To find the range of Alpha Particles in Air

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Abstract

This experiment was conducted in order to find the range of alpha particles in air. The range in water was also estimated. For $4.88MeV$ alpha particles, the range was found to be $36 \pm 2mm$, which corresponds to the given value of $35mm$ within scientific error. The range in water was estimated as 38 microns.

Introduction

Alpha Particles and Bragg Curves

When alpha particles are emitted from a radioactive source, they travel a well defined distance based on the stopping power of the material they are travelling through and their initial energy.

The aim of this experiment was to find the range of the alpha particles in air. A ^{209}Po source was used, which emits alpha particles with energies of $4.88MeV$.

The reason for this well defined range is that when a charged particle moves through some material, it ionizes the atoms of the matter around and loses energy.

The stopping power of a material is defined as the average loss of energy per unit length of path travelled for a given particle. If you plot the stopping power vs path length you will get a Bragg Curve, an increasing curve reaching a peak before dropping rapidly to zero. The peak is called a Bragg Peak.

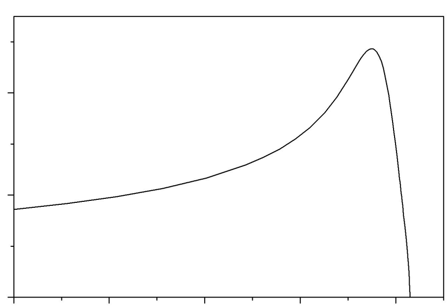

Figure 1: Bragg Curve

The stopping power is defined as : $S(E) = \frac{-dE}{dx}$

Solid Angles

In this experiement, it is also necessary to used solid angles to analyse the data.

The unit of solid angle is defined as the solid angle subtended at the centre of a sphere of unit radius by a region of the sphere whose area is one square unit. This is a steradian.

For a spherical cap of area A and spherical radius R, the solid angle Ω is given by: $\Omega = \frac{A}{R^2}$ The area, A, of the spherical cap is simply $2\pi rh$ where h is the height of the cap.

For a disk facing another disk, the solid angle is given by:

$$\Omega(\frac{R}{d}, \frac{S}{d}) = \frac{\int_0^S \Omega(d, R, x)xdx}{\int_0^S xdx}$$

In the special case when $R = S$, the values for Ω as a function of $\frac{R}{d}$ are given by the table below:

R/d	Solid Angle (Str.)	R/d	Solid Angle (Str.)
0.1	0.031	0.9	1.397
0.3	0.250	1.2	1.756
0.6	0.770	1.8	2.465
0.8	1.124	2.4	2.972

Using this data, a graph was plotted to find other values of Ω for $\frac{R}{d}$:

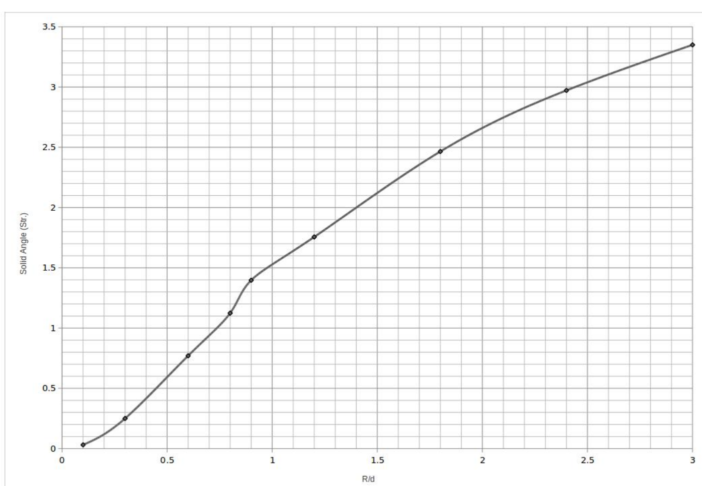

Figure 2: $\frac{R}{d}$ vs Solid Angle

Experimental Method

Apparatus

A sample of ^{209}Po was used as the alpha particle source in this experiment. It was attached to a movable rod which enabled the distance between the source and detector to be varied. The detector was a scintillation counter consisting of a photomultiplier tube with the entrance coated in ZnS scintillator powder. An amplifier and single channel analyser were used in conjuction with a pulse counter to count the pulses from the photomultiplier. An EG&G Ace-Mate was used to supply the required voltage to the photomultiplier and to do the single channel analysis. A digital counter was connected to the SCA output.

