Physics Department
Royal Holloway
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PH2510 - Nuclear Physics Laboratory

Alpha spectroscopy (NP7)

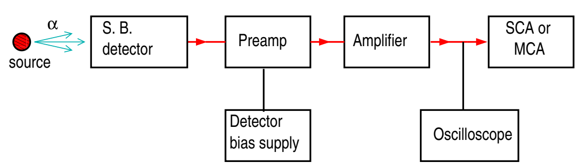
1 Objectives

The aim of this experiment is to demonstrate how α-particle energy spectra may be obtained using a semiconductor surface barrier charged particle detector. The spectrometer will be used to investigate the energy loss of α particles in air using an ^{241}Am α source.

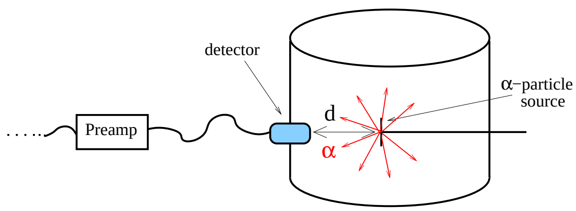
In order to prepare adequately for this experiment you will have to consult the material indicated in the References section.

2 Apparatus

The figure below shows the block diagram of a simple α spectrometer. Identify each of the components of your apparatus (in particular the surface barrier detector and the single-channel analyzer, SCA) and discuss their functionality with the demonstrator.



(a)



(b)

Figure 1: (a) Schematic diagram of the $\alpha-$spectrometer used in this experiment. SCA, MCA= Single-Channel Analyzer, Multi-Channel Analyzer. (b) The α-particle source is in a cilindrical closed container and is mounted at the end of a rod. The distance d between the source and the detector can be changed by pushing/pulling the rod.

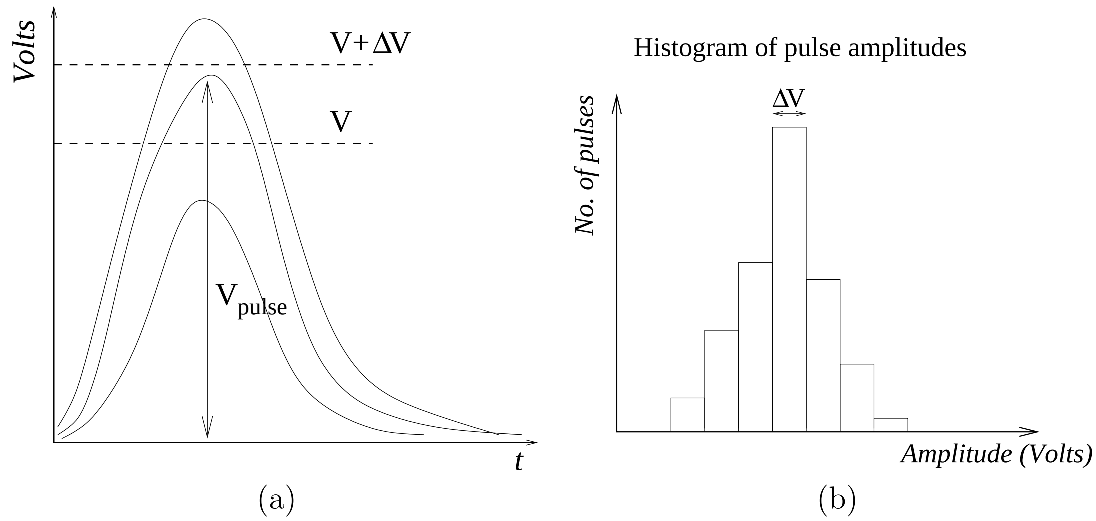


Figure 2: (a) Sketch of the pulses as viewed in the oscilloscope screen. Each pulse corresponds to the detection of a single α-particle. The amplitude of a pulse (V_{pulse}, shown) is a measure of the energy of the detected α-particle. Only one of the three pulses shown has amplitude in the interval $[V, V+\Delta V]$. (b) Histogram of pulse amplitudes: no. of pulses with amplitude in a given voltage interval; the pulse count is determined over a fixed time interval (for this experiment, typically $\sim$60s).

3 Procedure

1. The α-source is housed in a closed container, at atmospheric pressure, with a feed-through to vary the distance d between the source and the detector (Figure 1(b)). You will start by determining the energy of the detected α particles as a function of the distance travelled in air. The α-particle energy may be taken as proportional to the pulse height shown in the oscilloscope (Figure 2(a)). To calibrate the energy scale, use the fact that the α particles emitted in ^{241}Am decay have 5.4 MeV. (Note however that the minimum source-to-detector distance allowed by the apparatus is $\simeq$ 5 mm.)

In your report:

- Include the table of pulse height (in Volts) *vs.* d;
- Plot the energy-distance graph, and explain clearly how you converted pulse height into energy of the detected α particles;
- Discuss how the energy loss might be explained. Use your results to estimate the maximum distance that the emitted α particles can travel in air (this is called the "range") at atmospheric pressure.

2. Next, you will be using the Single Channel Analyzer (SCA), to count the number of voltage pulses with amplitude in a given voltage interval. For this experiment, you will be operating the SCA in *differential* mode, to count the number of pulses (in a fixed time interval) whose amplitude falls in the interval $[V,\ V+\Delta V]$ (Figure 2(a)).

Use the SCA to determine the α-particle energy spectrum at a source-detector separation of 10 mm using a voltage window of width ΔV=0.5 V. Determine ΔE, the full-width at half maximum (FWHM) of the peak.

When you have completed this, repeat the procedure for ΔV=0.2 V and 0.1 V.
In your report:

- Include the spectrum obtained with each voltage window (ΔV = 0.5 V, 0.2 V and 0.1 V). Plot the spectra as histograms (Figure 2(b)) with bins which are ΔV wide and are centred on $V + \Delta V/2$;
- How does the measured FWHM depend on the window size? Why is this so?

3. You will now investigate the broadening of the α-particle energy spectrum —as given by $\Delta E/\bar{E}$— as a function of the distance travelled in the air. ($\bar{E}$ is the energy peak position.) Based on your observations in part **2** above, choose the optimal value of ΔV to carry out this part of the experiment, and justify your choice. Measure the peak of the energy spectrum for five or six different values of d (*e.g.* 5, 10, 15, 20, 25 and 30 mm).
In your report:

- Include the spectra obtained for all the different source-detector distances;
- Plot the broadening of the energy distribution, as a function of the distance travelled by the α particles in air;
- Comment on the results you obtained: how do you explain the observed dependence?

Radiation safety

In this experiment you will need to use radioactive sources. These are to be dealt with with care. You must follow these rules:

- Keep the source in its container when not in use;
- Do not point the open end at yourself or anyone else;
- Do not tamper with the source;
- Handle using tongs or wearing disposable gloves;
- No eating or drinking in the lab;
- Wash your hands thouroughly before touching food;
- Do not handle the source if you are pregnant;
- When you have finished using the source, advise the demonstrator so that it can be returned to the store.

References

Introductory Nuclear Physics by Kenneth S Krane.
Chapter 7: "Detecting Nuclear Radiations" covers

- Interactions of radiation with matter (Section 7.1, pp. 192-6);
- Energy measurements (Section 7.6);
- Semiconductor detectors (Section 7.4).

PTD, February 2007.