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NAAC ACCREDITED 'A' GRADE

Topic: Alpha decay, Range, Geiger law, Straggling of range

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Name of the Department: Physics



## Alpha decay

Range of  $\alpha$ -particle,

Geiger law,

Specific ionisation

Straggling of range

Geiger-Nuttall law

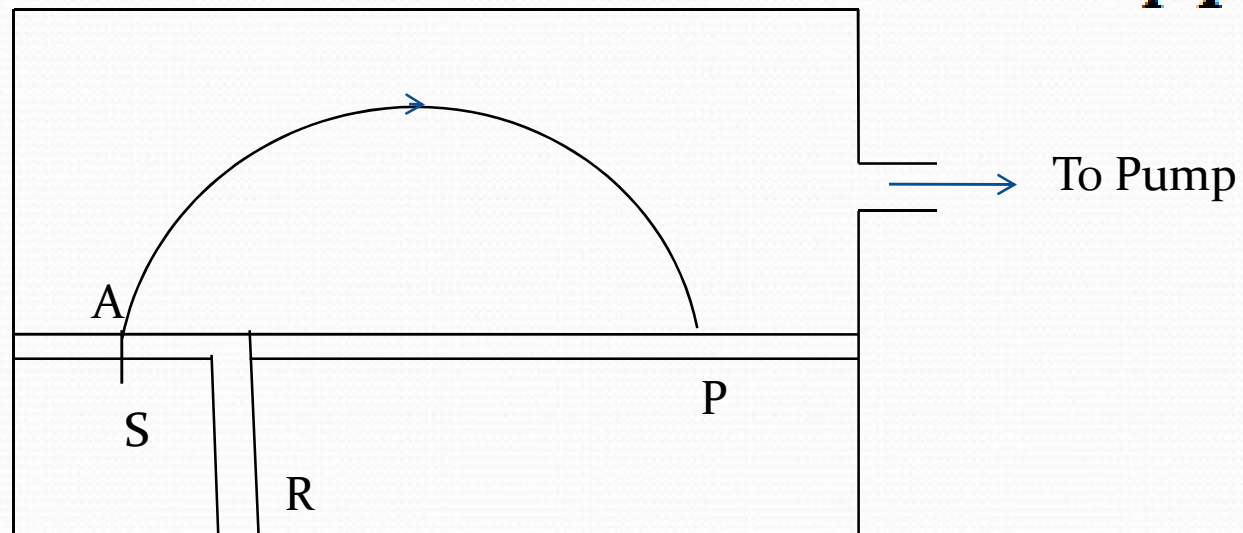
# Velocity of $\alpha$ - particles

RaC' - Radium C' - 213.995 (atomic mass)  
100% branch chance  
164.3  $\mu$ S half life  
7.83346 Mev energy released

