Objective

To study the range-energy relationship of beta particles using a Geiger-Müller (GM) counter.

Introduction

Beta particles are high-energy, high-speed electrons (β-) or positrons (β+) emitted by certain types of radioactive nuclei, such as potassium-40. The study of the range-energy relationship of beta particles is crucial in nuclear physics to understand how beta particles lose energy as they travel through matter.

The range of a beta particle is the distance it can travel before it is stopped by the medium, which is directly related to its energy. In this experiment, a GM counter is used to measure the count rate of beta particles at various thicknesses of an absorbing material, typically aluminium.

Apparatus and Materials Required

1. GM Counter
2. Pure Beta-emitting source (e.g., Strontium-90, Carbon-14, Thallium-204)
3. Absorber foils (Aluminium and copper sheets of varying thickness)
4. Source holder
5. GM tube holder with adjustable stand
6. Measuring scale

Theory

The range of beta particles in a material is influenced by their initial energy. As beta particles travel through the material, they lose energy primarily through ionization and excitation of atoms in the absorber. The relationship between the energy of beta particles (E) and their range (R) in a given material can be approximated by an empirical formula:

$$R = a \times E^n$$

where:

- R is the range of the beta particles.
- E is the energy of the beta particles.
- *a* and *n* are material-dependent constants.

For most materials, the range-energy relationship is non-linear, and *n* typically ranges between 1.5 and 2. The GM counter detects the count rate of beta particles, which decreases as more absorber material is placed between the source and the detector, allowing us to determine the range.

Procedure

1. **Setup:**
   - Connect the GM counter to the main supply and power it on.
   - Place the GM tube in its holder at a fixed distance from the source, typically 5-10 cm.
   - Place the beta source securely in its holder directly in front of the GM tube.

2. **Baseline Count:**
   - Without any absorber, measure the background radiation count for a specific time interval (e.g., 1 minute). Record this as the background count.
   - Next, measure the count rate of the beta source without any absorbers between the source and the GM tube for the same time interval. Record this as the initial count rate.

3. **Absorber Measurement:**
   - Place the thinnest aluminium foil between the beta source and the GM tube. Measure the count rate for the same time interval.
   - Repeat the above step by adding more aluminium foils incrementally, measuring and recording the count rate each time. Note the thickness of the foil after each addition.
4. **Continue until the count rate reaches the background level.** This point indicates that most beta particles have been stopped, giving an approximate range of the particles in the material.

5. **Data Recording:**
   - Record the count rate (corrected for background) and the corresponding total thickness of the aluminium foil after each measurement.

Observations and Data Analysis

1. **Observation Table:**

Sr. No.	Thickness of Aluminium Foil (mm)	Raw Count Rate (counts/min)	Background Count Rate (counts/min)	Corrected Count Rate (counts/min)
1	0.0			
2				
3				

2. **Graph:** `
   - Plot the corrected count rate (y-axis) against the thickness of the absorber (x-axis).
   - The range of beta particles can be estimated from the thickness at which the corrected count rate approaches zero.
3. **Analysis:**
   - Determine the range of beta particles from the graph.
   - Using the known relationship $R = a \times E^n$, estimate the energy of the beta particles if the constants *a* and *n* for aluminium are known.

Calculations

1. **Corrected Count Rate:**

   Corrected Count Rate = Raw Count Rate − Background Count Rate

2. **Range Determination:**
   - The range is determined from the point where the corrected count rate becomes negligible.

Precautions

1. Handle radioactive sources with care, using appropriate safety measures such as tongs.
2. Avoid any movement of the source or GM tube during the experiment to maintain consistency.
3. Record background radiation counts periodically to ensure accuracy

References

1. Nuclear Physics by Irving Kaplan
2. “Nuclei and particles” by Emilio Segre