Session-39th - Modern Physics-III.

(RA) Radioactivity - Rutherford-Soddy Theory (1902)

① Nuclear Phenomena

↳ RA doesn't depend upon e^- config.

→ RA decay can't altered by physical (T & P) & chemical means

↳ concentration.

$X + Y \rightarrow XY$

RA NRA

↓ chemical & RA properties are independent.

② Statistical nature

RA substance.

1). Out of billions & trillions of RA nuclei, which one will decay first is just a matter of chance.

2) We can't comment on what kind of decay ($\alpha/\beta/\gamma$) may happen.

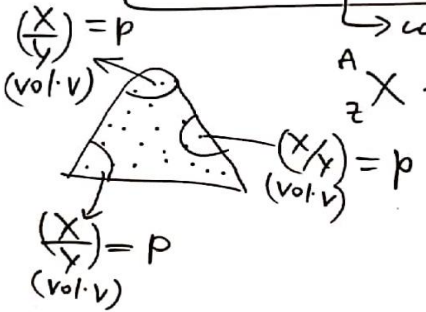
3) RA is purely a random process

4). Due to randomness, there is a uniformity also.

↓

(No. of disintegration/sec)/m^3

↳ constant.



$^{A}_{Z}X \rightarrow Y + Q$

$+\alpha$

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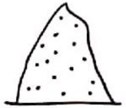
(RA) Radioactivity - Rutherford-Soddy Theory (3 points) (1902)

③ Exponential Decay → The rate of decay of RA nuclei is proportional to the number of RA nuclei present at any given time.

$X \rightarrow Y + Q$



@ $t=0$, N_0 Nuclei of X

@ $t=t$, N Nuclei of X

rate of decay @ $t=t$ → $\frac{dN}{dt}$

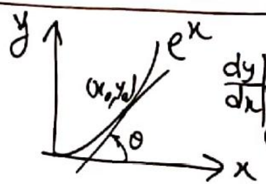
$$\boxed{\frac{dN}{dt} \propto N}$$

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

λ → (decay constant); $-\frac{dN}{dt}$ → (+ve)

$\lambda \rightarrow 0 \Rightarrow$ Non RA mat

$\lambda \uparrow \Rightarrow$ RA ↑



$\frac{dy}{dx}$ → $\tan\theta$ @ x_0

$$\boxed{\frac{d}{dx}(e^x) = e^x}$$

N → Number of active nuclei present

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

$$\Rightarrow \int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_{t=0}^{t} dt$$

$$\Rightarrow \ln N \Big|_{N_0}^{N} = -\lambda t$$

$$\Rightarrow \ln(N/N_0) = -\lambda t$$

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

$$\frac{dN}{dt} = \frac{d}{dt}\left(N_0 e^{-\lambda t}\right) = N_0(-\lambda)e^{-\lambda t} = -\lambda N$$

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

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

$$\boxed{\text{Activity, } A = -\frac{dN}{dt}} \quad \boxed{= \lambda N}$$

A → (+ve)

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① Half life →

It is the amt. of time in which the no of active nuclei of a RA substance will become half of their original (@t=0) number.

$X \rightarrow Y + Q$

@t=0: N_0, 0

@t = $t_{1/2}$: $N_0/2$, $N_0/2$

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

$\frac{N_0}{2} = N_0 e^{-\lambda t_{1/2}}$

$\frac{1}{2} = e^{-\lambda t_{1/2}}$

$-\ln 2 = -\lambda t_{1/2}$

$\Rightarrow \boxed{t_{1/2} = \frac{\ln 2}{\lambda}}$

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

Q.1. $X \rightarrow Y$

10^8 Nuclei

$t_{1/2} = 10$ hrs.

after 20 hrs, how many X nuclei will be there

(A) 0
(B) 10^4
(C) $10^8/2$
✓(D) $10^8/4$

in 10 hrs.

$X \rightarrow$

10^8 @t=0 → $\left(\frac{10^8}{2}\right)$ @t = 10 hrs → $(10^8/2)/2 = (10^8/4)$ @t = 20 hrs.

After a long time → X → 2 nuclei

Q.2. After how much time, only 1 nucleus will remain?

(A) 10 hrs (B) 20 hrs (C) ∞ time (D) can't comment.

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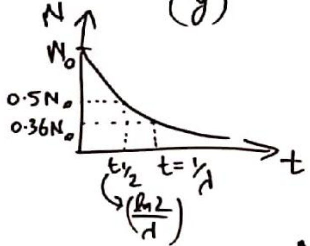
Q.3. X → Y a). Plot no. of active nuclei with time t.

$N_0 = 10^8$ nuclei @ $t=0$ b). —"— decayed nuclei (y) —"—

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

N → No. of active nuclei of X



@ $t = 1/\lambda$

$$N = N_0 e^{-1} = N_0/e = 0.36\,N_0$$

No. of decayed nuclei of X = $N_0 - N$

$$N' = N_0 - N_0 e^{-\lambda t}$$

$$N' = N_0(1 - e^{-\lambda t})$$

N' → No. of y nuclei produced.