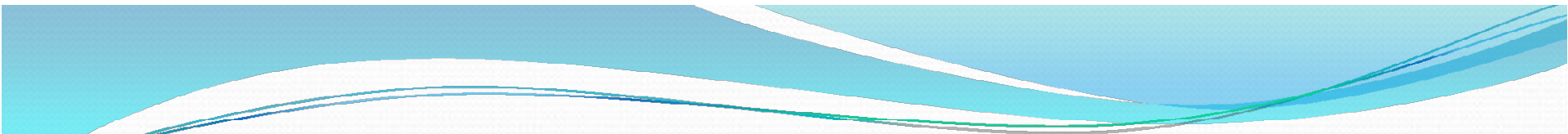
$$qvB = \frac{Mv^2}{r}$$

$$v = 1.9 \times 10^7 \text{ m/s}$$

$$v = \frac{Bqr}{M}$$



## Magnetic spectrograph



## Range of $\alpha$ -particles:

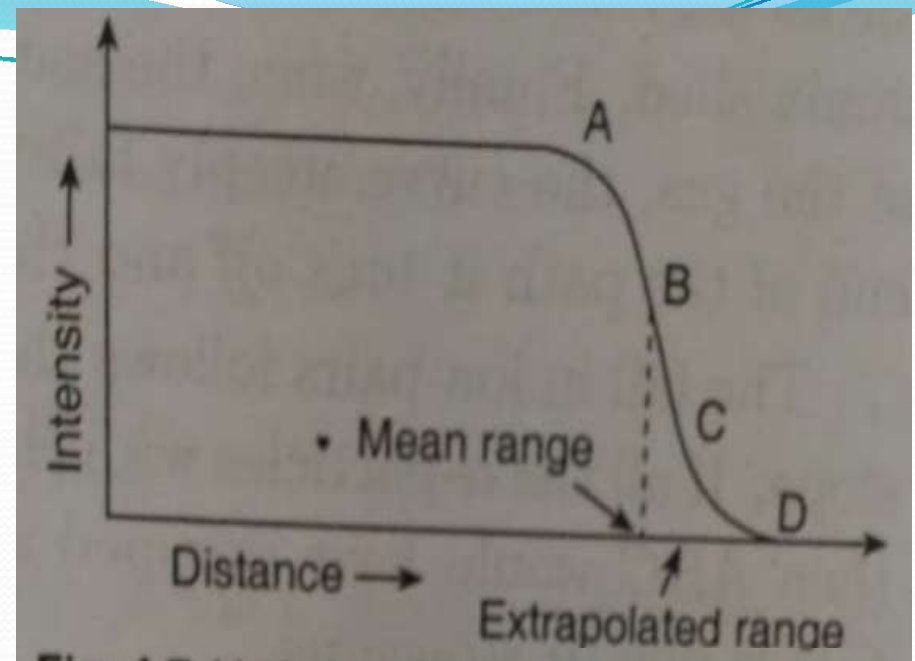
The distance through which an  $\alpha$ -particle travels in a specified material before stopping to ionise it, is called its range in that material. The range is thus a sharply ionisation path – length.

Naturally, the range is highest in gases, less in liquids and the least in solids.

Plainly, in a gas, the range depends upon

- i) The initial energy of the  $\alpha$ -particle i.e. velocity.
- ii) The ionisation potential of the gas.
- iii) The nature and the temperature and pressure of the gas.

## Range of $\alpha$ -particles in air from $^{214}\text{Po}$ straggling



## Geiger Law

Geiger showed from his experimental studies that for mono-energetic  $\alpha$ -particles of speed  $v$ , the range  $R$  in standard air is proportional to  $v^3$ ,

$$R \propto v^3$$

$$R = av^3$$

Where  $a$  is a constant. This relation is called Geiger law. The graph shows how the number of  $\alpha$ -particles stays practically constant up to a certain distance  $R$  from the source and drops rapidly to zero.

Alternative form of Geiger law:

From Range-energy relationship of Geiger law we have

$$R \propto v^3 \quad \text{or} \quad R = av^3$$
$$\text{again energy } E = \frac{1}{2}mv^2 \quad \text{i.e. } v \propto E^{\frac{1}{2}}$$

$$\therefore R \propto E^{\frac{3}{2}} \quad \text{or} \quad E \propto R^{\frac{2}{3}} \quad \text{or} \quad R = bE^{\frac{3}{2}}$$

If  $R$  is in meter,  $E$  is in Mev and  $v$  is in m/s

$$\text{Then } a = 9.416 \times 10^{-24} \quad \text{and} \quad b = 3.15 \times 10^{-3}$$



Specific ionisation:

The number of ion-pairs formed per unit path-length at any point in the path of the  $\alpha$ -particle is called specific ionisation,  $I$

$$R \propto E^{\frac{3}{2}}$$

$$\therefore I = \frac{dE}{dR} \propto R^{-\frac{1}{3}} \propto \frac{1}{v} \quad \because R \propto v^3$$

Thus the ionisation produced by an  $\alpha$ -particle at any point in its track is inversely proportional to its Velocity at that point.



