'RADIOACTIVITY'

* Exergonic Reaction (Energy Release).

Property or, process by which disintegration or, decay of unstable nucleus takes place with emission of α, β or γ ray rays.

!! * It is nuclear event not atomic & remain unchange with pressure, temp. or, any other physical or, chemical change.

* Ist order Reaction but Ist order ~~...~~ का कोई concept apply मत करो (Mind मत लगाना After study chemical kinetics).
* Random process.
* Nuclear configuration in Radioactive emission change but atomic configuration Remain same.

AIIMS * Proton never emitted by Radioactive substance during decay.

Decay to maintain $\frac{n}{p}$ ratio –

|1| → If $\frac{n}{p}$ ratio is greather than the required value for stability, β^- emision takes place.

|2| → If n/p ratio is less than the required value for stability α-decay, β^+ decay or, e^- capture takes place.

|3| → During Radioactive reaction or, nuclear reaction a nucleus in higher quantum state emit γ-ray & comes in lower quantum state.

[A] → α-emission → 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'

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

$$_{Z}X^{A} \longrightarrow {}_{2}He^{4} + {}_{A-2}Y^{A-4} + \text{Energy.}$$

Parent nucleus

Daughter nucleus / Remain nucleus / Product nucleus.

$N_p = Z$
$N_n = A - Z$

$\boxed{N_n - N_p = A - 2Z}$ two

$N_p = Z - 2$
$N_n = (A-4) - (Z-2)$
$= A - Z - 2$

$\boxed{N_n - N_p = A - 2Z}$

Isodiapher (no of neutron & proton same)

* Linear Momentum conservation.

$$V_D \leftarrow {}_{Z-2}Y^{A-4} = {}_{Z}X^{A} \rightarrow {}_{2}He^{4} \rightarrow V_\alpha$$

$$\boxed{\vec{P_D} = -\vec{P_\alpha} \Rightarrow |\vec{P_D}| = |\vec{P_\alpha}|}$$

AIIMS $\boxed{V_D = (-)\left(\frac{4}{A-4}\right)V_\alpha}$ *

Direction.

* Requile K·E of Daughter nucleus / Energy α-particle & D-nucleus

$$_ZX^A \longrightarrow {_2He^4} + {_{Z-2}Y^{A-4}} + E\ (Q\text{-value})$$

$$Q = K\cdot E_\alpha + \left(\frac{m_\alpha}{m_D}\right)K\cdot E_\alpha \Rightarrow K\cdot E_\alpha = \left(\frac{m_D}{m_D+m_\alpha}\right)Q = \left(\frac{A-4}{A}\right)Q$$

$$\boxed{K\cdot E_D = \left(\frac{m_\alpha}{m_\alpha+m_D}\right)Q = \left(\frac{4}{A}\right)Q}$$

$$\boxed{\frac{4}{A} <<< \Rightarrow K\cdot E_D << Q}$$

$$\boxed{\begin{aligned} K\cdot E_D &= \left(\frac{4}{A}\right)E <<< E \\ K\cdot E_\alpha &= \left(\frac{A-4}{A}\right)E \simeq E \end{aligned}}$$

* Grieger-Mular formula

$$\boxed{\log \lambda = A + B \log R}$$

λ → decay const of R·A; R → Range.

$$\boxed{R \propto (E_\alpha)^{3/2} \propto V_\alpha^3}$$

NOTE → * Release energy distribute in form of K·E & Approx. 99% part transfer to α-particle & remaning to daughter nucleus.

!! * K·E & velocity of α-particle is charasteristic of nucleus i.e vary nucleus to nucleus.

In α-Decay- ($_2He^4$)

- Atomic no. decrease by 2.
- Mass no. decrease by 4.
- No. of proton & neutron change by same amount.
- $\frac{n}{p}$ ratio increase.

[B] → β-emission
- → β^+ ($_{+1}e^0$) (positron)
- → β^- ($_{-1}e^-$) (electron)

NOTE → * β-particle is also called e which is comes out from nucleus. β-particle is not define consider β⊖ve. that's why type of β-particle is explain from weak nuclear interaction b/w proton & neutron.

* β-emission is explain from weak nuclear interaction b/w proton & neutron. & proton convert into neutron or, vice-versa. & emit β-particle.

2016 III

(i) → β^+ Emission ($_{+1}\beta^0$ or, $_{+1}e^0$) positron

$$\underset{\text{proton}}{_1H^1} \longrightarrow \underset{\text{neutron}}{_0n^1} + {_{+1}e^0}(\beta^+) + \nu\ (\text{nutrino})$$

$$\boxed{\underset{\text{parent nucleus}}{_ZX^A} \longrightarrow \beta^+(_{+1}e^0) + \underset{\text{Daughter nucleus}}{_{Z-1}Y^A} + \nu}$$

NOTE → Imp * It is particle whose all the properties are similar to electron, but it has a charge of $q = +1.6 \times 10^{-19}$ C.

