# $\alpha$-spectroscopy

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## 1 Introduction and Theory

The aim of this experiment was to investigate the phenomena of $\alpha$-decay. Calibration was preformed using $^{241}$Am, then the spectrum of an unknown source was obtained and the source was identified. The energy loss of $\alpha$-radiation in air was also investigated.

$\alpha$-decay is classed as the spontaneous emission of a $^4_2$He nucleus, or an $\alpha$-particle, from a heavy nucleus. $\alpha$-particles have a binding energy of 7MeV/nucleon, and their lifetimes are in the range of 10ns $- 10^{17}$yr, however they have a narrow energy range of $2 - 9$MeV. Most nuclei which emit $\alpha$-particles are heavier than lead.

The energy of $\alpha$-particles can be determined using a semiconductor counter. Energy is transferred from the $\alpha$-particles to the semiconductor via inelastic collisions resulting in electron-hole pairs, the number of which is proportional to the energy of the $\alpha$-particles. These charge carriers are separated in an electric field and a preamplifier integrates their current, generating a voltage pulse proportional to the energy of the $\alpha$-particles. The pulses are analysed using a multichannel analyser connected to a PC.

The loss of energy of $\alpha$-particles in matter is caused by inelastic collisions with electrons. The loss of energy depends on the distance travelled by the $\alpha$-particles in matter. If $\alpha$-particles travel a fixed distance $x_0$ in a vacuum chamber, then by varying the pressure $p$ in the chamber, the effective path length $x$ can be easily altered, and the relationship can be investigated. The effective path length relates to the pressure in the chamber as follows:

$$x = \frac{p}{p_0} x_0, \tag{1}$$

where $p_0$ is standard pressure.

## 2 Experimental Method

The experimental setup consists of a vacuum chamber containing the radioactive sources and the detector, a vacuum pump with a needle leak valve and pressure guage for varying the pressure in the chamber, a charge sensitive preamplifier, and a multichannel analyser which is connected to CASSY LAB 2 for data analysis. Inside the vacuum chamber, the $^{241}$Am source and the unknown source are both mounted on rotating shafts in order to move them in and out of the path of the detector. The experiment is carried out in a vacuum due to the short free path length of $\alpha$-particles even in air (at distances $<$ 10cm).

The $^{241}$Am source is used to calibrate the CASSY LAB 2 software. The $x$-axis of the graph represents discrete channels $n_A$, each of which correspond to an energy value. The spectrum of $^{241}$Am is obtained, the energies being known, and the channel which corresponds to the energies are determined, allowing the axis to be rescaled to represent energy. In this case, the energies of the emitted $\alpha$-particles are 5486keV and 5443keV with an intensity of 84 : 13. The semiconductor detector has a finite resolution, making these two energies indistinguishable, so the former is used for energy calibration due to the intensity relation. After the energy is calibrated, the unknown source can be identified. It is rotated into the path of the detector in the vacuum chamber, the spectrum is obtained on CASSY LAB 2 and the energy of the $\alpha$-particles can be measured, allowing the source to be determined.

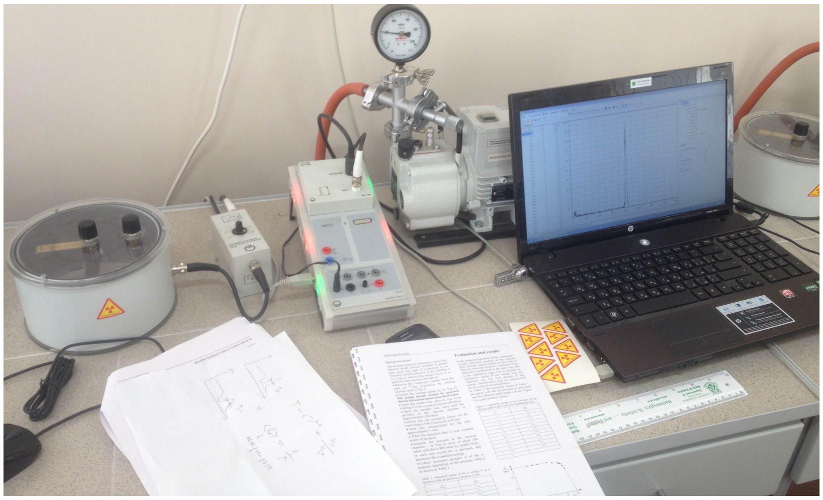

Figure 1: Experimental setup.

The energy loss of $\alpha$-particles in air can be measured by varying the pressure inside the vacuum chamber, since the distance between the $^{241}$Am source and the detector is less than the mean free path of $\alpha$-particles in air. By measuring the spectra of the $\alpha$-particles and hence the energy, then varying the pressure in the vacuum chamber by adjusting the needle leak valve, the dependence of energy on path length can be obtained. By approximating this relationship to be linear for small energy losses, the energy loss per unit path length can be determined from the slope.

# 3 Results and Analysis

After the energy calibration was completed, the unknown source could be identified. An energy of 5315.6keV was measured, and the unknown source was determined to be $^{232}$U, since the given for it was energy was 5.321MeV.

The energy loss was recorded for a series of values of pressures in the vacuum chamber. Given a value of $x_0 = 5.2$cm and using (1), the energy loss was plotted as a function of effective path length. The data was approximated to be linear for small energy losses, and using the slope, the energy loss was determined to be $\frac{dE}{dx} = 1456 \pm 44\text{keV}\,\text{cm}^{-1}$.

