

Exp. N-4 Rutherford Scattering of α -particles

References:

1. Melissinos, "Experiments in Modern Physics", 1st ed. (!) (see library)
2. Leybold Didactic (LD) Instrumentation Sheets:
55956/54/52 Rutherford Scattering Chamber
55992/93 Semi-conductor Detector, Discriminator-Preamplifier
55982 ²⁴¹Am Preparation (α -source)

Objective

To measure the differential cross-section for Rutherford scattering of α -particles by gold nuclei.

Theory

Read sections 1 and 2 of Chapter 6 in Ref.1. A copy of these sections will also be in the reference folder for this experiment. Please do not remove them from lab!

The differential cross-section, $d\sigma/d\Omega$, for Rutherford scattering is given by

$$\frac{d\sigma}{d\Omega} = \left(\frac{zZe^2}{4\pi\epsilon_0} \right)^2 \left(\frac{1}{4T_\alpha} \right)^2 \frac{1}{\sin^4\left(\frac{\theta}{2}\right)}$$

where ze , Ze are the charges of the projectile and the target respectively, T_α is the kinetic energy of the projectile, and θ is the scattering angle.

Experiment

Read the Leybold instruction sheets listed above before you proceed to do the experiment. In particular, pay attention to the Safety Notes. After you have finished reading, do the following:

A. Setting up the apparatus

Connect the equipment as outlined in section 3.2 of the Leybold Instruction Sheet 55956/54/52 with the following modifications:

1. The power supply for the pre-amplifier will be an AC-DC plug-in unit.
2. An external amplifier and discriminator will be used instead of the built-in discriminator of the pre-amplifier unit. Consequently, use the pulse height output of the preamp.

B. Familiarization with the equipment

Initially, set up the equipment without the foil, i.e. check the electronics using direct alpha hits on the photodiode detector. Check the pulse shapes on the scope after each step in the detection chain, i.e. after the preamplifier, after the amplifier, and after the discriminator. Record typical pulse shapes for each case. Note, you can plug a USB flashdrive into the scope to save image files of the scope display.

Perform experiments **3.3.1** and **3.3.2** (Leybold instruction sheets). It is critical to align the slit in parts B and C such that the scattering is symmetrical with respect to the line connecting the source and the detector. Check the counting rates with the scattering angles at $+10^\circ$ and -10° for proper alignment.

C. Verification of the Rutherford scattering formula for the differential cross section.

For the experimental calculation of the cross section (see Ref. 1), assume a thickness of $2\text{ }\mu\text{m}$ for the gold foil. Do experiments **3.3.3** and **3.3.4** (Leybold instruction sheets).

Important notes

In order to prevent the rupture of the thin Au foil, the following procedures must be followed before you evacuate the scattering chamber or open it to the atmosphere:

1. Check to see that the foil is placed near the center of the chamber and it is parallel to the 90° - 270° line.
2. The venting cock of the scattering chamber is closed before you turn on or off the pump that is connected to the chamber.
3. To evacuate or to vent the chamber, open the venting cock **slowly** until a hissing sound is heard for venting and a gurgling sound is heard for pumping. Open the venting cock wide after the disappearance of the hissing sound or the gurgling sound. The end of the rubber tubing connecting to the pump should be disconnected before you vent the chamber. You may also vent by opening one of the valves on the pump manifold.
4. For very small counting rates at large angles, you might have to subtract background counts due to electronic noise or cosmic ray background. Move the source out of the way and see if you still get any counts over comparably long counting times.
5. The photodiode detector has an entrance window. You might need to take the size of that window into account in your measurements.
6. In the analysis of your scattering data, it is not sufficient to only plot the count rates vs. the scattering angle. You must tabulate and plot the differential cross section. Make sure you record all parameters of the measurement that go into the calculation of the differential cross section.

CAUTION:

- The gold foil is very thin and fragile. **Never touch it, please!** It should be removed from the chamber before you install or remove the α -source.
- Note that the source goes into the empty banana socket. The other object with the gray slotted cap mounted inside the chamber is the (delicate) solid-state detector, a photodiode. Do not attempt to force the source into it as you will break the detector. (Yes, students have managed to do that in the past and thereby destroying the photodiode). **In fact, there is no need for you to touch the photodiode detector at all, so please don't!**