}$$

$$\langle T \rangle = \frac{1}{\lambda}$$

* $T_m = \frac{1}{\lambda}$

* $T_{1/2} = \frac{0.693}{\lambda}$

* $T_m > T_{1/2}$

* $T_{1/2} = 0.693 T_m \approx 69.3\% \text{ of } T_m$

* $T_m = 1.44 T_{1/2} \approx \text{More than } 44\% \text{ } T_{1/2}$

iiii) → Activity (R) → Disintegration rate of Radioactive substance.

$$R = -\frac{dN}{dt} = \lambda N$$

Unit → * 1 dps (disintegration per sec) = 1 Bq (Becquerel) (S.I.)

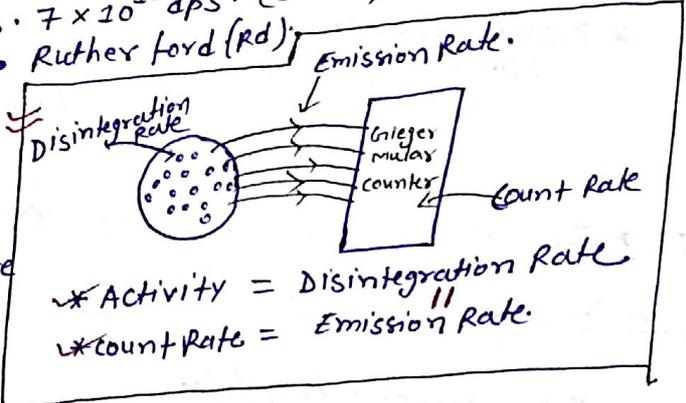
* 1 cu (curi) = 3.7×10^{10} dps. (C.G.S.)

* Practical unit → Rutherford (Rd)

* 1 Rd = 10^6 Bq.

* 1 mCu = 37 Rd

↑
millicuri



NOTE → Activity depend on nature of substance. It will ↓ exponentially w.r.t time & ↑ linearly w.r.t quantity/mass.

* Activity = Disintegration Rate
* Count Rate = Emission Rate

iv) → Specific Activity: → Activity of 1gm sample.

$M = 1\text{gm}, R = R_{\text{gm}}$

$$R_{\text{gm}} = \left(\frac{N_A}{A} \times 1 \right) \left(\frac{0.693}{T_{1/2}} \right)$$

↑
gm

NOTE → Sp. Activity Remain unchange w.r.t time.

Standard Result -

* Sp. Activity of R^{226} is 1cu/gm

1 gm = 1cu

X gm = Xcu

1 mgm = 1mCu

Prob. based on Radioactivity →

$$\begin{aligned} N &= N_0 e^{-\lambda t} \\ M &= M_0 e^{-\lambda t} \\ R &= R_0 e^{-\lambda t} \\ I &= I_0 e^{-\lambda t} \end{aligned}$$

$$X = X_0 e^{-\lambda t}$$

Case-I → If time given in terms of half life or, Active part is complete multiple of Half.

$$X_0 \xrightarrow{T_{1/2}} \frac{X_0}{2} \xrightarrow{T_{1/2}} \frac{X_0}{4} \xrightarrow{T_{1/2}} \frac{X_0}{8} \xrightarrow{T_{1/2}} \dots \xrightarrow{T_{1/2}} \frac{X_0}{2^n}$$

* n = no. of half life.

* Time in ' n ' half life $\Rightarrow t = n T_{1/2}$

* Active value after ' n ' half life $= X = \frac{X_0}{2^n}$

* Disactive)))))))))) $X' = X = X_0 \left(1 - \frac{1}{2^n}\right)$

* Active part / Active fraction / probability of Activeness (A.P) (A.fr) (P.S) = $\frac{X}{X_0} = \frac{1}{2^n}$

* Disactive part / Disactive fraction / probability of Disactiveness (D.P) (D.fr) (P.D) or, Probability of death (P.D) = $\frac{X'}{X_0} = 1 - \frac{1}{2^n}$

Case II → If time is given in terms of Mean life.

$$X_0 \xrightarrow{T_m} \frac{X_0}{e} \xrightarrow{T_m} \frac{X_0}{e^2} \xrightarrow{T_m} \frac{X_0}{e^3} \dots \xrightarrow{T_m} \frac{X_0}{e^n}$$

* n = no. of mean life.

* Time in ' n ' mean life $= t = n T_m$

* Active value After ' n ' mean life $= X = \frac{X_0}{e^n}$

* Disactive)))) ('n))))) = $X' = X_0 - X = X_0 \left(1 - \frac{1}{e^n}\right)$

* A.P / A.fr / P.A / P.S → $AP = \frac{X}{X_0} = \frac{1}{e^n}$

* D.P / D.fr / P.D → $DP = \frac{X'}{X_0} = 1 - \frac{1}{e^n}$

$$A.P + D.P = 1$$

Case III → If Active part not in complete multiple of Half. →

$$t = 3.32 T_{1/2} \log_{10} \left(\frac{1}{A.P}\right)$$

CASE IV → carbon dating or, Radioactive dating method.

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In most of the element nitrogen after receiving cosmic Rays (neutrons) convert them into carbon (14) which is radioactive element.

