VIVEKANANDA COLLEGE
THAKURPUKUR
KOLKATA-700063

NAAC ACCREDITED ‘A’ GRADE

Topic: Radioactivity

Course Title: Elements of Modern Physics

Paper: PHS-A-CC-4-9-TH

Unit: 4

Semester: 4

Name of the Teacher: Dr. Nirmalya Pahari

Name of the Department: Physics

Radioactivity:
Stability of the nucleus;
Law of radioactive decay;
Mean life and half-life;

Radioactivity:

The substances that spontaneously emit some particle or radiation due to disintegration of their nucleus is known as radioactive substance and this process is known as radioactivity.

Radioactive decay laws:

Displacement law (Soddy): When α-particle emits From a radioactive substance its mass number is Decreased by 4 and atomic number is decrease by 2, as a result a new nucleus will be formed i.e. the substance displaced their position in the periodic table.

$$ {}_{Z}^{A}X \rightarrow {}_{Z-2}^{A-4}Y + {}_{2}^{4}He $$

Similarly, when β⁻ particle emits from a radioactive atom its mass number remain unchanged but its atomic number is increased by 1.

$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e $$

Again, when β⁺ particle emits from a radioactive atom its mass number remain unchanged but its atomic number is decrease by 1.

$$ {}^{A}_{Z}X = {}^{A}_{Z-1}Y + {}^{0}_{+1}e $$

(ii) Disintegration law (Soddy's)

According to Soddy's disintegration law the rate of disintegration of a radioactive substance is Proportional to the number of atoms present at that instant.

Let N_o be the number of atoms present at t=o

Due to disintegration after time t the number of aton present is N.

The rate of disintegration at time t is proportional to N i.e.