- * Atomic no. +se.
- * Mass no. does not change.
- * $\frac{n}{p}$ ratio ↑se. [p ↓ by one & n ↑ by one]
- * A proton inside the nucleus convert it self into a neutron & positron.

* 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.

$$\boxed{{}_{Z}X^{A} \longrightarrow {}_{Z-1}Y^{A} + {}_{+1}\beta^{0} + \nu}$$

$$\boxed{Q = (\underbrace{m_x - m_y}_{\text{Mass of nuclei}} - m_e)c^2}$$

M_x = Mass of ${}_{Z}X^{A}$ atom
M_y = Mass of ${}_{Z-1}Y^{A}$ atom
m_e = Mass of e^-

$$\boxed{Q = (M_x - M_y - 2m_e)c^2}$$

(ii) → β^- Emission $(_{-1}\beta^{0})$ or, $(_{-1}e^{0})$

$${}_{0}n^{1} \longrightarrow {}_{1}H^{1} + {}_{-1}e^{0} + \bar{\nu} \text{ (Antineutrino)}$$

$${}_{Z}X^{A} \longrightarrow \beta^-({}_{-1}e^{0}) + {}_{Z+1}Y^{A} + \bar{\nu}$$

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

	$\nu/\bar{\nu}$	photon
* q →	0	0
* A →	0	0
* m →	Negligible	
* spin →	$\pm\frac{1}{2}$	+1

** * 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.

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

** $\left(\frac{N}{P}\right)$ → $\beta^+ \left(\frac{N}{P}\uparrow\right)$ (stability ↑); $\beta^- \left(\frac{N}{P}\downarrow\right)$ (stability ↓)

* In α-emission neutron & proton ratio must ↑ but in β-emission It may be ↑/↓.

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

M_x = Mass of ${}_{Z}X^{A}$ atom
M_y = mass of ${}_{Z+1}Y^{A}$ atom.
m_e = mass of e^-

$$Q = (\underbrace{m_x - m_y}_{\text{Mass of nuclei}} - m_e)c^2$$

$$\boxed{Q = [M_x - M_y]c^2}$$

* → Atomic no. increase by 1.
* → Mass no. doesn't change.
* → $\frac{n}{p}$ ratio decrease. (p ↑ is by 1 & n ↓ by 1)

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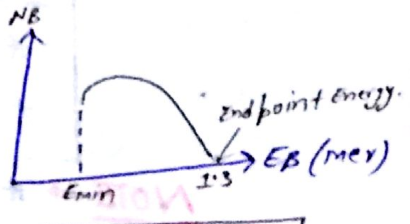
Energy spectrum of β-particle →

Diff energy of β-particle which is emitted from same Radioactive substance is explain with linear Momentum conservation.



$${}_{Z\pm1}Y^{A} \equiv {}_{Z}X^{A} \rightarrow \beta^+/\beta^-, \ \nu/\bar{\nu}$$

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

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

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A → β-particle Energy spectrum is continuous.
R → β-decay is a spontaneous statical process.
Ans → A

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

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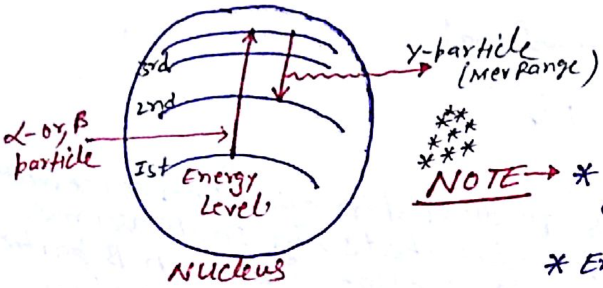
[C] γ or, γ Emission $[{}_0n^0]$ →

$${}_ZX^A \longrightarrow {}_0n^0(\gamma\text{-particle}) + {}_ZX^A$$

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 wich 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 → * Emission of γ-particle is takes place after emiting α or, β-particle.

* Emission of α- & β-particle not takes place simultaniously.
* Emission of 2 particle simultaniously not possible from same nucleus.

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

→ γ, α ✗	→ $\beta, \gamma, \alpha, \gamma$ ✓
→ γ, β ✗	→ $\alpha\ \beta, \gamma$ ✗
→ α, β, γ ✗	→ $\alpha, \beta, \gamma, \gamma$ ✗
→ β, α, γ ✗	→ β, γ, γ ✗
→ $\alpha, \gamma, \beta, \gamma$ ✓	

#

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

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

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

IIT 2016 ***

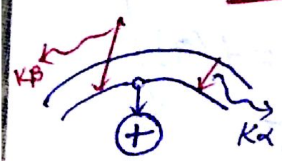
Electron kepture or, K-epbture →

Nucleus pulls an e^- from K-shell. Inside the nucleus & a proton combines with this e^- to ↑ $\frac{n}{p}$ ratio.