In all the live element, there is a fixed ratio of C^{14} & C^{12} , which remain const., till the element is alive, but when it becomes dead, C^{14} disintegrates continue & its ratio with C^{12} decreases. This decreased ratio is used to find the age of particular rock & it is known as carbon dating.

JIPMER 2016 * Living body $C^{14} : C^{12} = \boxed{1:1}$
 ↑ Active ↑ disactive

* $A \cdot P = \frac{X}{X+4}$

* Age of sample

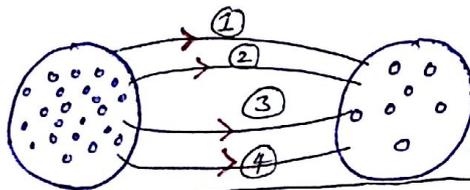
** $t = 3.32 \left(\frac{T_{1/2}}{C} \right) \log_{10} \left(\frac{1}{A \cdot P} \right)$

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- * $T_{1/2}$ of C^{14} is 5700 or 5730 yrs.
- * $T_{1/2}$ of α is 12 yrs
- * $T_{1/2}$ of B is 3 yrs

VI → CASE V → Radioactive branching concept →

If radioactive substance disintegrated by different process & disintegration rate of sample is a scalar addition of addition of individual process.



* $\left(\frac{-dn}{dt} \right)_{net} = \left(\frac{-dn}{dt} \right)_1 + \left(\frac{-dn}{dt} \right)_2 + \dots + \left(\frac{-dn}{dt} \right)_{net}$

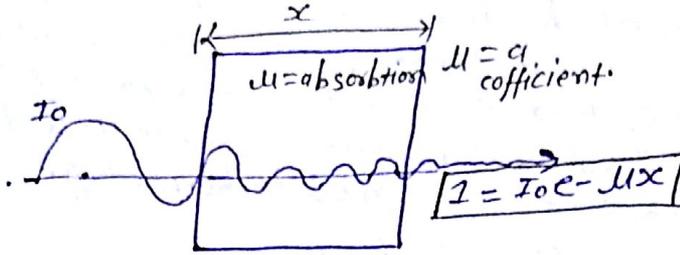
* $R_{net} = R_1 + R_2 + \dots + R_N$

* $\lambda_{net} = \lambda_1 + \lambda_2 + \dots + \lambda_N$

* $\frac{1}{(T_{1/2})_{net}} = \frac{1}{(T_{1/2})_1} + \frac{1}{(T_{1/2})_2} + \dots + \frac{1}{T_{mN}}$

** $\frac{1}{(T_m)_{net}} = \frac{1}{(T_m)_1} + \frac{1}{(T_{1/2})_2} + \dots + \frac{1}{T_{mN}}$

Case VI → Absorption of Radiation or, Absorption of X-ray →
 Intensity of Radiation ↓ exponentially w.r.t thickness of material.



$\mu_{\text{max}} = \text{Pb (Lead)}$
 $\mu_{\text{min}} = \text{Air}$

$I = I_0 e^{-\mu x}$

(Thickness)
 $x = X$
 $\mu = \frac{\text{Abs. coefficient}}$

$I = I_0 e^{-\mu X}$

i) → Half life = $T_{1/2} = \frac{0.693}{\mu}$

ii) → mean life = $T_m = 1/\mu$

iii) → $t = n \cdot T_{1/2}$
 ↑
 no. of Half life.

iv) → $t = 3.32 T_{1/2} \log_{10} \left(\frac{I_0}{I} \right)$

v) → $A \cdot P_2 = (A \cdot P_1)^{t_2/t_1}$

ii) → Half life yr = $T_{1/2} = \frac{0.693}{\mu}$

iii) → mean thickness = $1/\mu$

iiii) → $X = n \times 1/2$
 ↑
 no. of half thickness.

iv) → $X = 3.32 \times 1/2 \log_{10} \left(\frac{I_0}{I} \right)$

v) → $A \cdot P_2 = (A \cdot P_1)^{t_2/t_1}$

* penetration power → $\alpha < \beta < \gamma$ velo. of light
 $\frac{1}{20}$ $\frac{1}{3}$ to $\frac{9}{20}$

'X-RAYS'

Like photon.

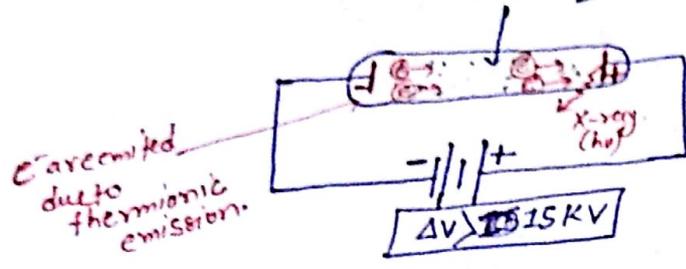
is not deflected from electric & magnetic field.

* Reverse of P.E.E.

condn → * When highly energetic e⁻ are made to strike metal target, electromagnetic radiation of the order 0.01 Å to 100 Å was observed & known as X-ray.

|| → Roentgen exp: → In presence of high potential & low potential, sum invisible radiation is emitted from anode which is called X-ray.

