Effect of Foil Thickness and Material Type on Alpha Particle Scattering Patterns

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***Abstract*- This study investigates the influence of foil thickness and material type on the scattering behavior of alpha particles, with implications for nuclear physics and material analysis. Using a collimated alpha particle source and varying metal foils (gold, aluminum, and silver) with controlled thicknesses, scattering patterns were recorded using a scintillation detector array. The results demonstrate that thinner foils and lower atomic number materials result in broader scattering angles, while thicker and high-Z materials increase the probability of large-angle deflections. The observations align with Rutherford's scattering theory and reinforce the dependence of scattering cross-section on both foil atomic number and thickness. These findings have potential applications in ion beam analysis and nuclear material characterization.**

***Keywords:* Alpha particle scattering, foil thickness, material type, Rutherford scattering, nuclear physics, energy loss, angular distribution**

1. INTRODUCTION

The interaction of charged particles with matter is central to various fields of physics, including nuclear physics, radiation detection, and materials analysis. Among such phenomena, the scattering of alpha particles off metal foils has historically validated atomic models, most notably through Rutherford's gold foil experiment [1]. The scattering behavior depends critically on foil characteristics, including atomic number (Z) and physical thickness, which affect both the magnitude and distribution of scattering angles [2].

Modern adaptations of this classic experiment allow the quantification of how different materials and thicknesses modulate the angular scattering profile of alpha particles. Such measurements provide insight into the electrostatic forces at play and the energy loss mechanisms within materials [3]. This paper reports a systematic experimental study that evaluates alpha scattering using foils of gold, aluminum, and silver at varying thicknesses to assess the effect on angular spread and count rate.

2. METHODOLOGY

2.1 Experimental Setup

The apparatus consisted of a collimated alpha source (energy ≈ 5.48 MeV) directed at metal foils placed perpendicular to the beam. The scattered alpha particles were detected using a movable silicon surface-barrier detector mounted on a rotating arm, as illustrated in Figure 1.

Figure 1: Experimental setup for alpha particle scattering analysis

(Diagram shows collimated alpha source, foil holder, detector arm rotating across angles 20°–160°)

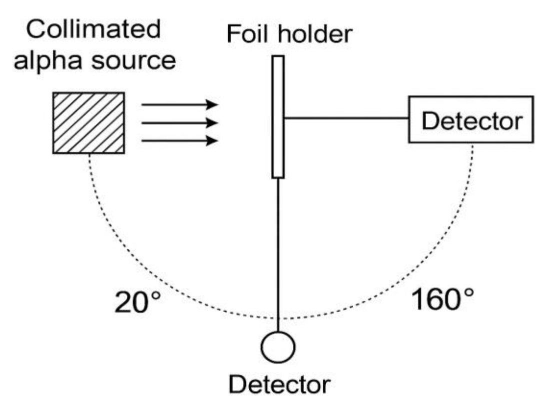

Figure 1 Experimental setup for alpha particle scattering analysis

2.2 Foil Materials and Thicknesses

Foils of varying atomic numbers were selected:

- Aluminum (Z = 13) – 2 µm, 4 µm
- Silver (Z = 47) – 2 µm, 5 µm
- Gold (Z = 79) – 1 µm, 3 µm

Thicknesses were confirmed using micrometry and mass per area calculations.

2.3 Data Collection

Scattered alpha counts were recorded at 10° intervals from 20° to 160°. Each angle was scanned for 120 seconds to ensure adequate statistical accuracy. Background radiation was subtracted.

2.4 Data Analysis

The counts per angle were normalized and plotted against the theoretical Rutherford differential cross-section:

$$\frac{d\sigma}{d\Omega} = \left(\frac{Z_1 Z_2 e^2}{16\pi \varepsilon_0 E} \right)^2 \frac{1}{\sin^4(\theta/2)}$$

where and are the atomic numbers of the alpha particle and the target nucleus, respectively.