***
* Atomic no. ↓ by 1.
* Mass no. does not change.
* $\frac{n}{p}$ ratio ↑.
* p ↓ by 1 & n ↑ by 1.

NOTE → * 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.



$$q = (\underbrace{m_x + m_e - m_y}_{\text{mass of nucli}})c^2$$

** $\boxed{q = [M_x - M_y]c^2}$

Rutherford - sodi law or, Disintegration law →

Disintegration rate ∝ to active nucleus (Amt) at that instant.

***

$$\boxed{\left(-\frac{dN}{dt}\right) = \lambda N}$$

D.I Rate ← $-\frac{dN}{dt}$; Disintegration Rate ; N → Active nucleus ; λ → Decay / Disintegration const.

$$\boxed{\lambda = \frac{1}{N}\left(-\frac{dN}{dt}\right)}$$

unit → sec^{-1}, min^{-1}, $hour^{-1}$, day^{-1}, $mounth^{-1}$.

***
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
  - $\lambda = 0$
  - $T_{1/2} = \infty$
    * $T_{1/2} = \frac{0.693}{\lambda}$
  - $T_m = \infty$

Relation b/w Active nucleus & Time →

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

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

N → Active nucleus At time 't' ; N_0 → Initial Active nucleus.

* Active nucleus at time 't' ⇒ $\boxed{N = N_0 e^{-\lambda t}}$
* " " " $t = 0$ ⇒ $\boxed{N_0}$
* Disactive nucleus at time 't' = $N' = N_0 - N$; $\boxed{N' = N_0(1 - e^{-\lambda t})}$

* Active Mass at $t = 0$ ⇒ $\boxed{M_0}$
* " " $t = t$ ⇒ $\boxed{M = M_0 e^{-\lambda t}}$
* Disactive mass at time 't' ⇒ $\boxed{M' = M_0 - M = M_0(1 - e^{-\lambda t})}$

***
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 'λ', faster is the decay of Radioactive sample.

Packing fraction (f) →

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

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

Special condition

$\lambda <<< 1$ (short Range)

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

$L^1 = 1$

$L^2 = 2 \times 1$

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

⋮

$L^n = n(n-1)(n-2) - - - - 1$

*****

BASIC DEFINATION

|i|→ Half life ($T_{1/2}$ or, $t_{1/2}$)

|ii|→ Mean life (T_m)

|iii|→ Activity (R)

|iv|→ Specific Activity (R_{gm})

|i|→ Half life → Time in wich active nucleus Remain 50% or, half of Initial value.

***

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

*****
NOTE → If half life of sample is given as $t_{1/2}$

at $t = 0$, $N = N_0$

at $t = t$, $N = N$

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

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

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

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(ii) → **Mean life** → Time in which active nucleus remain 37% of Initial Value or, disintegrate 63% call mean life.

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

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

* $T_m = \frac{1}{\lambda}$
* $T_{1/2} = \frac{0.693}{\lambda}$
* $T_m > T_{1/2}$
* $T_{1/2} = 0.693\, T_m \simeq 69.3\%$ of T_m
* $T_m = 1.44\, T_{1/2} \simeq$ More than 44% $T_{1/2}$.

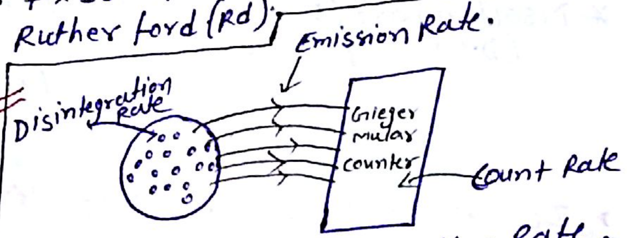
(iii) → **Activity (R)** → Disintegration Rate of Radioactive substance.

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

*** **unit** → * 1 D.P.S (Disintegration per sec) = 1 Bq (Baqurel) (S.I)
* 1 cu (curi) = 3.7×10^{10} dps. (C.G.S)
* practicall unit → Ruther ford (Rd)
* 1 Rd = 10^6 Bq.
* 1 mcq = 37 Rd

(milicuri)

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



* Activity = Disintegration Rate
  ||
* Count Rate = Emission Rate.