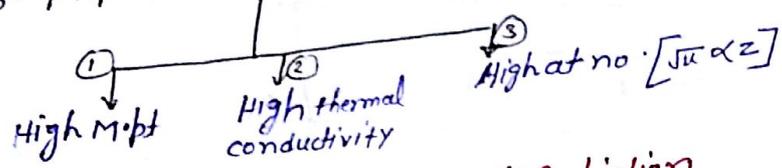
E.D.T [20³ mm of Hg column]



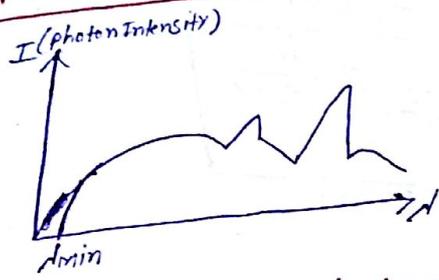
~~Condition~~

Basic requirement of X-ray production

- 1) e⁻ producing source
- 2) e⁻ Accelerating source (more than 15KV pot.)
- 3) Sp. property of target.



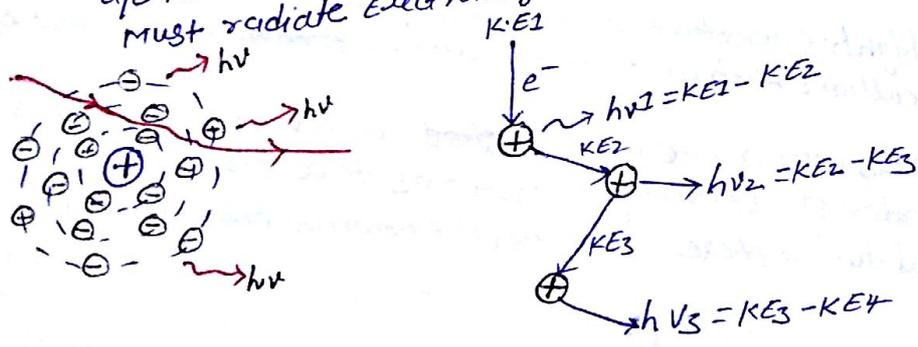
Graph b/w Intensity & Wavelength of Radiation



* There was a wavelength, below which no radiation was obtained, this λ_{min} was named as cutoff wavelength.
 * If we observe the graph, then we see there are two type of variation, one is conti & the other is disconti or, in form of peak.

Production (Explanation) of continuous X-ray / White X-ray.

When highly energetic e⁻ passed through an atom with very high K.E, they are strongly decelerated in electric field of nucleus & a/c to Maxwell electromagnetic theory every decelerating charge particle must radiate electromagnetic radiation & hence photon are emitted.



In successive collision e^- loses some part of its K.E energy & new photon with lost energy is generated.

** If accelerating voltage across coolidge tube is ' V_0 '
K.E of e^- just before hitting the target

$$\frac{1}{2} m v_e^2 = e V_0$$

$$v_e = \sqrt{\frac{2 e V_0}{m}}$$

** Photon with highest energy is liberated when an e^- lose all its K.E in a single collision & corresponding to this loss only one photon come out.

$$h \nu_{\max} = e V_0 = K.E$$

$$\frac{h c}{\lambda_{\min}} = e V_0$$

$$\text{cutoff wave length} = \lambda_{\min} = \frac{h c}{e V_0}$$

** other photons will have lesser energy so their wavelength will vary from λ_{\min} to ∞ .

$$\Delta \cdot K_{\text{loss}} = E_{\text{x-ray}} = \frac{1}{2} m (v_1^2 - v_2^2)$$

$$\lambda_{\text{x-ray}} = \frac{h c}{E_{\text{x-ray}}} = \frac{h c}{\frac{1}{2} m (v_1^2 - v_2^2)}$$

** Range of $v_2 = 0 - \infty$

$$* v_2 - v_1 = E_{\text{x-ray}} = 0 \Rightarrow \lambda_{\max} = \infty$$

$$* v_2 = 0 \Rightarrow (E_{\text{x-ray}})_{\max} = \frac{1}{2} m v_1^2 = W = e \Delta V$$

$$\lambda_{\min} = \frac{h c}{(E_{\text{x-ray}})_{\max}} = \frac{h c}{\frac{1}{2} m v_1^2} = \frac{h c}{e \Delta V}$$

$$\lambda_{\min} = \frac{12400}{\Delta V (\text{volt})} \text{ \AA}$$

**

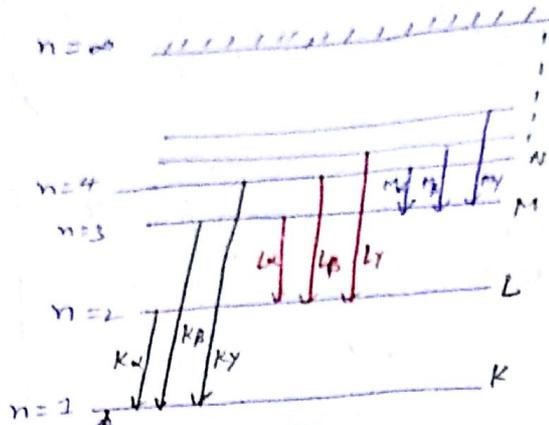
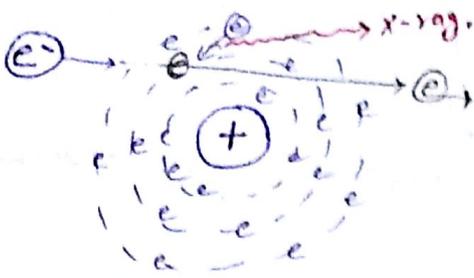
NOTE → Min wavelength of continuous X-ray only depend on anode potential. It is independent from at. no and nature of target.