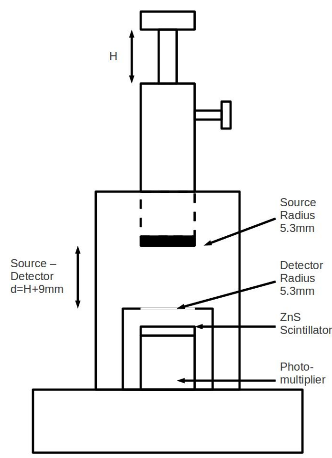

Figure 3: Aparatus

Set Up

The photomultiplier was connected to the EG&G Ace-Mate. The source was lowered to as close as possible to the scintillator. The HV potentiometer was set to zero, turned on, and then slowly brought up to 0.85kV. The coarse gain was set to 20V and the fine gain was set to 5V. The UL and LL were checked to make sure they were set to the appropriate values (0.5V and 9V respectively)

Experiment

Starting with the source as close as possible to the detector (H=0 $\rightarrow$ d=9mm) it was slowly raised and the count rate over 10 minutes was taken at regular intervals. The background count was also found, with the source as far away as possible from the detector.

Results and Conclusion

Range in Air

The Count Rate over 10 minutes for varying height H was recorded. Results are shown as follows:

Height(mm)	Count	Height(mm)	Count
0	1729	20	154
2	1119	25	57
4	848	26	31
6	693	27	20
8	563	27.5	19
10	473	28	12
12	349	28.5	8
14	271	29	6
15	262	30	6
16	223	40	6
18	194	50	6

Using this data, a graph of the count rate against the distance d between the source and the detector was plotted:

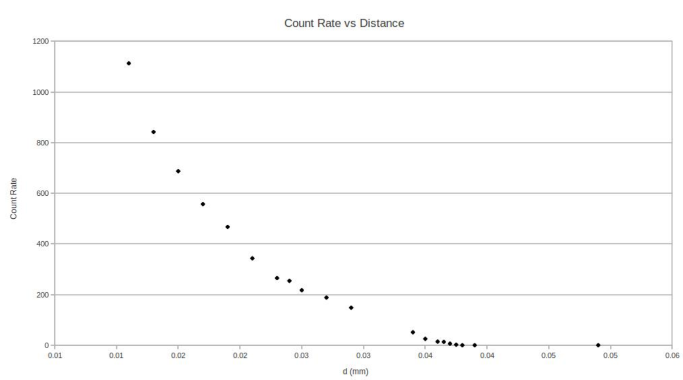

Figure 4: Count Rate against Distance

The graph is similar to that of the Rutherford scattering, with the count rate decreasing exponentially as the distance increases. If alpha particles have a well defined range, we would expect to see an almost constant line with a steep drop to zero at the limit of the range. This is not the case however, as the probability of detection by the counter is proportional to the area of the counter and the source detector distance. Hence we analyse our data using the solid angle between the source and the detector.

Initially, the solid angle Ω was estimated, assuming the source is a point and the detector is a spherical cap rather than a flat disk. Then a graph of $\frac{C}{\Omega} vsd$ was plotted as shown:

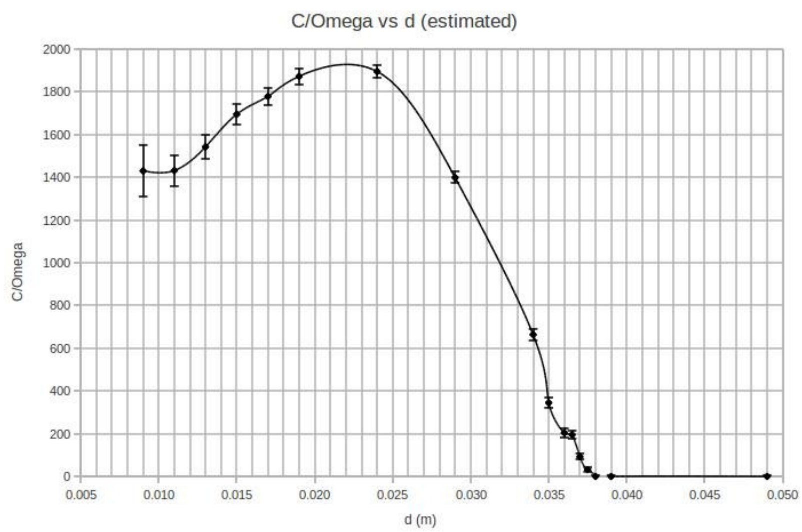

Figure 5: $\frac{C}{\Omega}$ vs d for estimated Ω

The graph goes to zero in the region of $36 \pm 2mm$
Subsequently, the actual solid angle was calculated,

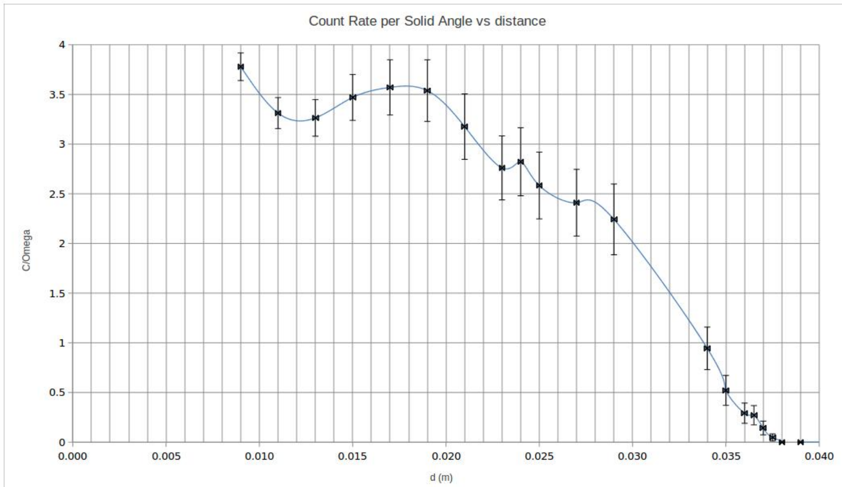

Figure 6: $\frac{C}{\Omega}$ vs d for actual Ω

It is clear that the number of alpha particles drop to zero at the region $36 \pm 2mm$. This is in line with the estimated solid angle and corresponds to the given value of 35mm for 4.88MeV particles.

Estimated Range in Water

To estimate the range in water, we use the Bragg Kleeman Rule:

$$\frac{R_1}{R_0} = \frac{\rho_0}{\rho_1}\sqrt{\frac{A_1}{A_0}}$$

The density for water and air is well known: $\rho_a = 1.2Kg/m^3$ $\rho_w = 1000Kg/m^3$ However the atomic weights for molecules must be estimated: $A_a = 29$ $A_w = 36$

Using the range found for alpha particles in air, the range in water was estimated as 48±8 microns. According to experimental data, the actual range in water is 38 microns for 5MeV alpha particles. While this is outside the errors of our result, it is still reasonably close. This suggests that there is a small problem either in the estimation of the atomic weights, or the fact that water is a liquid rather than a gas which may cause some conflict with the Bragg-Kleeman Rule.

Errors

The errors on the x-axis of the graphs are quite small. This is due to the fact that the distance between the source and the detector at its lowest point is known (9.0mm) and that the variation in the height was measured with a vernier calipers. There was no calculations involved with this data.

For the estimated solid angle, the error in the count ($\sqrt{C}$) is the cause for most of the uncertainty. This could be reduced by taking additional counts at each distance, or by taking counts over a longer period of time.

The largest errors are in the graph of the actual solid angle. This is due to the fact that there wasn't enough information given about the relationship between $\frac{R}{d}$ and Ω. While nine points were given, esentially only three of these were in the range that we were investigating.