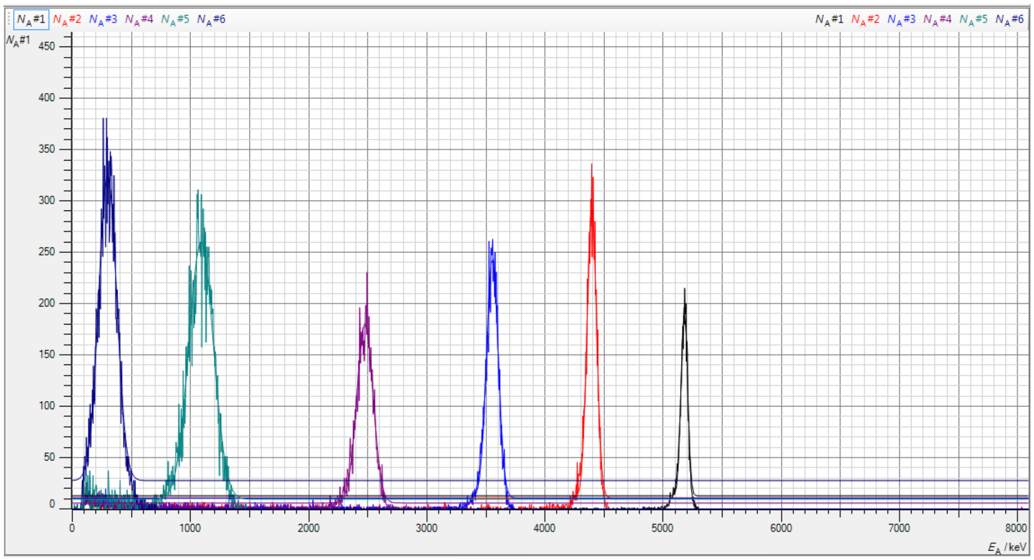


Figure 2: Spectra for different pressure values.

# 4 Discussion and Conclusions

After completing the energy calibration, the unknown source was successfully determined to be $^{232}$U. The value of energy loss obtained from the graph was $\frac{dE}{dx} = 1456 \pm 44\text{keV}\,\text{cm}^{-1}$. This was much larger than the quoted value of $23\text{keV}\,\text{cm}^{-1}$, which suggests that the experiment was incorrectly executed. The intercept given was $5534 \pm 31$ which is close to the energy of $^{241}$Am: 5486keV, so the mistake was not made in plotting the data. It is possible that the quoted value of $x_0$ in the instructions was different to the actual value in the experiment, as the vacuum chamber was not opened to verify this measurement. Another possible source of error was the length of measurements. Each spectrum was only measured for 60 seconds, and longer measuring intervals could have reduced the error in our energy loss rate.

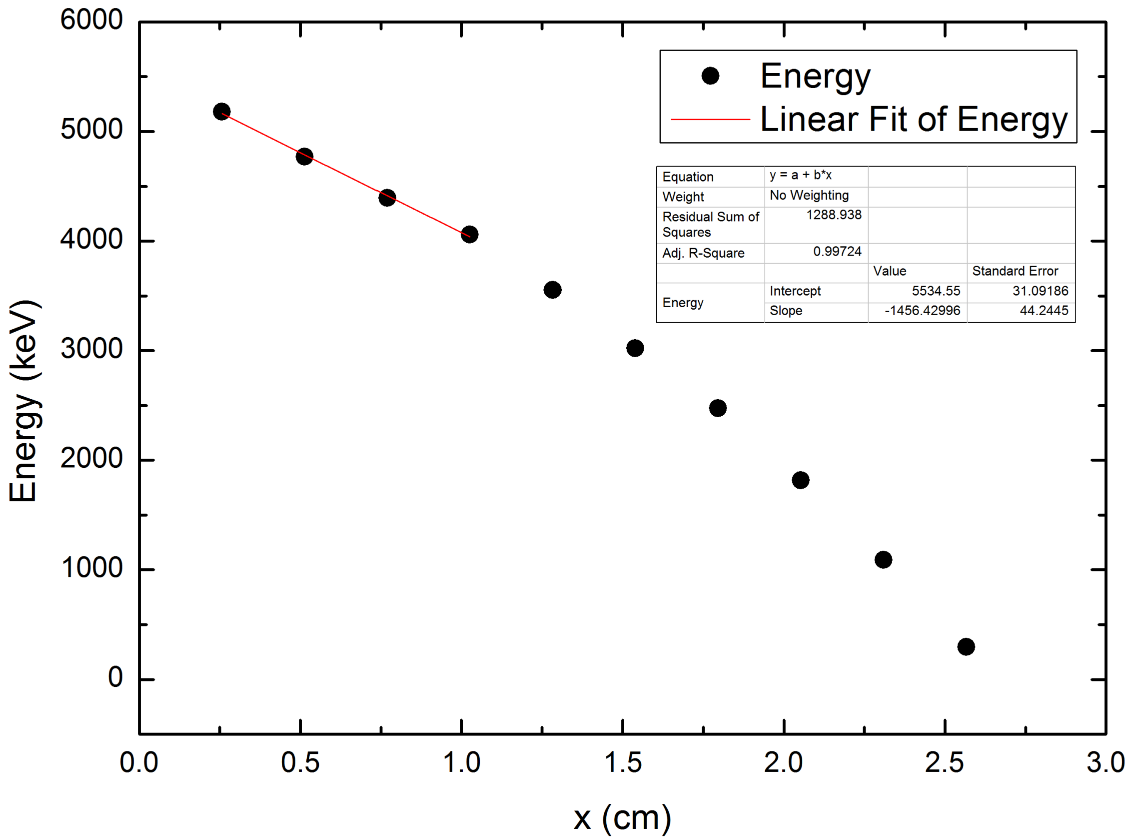


Figure 3: Energy loss for different path lengths.