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Explanation or, production of characteristic X-ray or, explanation of peaks →

When highly energetic e^- enters into an atom, there is also some possibility that it collides with an e^- of the atom & knock out of the shell.

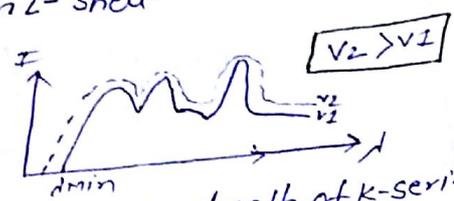
In this way a vacancy is ~~filled~~ created in shell, which is filled by higher order e^- s by making transitions to a lower stage, radiation emitted during these transition is known as characteristic X-ray.



$$\begin{aligned} &V_{K\alpha} < V_{K\beta} < V_{K\gamma} \\ &\lambda_{K\alpha} > \lambda_{K\beta} > \lambda_{K\gamma} \end{aligned} \quad \begin{aligned} &V_{K\alpha} > V_{L\alpha} > V_{M\alpha} \\ &\lambda_{K\alpha} < \lambda_{L\alpha} < \lambda_{M\alpha} \end{aligned}$$

NOTE → Energy (E_K, E_L, E_M, E_N) are not found from Bohr Model. If e^- is knocked out from L-shell.

$L\alpha, L\beta, L\gamma$
 $h\nu_{L\alpha} = E_L - E_M$
 $h\nu_{L\beta} = E_L - E_N$



- * In a same transition (α, β, γ) Wavelength of K-series is min.
- * In a same series (K, L, M) Wavelength of α -transition is max.
- * Wavelength of characteristic X-ray doesn't depend on Accelerating voltage, they depend only on target material.

Moseley's Law → Square root of frequency \propto to effective atomic no. of multi e^- system.

bor 6
 ↑
 screening const.

$$\sqrt{\nu} \propto Z_{eff}$$

$$\sqrt{\nu} = aZ_{eff}$$

$$Z_{eff} = Z - b$$

↑
At no.

- $K \Rightarrow b \Rightarrow 1$
- $L \Rightarrow b \Rightarrow 7.2$
- $M \Rightarrow b \Rightarrow 18.2$

Screening const (b) → He explained screening const. as when an e^- whose a vacancy is created, then the effective nuclear charge ↓ by a factor 'b' known as screening const.
 In 'K' shell there is only one e^- , which belongs to 's'-orbitals i.e. spherically symmetry so for K-line, effective nuclear charge ~~become~~ become $Z - 1$

* For $K\alpha$ -line

$$\sqrt{\nu_{K\alpha}} = \sqrt{\frac{3RC}{4}} (Z-1)$$

* For $K\beta$ -line

$$\sqrt{\nu_{K\beta}} = \sqrt{\frac{8RC}{9}} (Z-1)$$

* For $K\gamma$ -line

$$\sqrt{\nu_{K\gamma}} = \sqrt{\frac{15RC}{16}} (Z-1)$$

*** → By this observation he concluded that property of material/atom depend on atomic no. not on atomic mass.

$$a = \text{proportional} = \sqrt{Rc \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)}$$

const

NOTE → 'a' depend on transition & 'b' depend on series but both are independent from at. no. of element.

$$\sqrt{V} = a(z-b)$$

$$V = R(z-b)^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

$$\frac{1}{\lambda} = R(z-b)^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

$$E = h\nu = Rch = (z-b)^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

* R = Rydberg const = 10^7 m^{-1}

* $\frac{1}{R} = 912 \text{ \AA}$

* 1 Rydberg = $Rch = 13.6 \text{ eV}$
↑
unit of energy

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

$$V = 2 \times 10^{25} (z-b)^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

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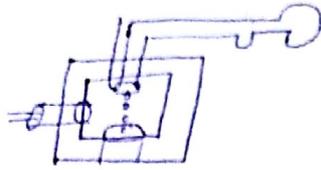
A → crystalline solid can cause x-ray to diffract.
 R → Interatomic distance in crystalline solid is of order of 0.2 nm.

Ans → A

'POSITIVE RAY'

1.1 → Milliken oil drop exp →

1.1.1 → By M.O. drop exp practically prove quantization of charge.



1a) $E=0$

$F_v = 6\pi\eta r v_1$
 $F_b = v_1 dm g = m'g$
 mg
 $E_{net} = 0 \Rightarrow a \Rightarrow 0 \Rightarrow v = \text{const}$
 $F_v + F_b = mg$
 $6\pi\eta r v_1 = m'g = mg$
 $mg - m'g = 6\pi\eta r v_1 \quad \text{--- (1)}$

1b) $E \neq 0$

$F_e = qE$
 $F_b = v_2 dm g = m'g$
 mg
 $F_v = 6\pi\eta r v_2$
 $F_e + F_b = mg + F_v$
 $qE = m'g = mg + 6\pi\eta r v_2$
 $qE = (mg - m'g) + 6\pi\eta r v_2$
 $qE = 6\pi\eta r v_1 + 6\pi\eta r v_2$

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$v_1 \Rightarrow$ Terminal velo. in \ominus ce of electric field
 $v_2 \Rightarrow$ Terminal velo. in \oplus ce of electric field.

