Physics Lab
ETH zürich

α-Absorption Experiment

D PHYS

Abstract

When charged particles move through matter, they interact with the electrons of atoms in the material. The interaction excites or ionizes the atoms. This results in an energy loss of the traveling particle.
The aim of this experiment is to study the energy loss (dE/dx) of α-particles in air. Also the stopping range of the 5.5 MeV particles in air is determined. Finally, the thikness of thin foils (few µm) is determined by means of the energy loss in the material.

Physics

The Bethe formula describes the energy loss per distance of fast travelling charged particles (protons, alpha particles, atomic ions, but not electrons) traversing matter (or, alternatively, the stopping power of the material). The non-relativistic version was found by Hans Bethe in 1930:

$$-\frac{dE}{dx} = \frac{4\pi n z^2}{m_e v^2} \cdot \left(\frac{e^2}{4\pi\varepsilon_0}\right)^2 \cdot \left[\ln\left(\frac{2m_e v^2}{I}\right)\right].$$

v	velocity of the particle
E	energy of the particle
x	distance travelled by the particle
z	particle charge (2 for an α-particle)
e	charge of the electron
m_e	rest mass of the electron
n	electron density of the target
I	mean excitation potential of the target
ε_0	vacuum permittivity

The energy loss is not constant according to the formula, but dependent on the velocity (or energy) of the projectile.

Experimental Setup

The energy of α-particles emmitted by an Am-241 source is measured after they passed either a gas (of a known thickness) or a foil (of an unknown) thickness (see Fig. 1).

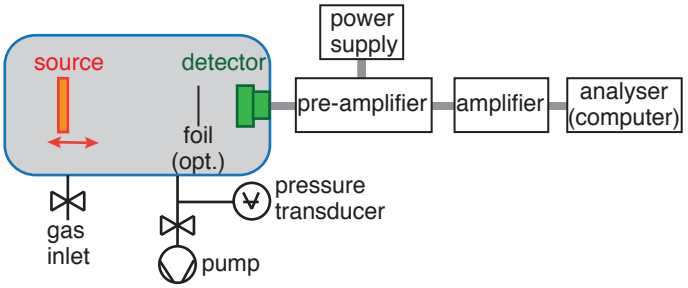

Figure 1: *An Am-241 source emitting 5.5 MeV α-particles is installed in a closed, gas tight vessel. A surface barrier detector is used to analyse the (remaining) energy of arriving α-particles. The distance between detector and source is adjustable. Additionally, the air pressure in the closed vessel may be adjusted between 1 hPa and 950 hPa.*

Results

The 5.5 MeV α-particles are stopped within about 40 mm in air (see Fig 2). Because the energy loss is a statistical process (of individual particle collisions), the α-particles are stopped within a range of about 2 mm.

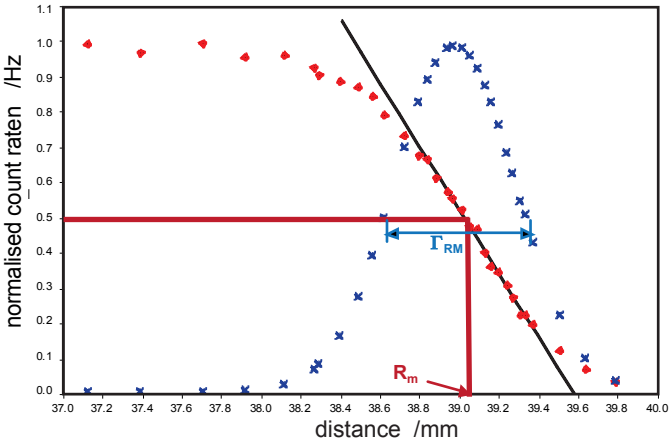

Figure 2: *The measured count-rate of the α-particles reaching the detector after passing a certain distance in air is given (red dots). The distribution of the stopping ranges (blue crosses) is deviated of the count-rate . All particles are stopped between 38 and 40 mm under standard conditions (STP).*

The energy over the travelling distance in air reduces not linearly, as predicted by the Bethe formula. In Figure 3 the measured energy loss dependent on the particle energy is given. The measured values are in good agreement with the Bethe formula for energies above 1 MeV. For energies below 1 MeV, the measured values differ significantly. A reason for this is that the α-particles do not all carry the 2+ charge state anymore.

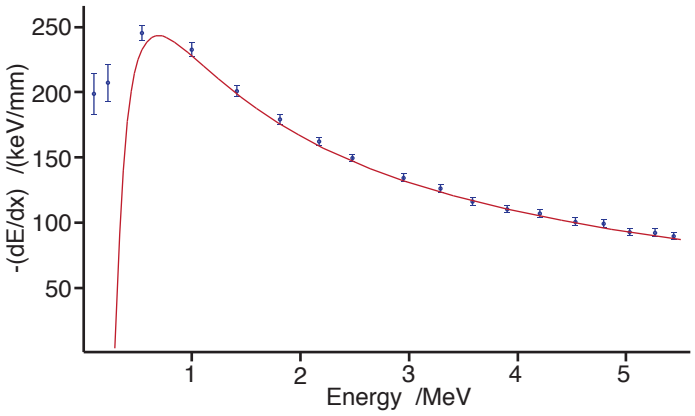

Figure 3: *The measured energy loss in air (under standard conditions) of the α-particles is plotted as function of energy in blue. The red curve is calculated by the Bethe formula. A maximum energy loss is found for particles with an energy of about 600 keV.*

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