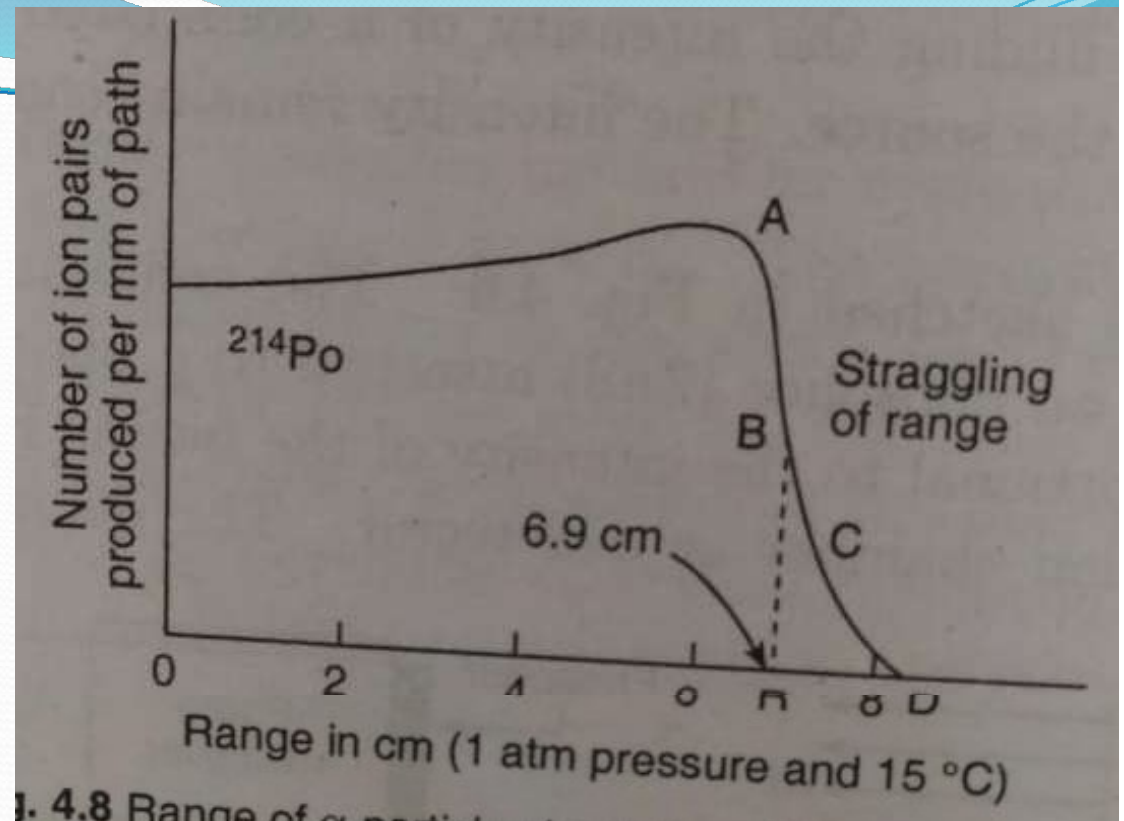
Straggling of range:

The  $\alpha$ -particles of the same initial energy have more or less the same range in a given substance. However a small spread in the values of ranges about a mean value is observed. This phenomenon is known as the straggling of the range.

The curve shows the variation of the number of ions produced along the path of an  $\alpha$ -particle with the distance from the source.

This curve is known as Bragg Curve and the Maximum at the point A is known as Bragg hump.

This is due to the fact that the  $\alpha$ -particles move slowly there and have more time to interact with the surrounding atoms and molecules.



Reasons for straggling:

The straggling occurs mainly due to two reasons:

- i) There is a statistical fluctuation in the number of collisions suffered by the different particles about a mean value in travelling a given distance.



ii) There is also a statistical fluctuation about a mean value in the energy loss per collision.

Geiger- Nuttall Law:

The  $\alpha$ -particles emitted by substances having larger decay constant  $\lambda$  (or shorter half-lives) ( $T_{1/2} = \frac{\ln 2}{\lambda}$ ) have longer ranges and vice versa.

If  $R$  be the range of  $\alpha$ -particle and  $\lambda$  be the decay constant of the emitting nuclei then according to Geiger-Nuttall law

$$\ln \lambda = A + B \ln R$$

Where  $A$  and  $B$  are constants having different values for different radioactive series.

This law gives the estimated value of half-lives of common  $\alpha$ -emitters that could not be determined easily experimentally.

Again *Since*  $R \propto E^{\frac{3}{2}}$

$$\ln \lambda = C + D \ln E$$

Another form of G-N law