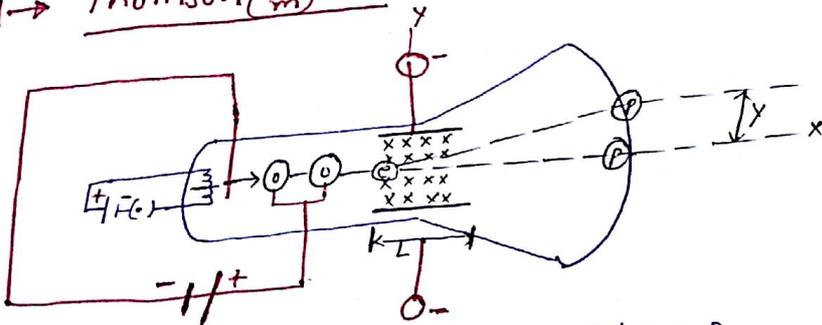
$$q = \frac{6\pi\eta r (v_1 + v_2)}{E}$$

radius of drop.
viscous const.

From eqn (1)

$mg - m'g = 6\pi\eta r v_1$
 $r = \sqrt{\frac{9}{2} \frac{n r v_1}{d\rho - d m}}$

1.2 → Thomson ($\frac{e}{m}$) Exp: →



1a) $a=0, B=0 \Rightarrow e^-$ strike at point P.

1b) $E \neq 0, B=0$

$x = ut \quad \text{--- (1)}$
 $t = \frac{x}{u}$

$y = \frac{1}{2} a t^2 \quad \text{--- (ii)}$

$y = \frac{eE}{2m} \frac{x^2}{u^2}$

$x=L$
 $\frac{e}{m} = \frac{2yu^2}{EL^2}$

1c) $E \neq 0, B \neq 0, e^-$ strike at point P'

$u = E/B$

$\frac{e}{m} = \frac{2yE}{B^2 L^2} = 1.78 \times 10^{11} \frac{C}{Kg m}$

'ATOMIC STRUCTURE'

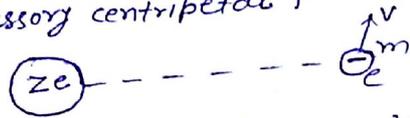
Spectrum of a matter.
 When a body is heated it emits radiation, which consist of various wave length, when these wavelength are plotted against a calibrated scale then, this part is called spectrum of matter.
 In case of Hydrogen radiation of 6562 \AA & then radiation 4860 \AA was observed, these lines denoted the spectrum of Hydrogen.

Bohr Model of Hydrogen-like atom → This model was developed specifically for hydrogenic atom which const of $1e^-$.
 Ex: → H-atom, He^+ , Li^{++}

NOTE → Although bohr model seems appropriate for hydrogen like atom & it is able to explain line of spectrum but still it doesn't give the true picture of even H-atom.
 The true picture is derived from quantum mechanics affair which is different from Bohr model in 2 fundamental way.

* 1st postulate →

- * Mass of nucleus is very large.
- * e^- is orbiting in circular orbit.
- * Necessary centripetal force is given by Coulombing attraction.



$$\frac{1}{4\pi\epsilon_0} \frac{ze^2}{r^2} = \frac{mv^2}{r} \quad \text{--- (1)}$$

$$* mv^2 = \frac{ze^2}{4\pi\epsilon_0 r} *$$

* 2nd postulate →

* Angular momentum of e^- is integral multiple of $\frac{h}{2\pi}$ or \hbar .

For nth orbit,
$$mvr = \frac{nh}{2\pi} \quad \text{--- (2)}$$

postulate: * While moving around these stable orbit charged particle does not emit any kind of electromagnetic radiation. Energy of e^- is const.

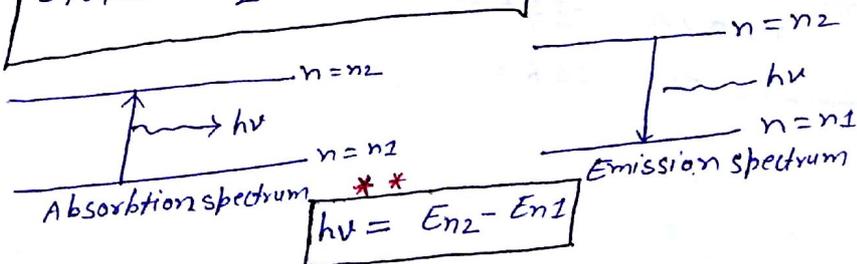
* 3rd postulate →

$$P.E = \frac{1}{4\pi\epsilon_0} \frac{ze^2}{r} \quad (\text{For nth orbit})$$

$$K.E = \frac{1}{2} mv^2$$

$$E_{\text{total}} = K.E + P.E = \text{const. for a stable orbit.}$$

$$E_{\text{total}} = \frac{1}{2} mv^2 - \frac{ze^2}{4\pi\epsilon_0 r}$$



* Radius of orbit \rightarrow

$$r = \frac{n^2 h^2 \epsilon_0}{\pi m z e^2} = 0.53 \frac{n^2}{z} \text{ \AA}$$

* velocity of e^- in n th orbit \rightarrow

$$v = 2.18 \times 10^6 \frac{z}{n} \text{ m/sec}$$

- ii) \rightarrow current in n th orbit $\propto z^2/n^3$
- iii) \rightarrow Time period of n th orbit $\propto n^3/z^2$
- iiii) \rightarrow Angular momentum (ω) $\propto z^2/n^3$
- liv) \rightarrow Magnetic Induction (B) $\propto z^3/n^5$
- lv) \rightarrow Magnetic moment (μ) $\propto n$

