Rutherford Scattering

Lord Ernest Rutherford of Nelson
Nobel price in chemistry 1905
Rutherford Scattering

Rutherford scattering is based on the elastic deflection of charged particles in the Coulomb field of an atomic nucleus. It can be observed and measured by radiating $\alpha$-particles on a thin metallic foil and measuring the angular distribution of the scattered $\alpha$'s behind that foil. The intensity of the $\alpha$-particle beam varies with the deflection angle and the proton number of the used material (see formula). Rutherford's measurement was the basis of Bohr's atomic model and the size of the nucleus.

In this experiment both the angular and the Z-dependence can be measured in a broad dynamic range. However some corrections due to the thickness of the foil which causes multiple scattering and angular straggling are necessary.

Nowadays Rutherford scattering is applied for material analysis and as a cross section calibration in nuclear experiments.
\[ \frac{\partial \sigma}{\partial \Omega} = \left( \frac{Ze^2}{4\pi\varepsilon_0 E} \right)^2 \cdot \frac{1}{\sin^4(\theta/2)} \]

_Rutherford scattering formula_
Preamp
Ortec 109A

HV
Canberra 3102/2

Linear Amp.
Tennelec
TC202BLR

Edge/Crossover
Timing SCA
Canberra 2037A

Preamp
Ortec 109A

Log/Lin
Ratemeter
Ortec 9349

Si Detector

Si Detector

Scattering
Chamber

Computer (PC)
ThinkCentre IBM

Diaphragm
Pump
Neuberger
N813.5 ANE

Absorption
Pump and
Dewar

Vacuum Pressure Gauge

Valve
Rutherford Scattering: Required Knowledge

- Bohr’s theory of the atom
- Rutherford’s experiment
- Theory of the scattering, two body problem
- Definition of the cross section
- Derivation of the Rutherford scattering cross section $\sigma_{\text{Ruth}}$
- Z-dependence and angular dependence
- Energy loss and straggling: corrections for the measurements

- Deviations from $\sigma_{\text{Ruth}}$ at higher energies: nuclear interaction
- Radioactive $\alpha$-emitters, preparation of $\alpha$-sources
- Applications: 1. standard cross section for comparison and calibration; 2. RBS-method
- Finite geometry corrections
- Physics of particle detectors, especially Si-detectors
- Electronics for spectroscopy
- Principles of vacuum techniques
Rutherford Scattering: Tasks and Goals

- Produce vacuum in the range $10^{-5}$ mbar (our instrument shows only $10^{-3}$ mbar)
- Switch on NIM-power
- Watch detector signal on oscilloscope and turn on slowly bias voltage of Si-detector (+ 25 Volts), angular position of $^{241}$Am-source at 5°, gold foil
- Get a signal from the $\alpha$-line at about 7 Volts and get the line at the MCA (set to 256 or 512 channels)
- Measure the line resolution with and without foil (angle 0°)
- Measure the angular distribution using the gold foil; the larger angles need longer measuring time, evaluate the line always at the MCA, consider background and uncertainties
- Determine the Z-dependence using the three foils Havar, Silver, Gold and an angle of 10°
- Consider energy loss, straggling and double scattering at small angles and correct for those effects
WARNINGS

- Close chamber window with black cover because Si-detector is light sensitive
- Don’t forget to fill the dewar. For overnight runs: fill at least at 10-hourly intervals
- After finishing the measurement: hide source behind bar in order to protect the detector, $\alpha$-source stays in the chamber
- Shut down detector bias
- Close the gate valve
- Never vent the chamber or get help
- From time to time regeneration of the Zeolith is necessary, heating up with pumping using the forepump, main gate valve closed. Forepump (diaphragm) often starts only after venting