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

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

M = 1gm , R = Rgm

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

(A ↑ gm)

*** # **Standard Result** –

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

1 gm = 1 cu
X gm = X cu
1 mgm = 1 mcu

Prob. based on Radioactivity →

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

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

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

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

* n = no. of half life.
* Time in 'n' half life ⇒ $t = \boxed{n T_{1/2}}$
* Active value after 'n' half life $= X = \boxed{\frac{X_0}{2^n}}$
* Disactive " " " " $X' = -X = \boxed{X_0\left(1 - \frac{1}{2^n}\right)}$
* Active part (AP) / Active fraction (A·fr) / probability of Activness (A·A) or, Probability of survival (P·S) $= \boxed{\frac{X}{X_0} = \frac{1}{2^n}}$
* Disactive part (D·P) / Disactive fraction (D·fr) / probability of Disactivness (P·D) or Probability of death (P·D) $= \boxed{\frac{X'}{X_D} = 1 - \frac{1}{2^n}}$

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

$$X_0 \xrightarrow{T_m} \frac{X_0}{e^1} \xrightarrow{T_m} \frac{X_0}{e^2} \xrightarrow{T_m} \frac{X_0}{e^3} - - - - \xrightarrow{T_m} \frac{X_0}{e^n}$$

* n = no. of mean life.
* Time in 'n' Mean life $= t = \boxed{n T_m}$
* Active value After 'n' Mean life $= X = \boxed{\frac{X_0}{e^n}}$
* Disactive " " 'n' " " $= X' = X_0 - X = \boxed{X_0\left(1 - \frac{1}{e^n}\right)}$
* A·P / A·fr / P·A / P·S → $\boxed{A{\cdot}P = \frac{X}{X_0} = \frac{1}{e^n}}$
* D·P / D·fr / P·D / D·D → $\boxed{D{\cdot}P = \frac{X'}{X_0} = 1 - \frac{1}{e^n}}$

$$\boxed{A{\cdot}P + D{\cdot}P = 1}$$

Case III → If Active part not in complete Multiple of Half →

$$\boxed{t = 3.32\, T_{1/2} \log_{10} (1/A{\cdot}P)}$$

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 as 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 $\underset{\text{Active}}{C^{14}} : \underset{\text{disactive}}{C^{12}} = \boxed{1:1}$

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

* Age of sample $\boxed{t = 3.32 \left(T_{1/2}\right)_{C^{14}} \log_{10}\left(\dfrac{1}{A \cdot P}\right)}$ **

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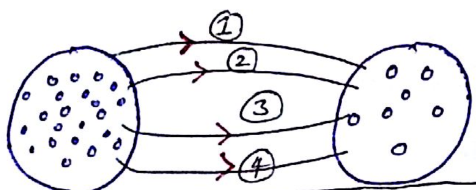
* $T_{1/2}$ of C^{14} is 5700 or, 5730 yrs.
* $T_{1/2}$ of α is 12 yrs
* $T_{1/2}$ of β is 3 yrs

IVI → CASE V → Radioactive branching concept →

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



* $$\left(-\frac{dN}{dt}\right)_{net} = \left(-\frac{dN}{dt}\right)_1 + \left(-\frac{dN}{dt}\right)_2 + \cdots + \left(-\frac{dN}{dt}\right)_{Net}$$

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

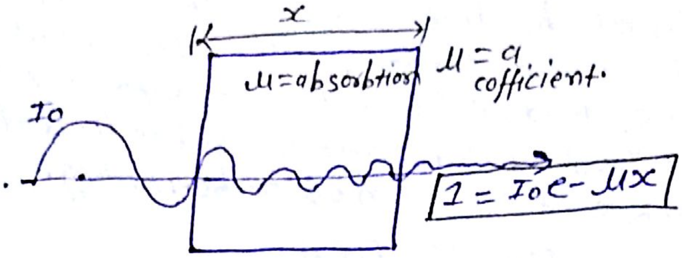
$$\lambda_{net} = \lambda_1 + \lambda_2 + \lambda_3 \cdots + \lambda_N$$

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

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

Case VI → Absorbtion of Radiation or, Absorption of X-ray →

Intensity of Radiation ↓ exponentially w.r.t thickness of material.



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

$I = I_0^{-\lambda t}$ (Thickness) $I = I_0 e^{-\mu x}$

$t \rightleftharpoons x$

$\lambda \rightleftharpoons$ ab. cofficient

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

(ii) → Mean life $= T_m = 1/\lambda$

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

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

(V) → $A.P_2 = (AP_1)^{t_2/t_1}$

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

(ii) → Mean thickness $= 1/\mu$

(iii) → $x = n\, x_{1/2}$ ↑ no. of half thickness.

(iv) → $x = 3.32\, x_{1/2} \log_{10} (1/A.P)$

(V) → $A.P_2 = (AP_1)^{x_2/x_1}$

* penetration power → $\boxed{\alpha < \beta < \gamma}$ velo. of light

$\frac{1}{10}$ $\frac{1}{3}$ to $\frac{9}{10}$