* current = $i = z \frac{v}{2\pi r} e$

* Time period = $T = \frac{2\pi r}{v}$

* $\omega = \frac{v}{r}$

* $B = \frac{\mu_0 i}{2r} \propto \mu_0 \frac{z^2}{n^3} \times \frac{z}{n^2}$

* $\mu = iA = i \times \pi r^2 \propto \frac{z^2}{n^3} \times \frac{n^4}{n^2} \propto n$

Total energy in n th orbit

$$PE = -\frac{1}{4\pi\epsilon_0} \frac{ze^2}{r}$$

$$K.E = \frac{1}{2} m v^2 = \frac{1}{2} \frac{ze^2}{4\pi\epsilon_0 r}$$

$$K.E = \frac{1}{2} |PE| = -\frac{1}{2} PE$$

$$E_n = \text{Total energy} = K.E + PE = \frac{PE}{2} = -\frac{ze^2}{8\pi\epsilon_0 r}$$

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

$$= 13.6 = R h c$$

$$1 \text{ Rydberg Energy} = 13.6 \text{ eV} \Rightarrow R = \frac{2\pi^2 m k^2 e}{ch^3}$$

$$\text{Rydberg const} = R = \frac{2\pi^2 m k^2 e^4}{ch^3} = 1.09 \times 10^7 \text{ m}^{-1}$$

Different Energy level:

_____ $n=3, E_3 = -\frac{13.6 z^2}{9}$

_____ $n=2, E_2 = -\frac{13.6 z^2}{4}$

_____ $n=1, E_1 = -13.6 z^2$

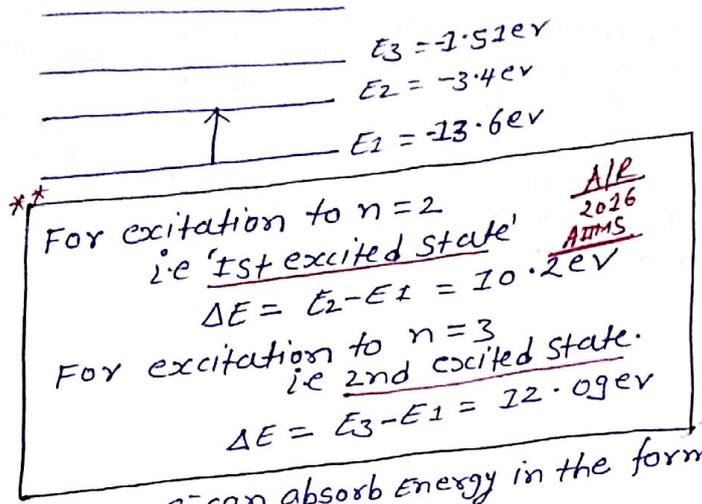
** → For H-atom →

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$$\begin{aligned}
 E_1 &= -13.6 \text{ eV} \\
 E_2^* &= -3.4 \text{ eV} \\
 E_4 &= -0.85 \text{ eV} \\
 E_5 &= -0.54 \text{ eV}
 \end{aligned}$$

Excitation of e^- in an atom → Whenever an e^- in lower energy state or ground state get some energy from external source, it may make a transition to a energy level, this process is called excitation & the upper or, higher energy state of e^- is termed as excited state.

For Ex - Hydrogen atom



e^- can absorb energy in the form of photon or, form of colliding particle -

- ii) → From photon → An e^- will absorb photon only of the energy $10.2 \text{ eV}, 12.09 \text{ eV}, 12.75 \text{ eV}$ - - - for its excitation.
- iii) → From colliding particle → The collision with the colliding particle must be inelastic so that K.E lost during the collision can be used to excite the atom.

We can use following Law -

- 1a) → conservation of Linear momentum.
- 1b) → conservation of Energy.

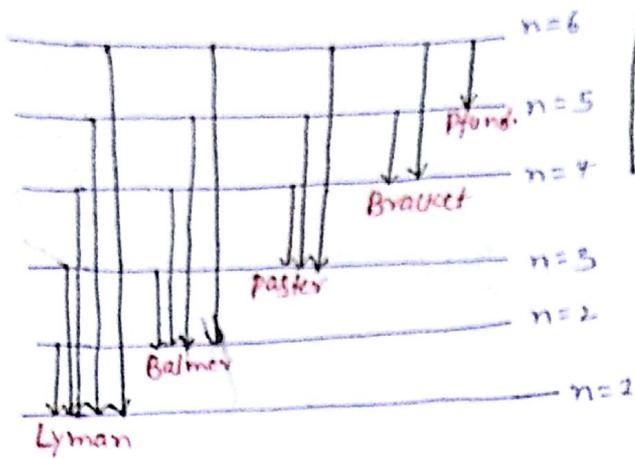
Ionisation Energy or, Ionisation potential : → For H-atom.
 Min energy needed to remove the e^- from

ground state.

