RADIOACTIVITY

Radioactivity is a nuclear phenomenon in which an unstable nucleus undergoes a decay. This is referred to as radioactive decay. Three types of radioactive decay occur in nature :

(i) α -decay in which a helium nucleus He_4 is emitted;

(ii) β -decay in which electrons or positrons (particles with the same mass as electrons, but with a charge exactly opposite to that of electron) are emitted;

(iii) γ-decay in which high energy (hundreds of keV or more) photons are emitted.

Law of radioactive decay

If N is the number of nuclei in the sample and ΔN undergo decay in time Δt then

$\Delta N / \Delta t \propto N$ or, $\Delta N/\Delta t = \lambda N$,

where λ is called the radioactive decay constant or disintegration constant.

Thus the rate of change of N is (in the limit $\Delta t \rightarrow 0$)

$$\frac{dN}{dt} = -\lambda N \qquad \text{or,} \quad \frac{dN}{N} = -\lambda dt$$

Now, integrating both sides of the above equation,we get,

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_{t_0}^{t} dt$$

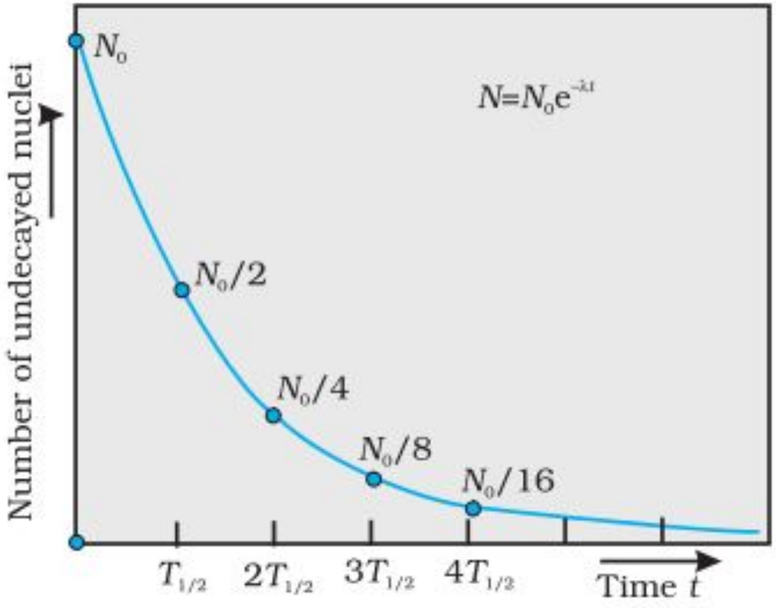
$$\text{or,} \quad \ln N - \ln N_0 = -\lambda (t - t_0)$$

Here N_0 is the number of radioactive nuclei in the sample at some arbitrary time t_0 and N is the number of radioactive nuclei at any subsequent time t.

$$\ln \frac{N}{N_0} = -\lambda t$$

which gives

$$N(t) = N_0 \, e - \lambda \, t$$



The total decay rate R of a sample is the number of nuclei disintegrating per unit time.

The positive quantity R is then defined as $R = -\frac{dN}{dt}$

$$R = \lambda N_0 \, e^{-\lambda t}$$

$$\text{or,} \quad R = R_0 \, e^{-\lambda t}$$

The decay rate R at a certain time t and the number of undecayed nuclei N at the same time are related by **$R = \lambda N$**

1 becquerel is simply equal to 1 disintegration or decay per second.

There is also another unit named “curie” that is widely used and is related

to the SI unit as:

1 curie = 1 Ci = 3.7 × 1010 decays per second

= 3.7 × 1010 Bq

After a lapse of $T_{1/2}$, population of the given species drops by a factor of 2.

Half-life of a radionuclide (denoted by $T_{1/2}$) is the time it takes for a sample that has initially, say N0 radionuclei to reduce to $N_0/2$. Putting

$N = N_0/2$ and $t = T_{1/2}$

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

average or mean life τ

Another related measure is the average or mean life τ .

The number of nuclei which decay in the time interval **t** to **t+Δt** is

R = λN

ie $R(t)\Delta t$ $(= \lambda N_0 e^{-\lambda t} \Delta t)$.

To obtain the mean life, we have to sum (or integrate) this expression over all times from **0 to ∞** , and divide by the total number N_0 of nuclei at t = 0. Thus,

$$\tau = \frac{\lambda N_0 \int_0^\infty t e^{-\lambda t} \mathrm{d}t}{N_0} = \lambda \int_0^\infty t e^{-\lambda t} \mathrm{d}t$$

One can show by performing this integral that **$\tau = 1/\lambda$**

We summarise these results with the following:

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