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

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

Where λ is a constant

Disintegration constant of the radioactive substance

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

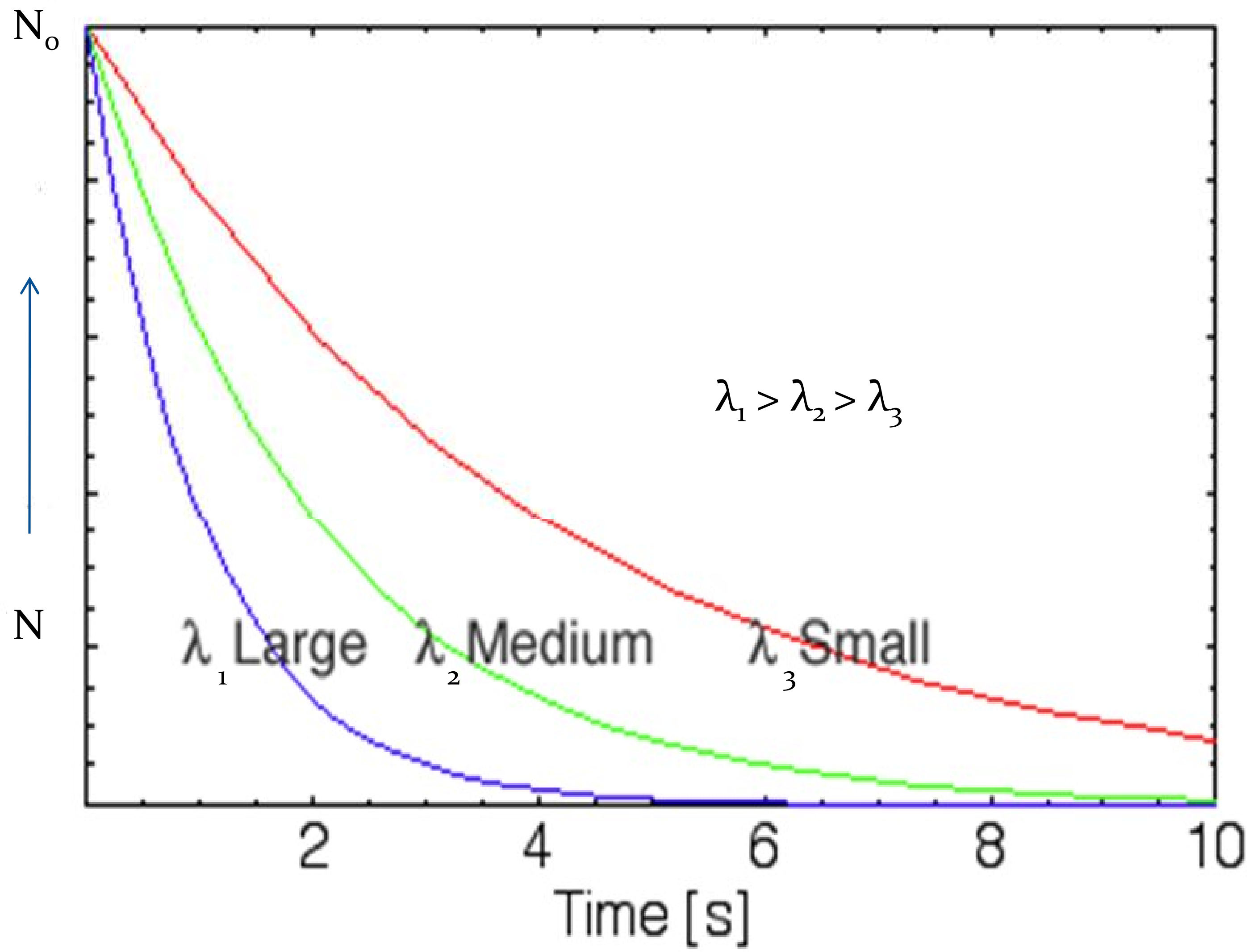
Integrating we get

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

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

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

This equation indicates that the number of atoms exponentially decreases as shown in the graph. The number of radioactive atoms decreases rapidly at first, then more and more slowly, as time goes on. The rate of disintegration is large as $\boldsymbol{\lambda}$ is large.



N_o
N
$\lambda_1 > \lambda_2 > \lambda_3$
λ_1 Large
λ_2 Medium
λ_3 Small
2
4
6
8
10
Time [s]

Half-life of disintegration:

The half life of disintegration of a radio active substa
is the time at which the number of atoms present in t
substance is half of its initial atom, due to disintegra
Let at t=o the number of atom present in the substanc
be N_o and at t=t that in the substance be N
Therefore by disintegration law

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

When t=T = half life of disintegration

Then $N = \frac{N_0}{2}$

$$\therefore \quad \frac{N_0}{2} = N_0 e^{-\lambda T}$$

$$e^{\lambda T} = 2 \quad \Rightarrow \quad T\lambda = \ln 2 \quad \Rightarrow \quad T = \frac{1}{\lambda}\ln 2$$

$$T = \frac{0.693}{\lambda} \quad \textbf{or} \quad T \propto \frac{1}{\lambda}$$

Mean life of disintegration:

It is evident that some atoms of radioactive substanc will disintegrate almost immediately, other will last For a long time. So the possible time of existence of an atom may vary from zero to infinity. So statisticall

the mean life $= \dfrac{Total\ life\ of\ all\ the\ atoms}{Total\ number\ of\ such\ atoms}$

At any instant t, the number of radioactive atoms present is given by

$$N = N_0 e^{-\lambda t} \; and \; -\frac{dN}{dt} = \lambda N$$

$$dN = \lambda N dt$$

Leaving out the negative sign which merely indicate that dN atoms disintegrate in the very short interval d

dN be the number of atoms having life time lying between t and t+dt.

Since dt is very small, so the total life-time of these dN atom is equal to tdN.

Since the possible life time of any of the total number N_o Atoms varies from 0 to ∞ .

The total life time of all the N_o atoms is given by $\int_{t=0}^{\infty} t \, dN$

$$\therefore \ the\ mean\ life\ \tau = \frac{\int_{t=0}^{\infty} t\ dN}{N_0}$$

$$= \frac{\int_{t=0}^{\infty} t\ \lambda N dt}{N_0}$$

$$= \frac{\int_{t=0}^{\infty} t\ \lambda N_0 e^{-\lambda t} dt}{N_0}$$

$$= \int_{t=0}^{\infty} t\ \lambda e^{-\lambda t} dt$$

$$= \int_{x=0}^{\infty} x\ e^{-x} \frac{dx}{\lambda}$$

Let $\lambda t = x$

$$\lambda\ dt = dx$$

$$dt = \frac{dx}{\lambda}$$

$$= \frac{1}{\lambda} \int_{x=0}^{\infty} x\, e^{-x} dx$$

$$= \frac{1}{\lambda} \Gamma 2$$

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

Thus the mean life time τ Is reciprocal of λ

$$T = \frac{\ln 2}{\lambda}$$

$$T = \tau \ln 2$$