$E = 13.6 \text{ eV} \Rightarrow \text{B.E of } e^-$

Ionisation pot. is the min pot. through which an e^- must accelerate before making collision with the e^- of H-atom to knock out it.

Spectral line of H-atom



NOTE →
* For e^- in n th state, spectral line = $n-1$
* Max no. of photon emitted = $n-1$

NOTE → * No two elements will have identical spectral lines, since no two elements have identical energy levels. Therefore they are described as fingerprints of atoms differing from each other like fingerprints of humans.
* In H-atom an e^- jumps from six energy levels to 1st excited state. The no. of lines corresponding to the Lyman series are → zero, because e^- is not jumping in ground state.

'COMMUNICATION SYSTEM'

COMMUNICATION → It is process of transmission of information from one place to another place without distortion.

Each & Every communication system have 3-basic part.

ii) → Transmitter → It is source of information which propagate the information towards the distant end with via communication channel.

iii) → Receiver → It is device which receive the information from communication channel which transmitted by transmitter.

iiii) → Communication channel → It is medium in b/w transmitter & receiver & receiver which propagate the signal from one place to another place.



Classification of communication system

on the basis of Information →

1) → voice communication → Eg → Radio, Mobile, Telephone, T.V

2) → picture communication → Eg → T.V, Internet, mobile.

3) → Document communication → Eg → FAX (Facsimile transmission)

4) → code communication → Eg → Internet, telegraphy.

on the basis of signal →

ii) → Analog communication.

iii) → Digital communication.

on the basis of channel → (20 Hz to 20 KHz)

$$I = (P/A) \propto a^2 f^2$$

1) → Line communication

1a) → two wire communication

1b) → co-axial "

1c) → optical fibre

2) → Wireless communication

2a) → Ground wave propagation

2b) → Sky wave propagation

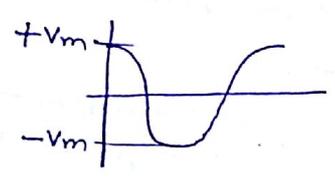
2c) → Space wave propagation.

On the basis of Modulation (MHz to GHz)

$$y = A \sin(\omega t + \phi)$$

- ii) → Amplitude Modulation (A.M)
- iii) → Frequency Modulation (F.M)
- iiii) → Phase Modulation (P.M)

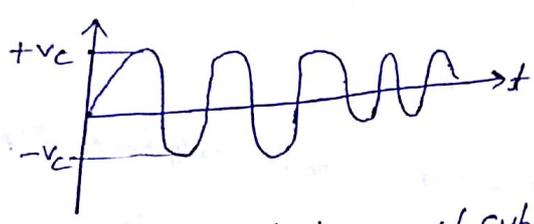
1) → Message signal → only electricity which contain the information.



$$V_m = V_m \cos \omega_m t$$

↳ 20 Hz to 20 KHz

2) → carrier wave → It is a high frequency wave which propagate the message signal from one place to another place without distortion.



$$V_c = V_c \cos(\omega_c t + \phi)$$

↳ MHz to GHz

Modulation → It is process of superimposing of low frequency msg. signal (20 Hz to 20 KHz) over high frequency carrier wave (MHz to GHz) or, variation in Amplitude or, frequency or, phase of carrier wave a/c to the msg. signal is known modulation.
Modulation is 3-type

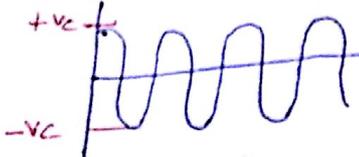
1) → A.M → to change in amplitude of carrier wave a/c to msg. signal by keeping the phase & Freq const

1a) → Message signal →



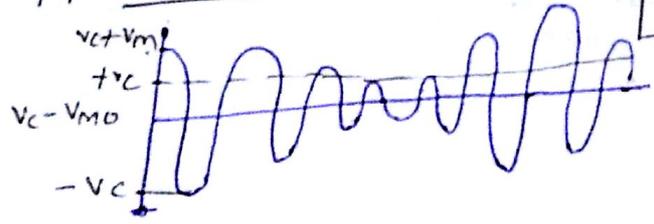
$$V_m = V_m \cos \omega_m t$$

1b) → carrier wave →



$$V_c = V_c \cos \omega_c t$$

1c) → A.M Wave →



$$V_{AM} = (V_c + V_m \cos \omega_m t) \cos \omega_c t$$

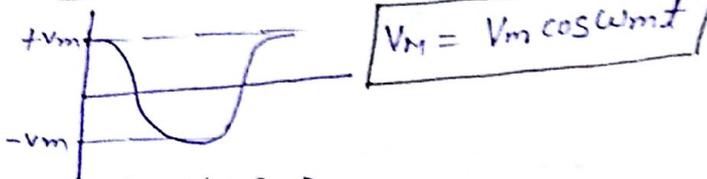
$$P_T = P_c \left(1 + \frac{m^2}{2}\right)$$

P_T = total power require to transmission A.M Wave from Radio station.