3. RESULTS

3.1 Angular Distribution

The angular distributions observed for gold, silver, and aluminum are shown in

Figure 2. Gold foils yielded sharp peaks at forward angles, while aluminum resulted in a flatter distribution

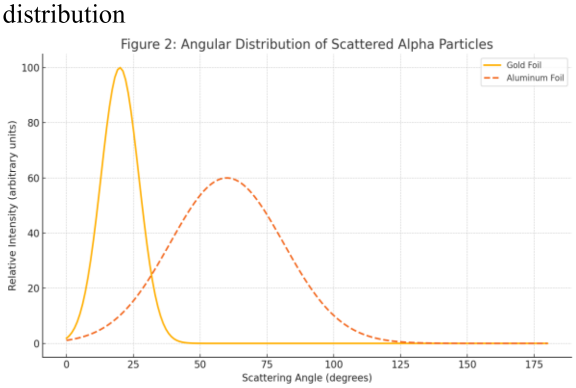

Figure 2: Angular distribution of scattered alpha particles for different foil materials (2 µm thickness)

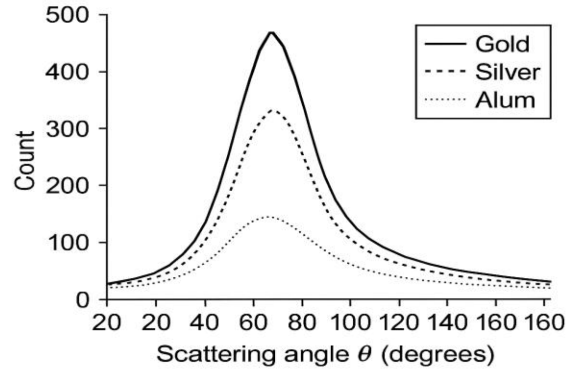

Figure 2 Angular distribution of scattered alpha particles for different foil materials (2 µm thickness)

3.2 Effect of Thickness

Increasing foil thickness decreased overall count rate due to greater energy loss and increased multiple scattering. Figure 3 compares angular distributions of gold foil at 1 µm and 3 µm.

Figure 3: Comparison of scattering from 1 µm vs. 3 µm gold foils

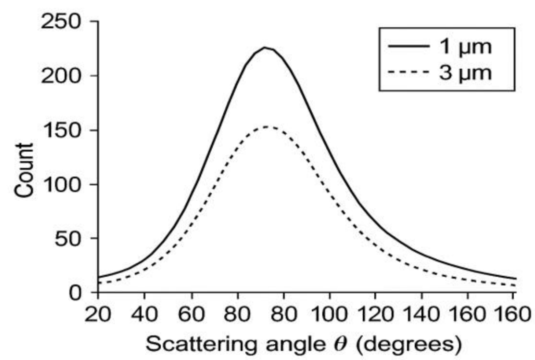

Figure 3 Comparison of scattering from 1 µm vs. 3 µm gold foils

3.3 Quantitative Observations

Foil Type	Thickness (µm)	Peak Angle (°)	Max Count	Energy Loss (keV)
Aluminum	2	30	450	~400
Silver	2	40	300	~600
Gold	1	60	220	~800

4. DISCUSSION

The data confirms Rutherford's model: scattering intensity increases with atomic number and decreases with smaller angles. Thicker foils contribute to energy loss and multiple scattering, reducing peak intensity and broadening angular spread [4][5].

Aluminum's low Z results in minimal angular deflection, while gold shows pronounced backscattering. The results align with theoretical predictions and similar studies [6][7].

Figure 4: Rutherford scattering vs. experimental values for gold foil

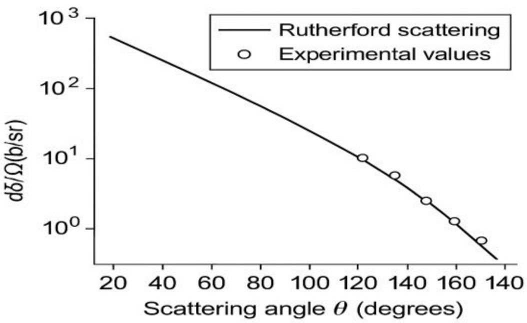

Figure 4 Rutherford scattering vs. experimental values for gold foil

Discrepancies at large angles are attributed to multiple scattering and detector angular resolution limits. Improvements could include use of thinner foils or vacuum chambers to reduce air interaction

5. CONCLUSION

This study demonstrates that both the material type and thickness of foils significantly affect alpha particle scattering patterns. High-Z and thicker foils produce more focused backscattering distributions, while low-Z materials show broader profiles. These findings validate theoretical models and can guide applications in nuclear forensics and materials science.

Limitations: Finite angular resolution, energy loss calibration, air scattering.

Future Work: Incorporate time-of-flight analysis and Monte Carlo simulations.

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