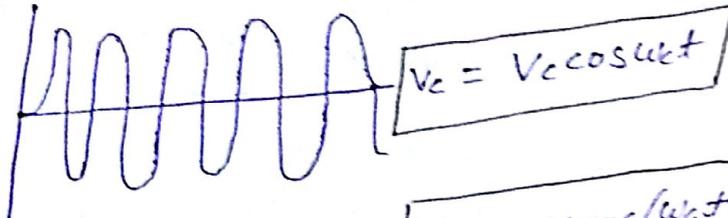
P_c = power carrier.

12) \rightarrow F.M \rightarrow to change in the frequency in the carrier wave a/c to the message signal by keeping the amplitude & phase const.

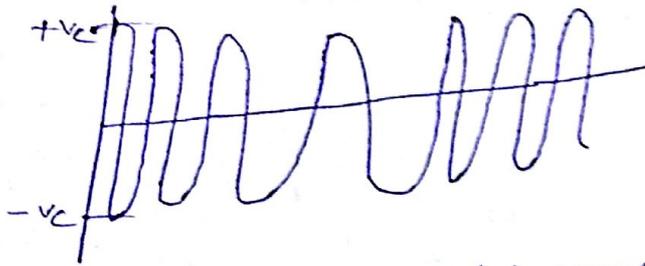
11) \rightarrow Message signal \rightarrow



12) \rightarrow Carrier wave \rightarrow



13) \rightarrow F.M Wave \rightarrow



* F.M radio is true only in range 88 MHz to 108 MHz
 AMU 2026 * Any unwanted signal is known as the noise.

Comparison b/w A.M & F.M

A.M

- * Cost of A.M radio station is low bcoz its transmitter ckt is not complex.
- * In A.M we are adding the signal (voltage) In Amplitude (voltage)
- * Less frequency band width is required so can transmit more no. of signals at a time.
- * Here noise corruption is easy so quality of signal is not so good.
- * Range of A.M radio is less.

F.M

- * Cost of F.M radio station is very high bcoz its transmitter ckt is very complex.
- * In F.M we are adding the signal (voltage in frequency).
- * More frequency band width is required so we can transmit less no. of signals at a time.
- * Here noise corruption is not easy so, quality of signal is very good.
- * Range of F.M radio is more.

* → For good reception of signal, height of antenna must be $\lambda/4$

Need of Modulation →

1a) → To increase the power of signal → When we shift the low freq. over high freq. carrier wave than freq. of signal is ↑ so power of signal is ↑ so we can transmit the signal over longer distance without distortion.

1b) → To make the height of Antenna practical →

* Before Modulation (20Hz to 20KHz)

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{10 \text{ KHz}} = 3 \times 10^4 \text{ m} = 30 \text{ km}$$

$$\text{height of Antenna} = \lambda/4 = 7.5 \text{ km}$$

* After Modulation (MHz to GHz)

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{20 \text{ MHz}} = 15 \text{ m} \quad \text{height of antenna } (\lambda/4) = 3.75 \text{ m}$$

1c) → To avoid the mixing of noise & signal → noise & voice both are lies in same frequency range, so, large chance of interference b/c freq. gap is less but as we modulate the signal (voice) freq. gap b/w voice & noise is ↑ so less chance of mixing & interference.

1d) → To avoid the mixing of signal which are transmitted from diff transmitter → When large no. of signals are lies in short range (20Hz to 20KHz). so freq. gap b/w signal is less so, large chance of interference (mixing). but when these signals are shifted over large freq. range (MHz to GHz). so freq. gap ↑ so less chance of mixing.

Wireless communication → propagate without wire information

is in the form of EMW.

1a) → ground wave propagation

1b) → sky wave propagation (Ionosphere)

1c) → space wave propagation.

Space Wave propagation (Line of sight communication)

Here, EMW (signal) is transmitted from transmitting antenna to receiving antenna in straight line so, it is only possible up to that distance there is no obstacle b/w them.

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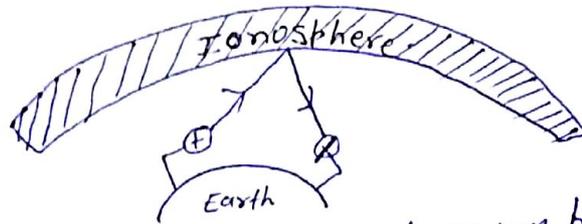
$$d = \sqrt{2h_1R} \quad d \propto h^{3/2}$$

$$d = \sqrt{2h_1R} + \sqrt{2h_2R}$$

→ If two tower than add.

Sky Wave propagation → Here, signal (EMW) are transmitted from transmitting antenna towards the sky. It is reflected back from ionosphere by T.I.R phenomena towards receiving antenna. Those signals which have freq. in ($< 30\text{MHz}$) is reflected from ionosphere.

Those signal have freq $> 30\text{MHz}$ refracted from ionosphere (not reflected) from ionosphere and for it satellite is used as a reflector.



**critical freq (f_c) → max freq. of sky wave propagation up to that the reflection from ionosphere will detect place or, just after that signal is reflected.

It depend on ion density of that place & its value

$$f_c = 9\sqrt{N_0}$$

N_0 → max ion density ($\frac{\text{ion}}{\text{m}^3}$)

sky wave propagation is possible $f \leq f_c$

$$N_0 = \frac{f_c^2}{81}$$