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PHY3004W

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Gamma Ray Spectroscopy

Abstract

Gamma-ray Spectroscopy is the quantitative study of the energy spectra of gamma-ray sources. This experiment explores the relationship between the gamma-rays emitted by these sources and the translated electric signal (pulse) proportional to the voltage. Plots and diagrams are included in this report for further illustration. For this experiment the gamma-ray spectrum of 137Cs is studied in more detail than other radionuclides to provide an analysis of the characteristics of these of these radionuclides. Other radionuclides may behave differently but are understood in a similar manner.

Introduction.

Gamma rays are electromagnetic energy emitted by the nucleus of some radionuclides following radioactive decay. These rays are detected and studied in the field of Gamma-ray Spectroscopy and are interpreted in terms of a voltage signal that is received by a detector. For this experiment a scintillation detector was used. This process of gamma-ray detection is known as Scintillation.

This is a Nuclear Physics experiment which aims to determine the relationship between the voltage signal and the energy levels of the atomic nuclei of the gamma-ray sources used in this experiment. Using this relationship, the experiment attempts to determine the energy spectrum of an unknown radionuclide and thus the radionuclide in question.

Experimental detection of gamma-rays.

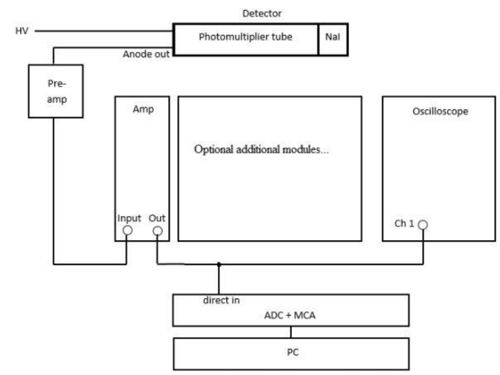


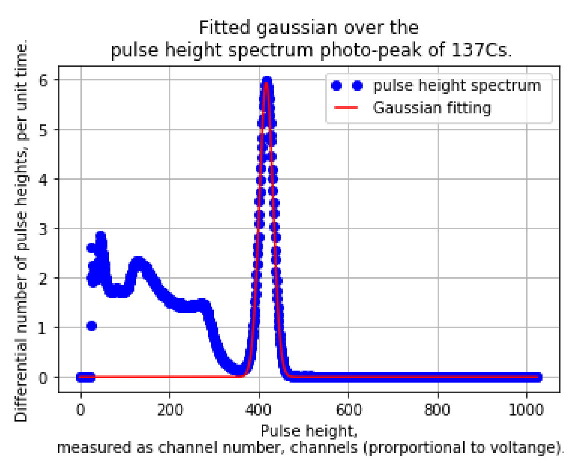
Fig. 1: A diagrammatic illustration of the connection scheme of the apparatus mentioned above. This diagram was obtained from the *PHY3004WGammaRaySpectroscopyPractical_2021.pd*f file which was uploaded to the PHY3004W,2021 tab in the laboratory section on vula.

For this experiment, A Model 556H High Voltage Power Supply with an instrument rating of 0.03%, A ORTEC Model 113 Scintillation Preamplifier which has an instrument rating of 0.25% and the ORTEC Model 572 Amplifier were used. Due to the signal amplification, the Amplifier shifts the energy spectrum peak centroid value of the measured signal by 0.024% and broadens the gamma-ray spectrum by 16% of the FWHM. A sodium iodide scintillator crystal (connected to the high voltage power supply) coupled with a photomultiplier tube was used to detect the gamma-rays. These gamma-rays were transmitted out of the photomultiplier tube as electrical signals (voltage pulses) through the anode of the photomultiplier tube. This output was then fed into the preamplifier as shown in figure 1 besides and the rest of this connection was carried out as shown. The ADC and the MCA are devices used for translating the electric signals into a digital spectrums analyzed in this lab experiment.

Among the unknown radionuclide mentioned in the introduction, the gamma-ray sources used were Caesium-137, Sodium-22, Europium-152, Cobalt-60, Barium-133 and Cadmium-109. To detect these gamma-rays, a sodium iodide scintillator crystal attached to the photomultiplier tube was connected to the input of the preamplifier this

A gamma-ray source (Caesium-137 for example) was placed right below the detector within the gamma-ray detector shield. A plot of the gamma-ray spectrum for Caesium-137 is shown in figure 2.

In figure 2, right besides, we see a backscatter peak at an approximate channel number 100 and a Compton edge peak at a channel number of approximately 250. The full energy photopeak fitted with a gaussian has a peak centroid value of 4173.3 with an uncertainty due to the instrument ratings of the equipment used and the uncertainty associated with the determination of the gaussian peak centroid. This will be further revisited in the analysis section.



The same data (as above) was obtained for each of the gamma-ray sources mentioned. With this data we could then determine the resolution of each of each of the gaussian fittings, the uncertainty of the known energy, and the uncertainty of the peak centroid. These values were obtained using a fitting program called a curve_fit program in python.

The table below shows the results obtained from the Gaussian fitting.

Gamma-ray Source	Centroid (H)	u(H)	Known Energy (keV)	u(E)	sigma	Resolution	Area
137Cs	4.17353775e+2	4e-5	661.7	0.2	6.52015217e-2	3.6788e-4	9.68789117e-1
22Na	3.19937805e+2	4e-5	511	0.3	7.00874739e-02	5.158608513e-4	4.57301403
22Na	7.82572858e+2	3e-5	1275	0.2	4.44555255e-02	1.337699889e-4	3.12987985e-01
109Cd	54.81281479	4e-4	88	0.4	0.10371467	4.455698632e-3	0.33914516
133Ba	49.53419005	1e-4	81	0.5	0.12051456	5.729176177e-3	10.32885718
133Ba	2.21291761e+02	4e-5	356	0.1	3.76267494e-02	4.003954929e-4	8.36513195e-01
152Eu	5.78493269e+01	3e-5	122	0.1	2.48327298e-02	1.010843393e-3	6.72738939e-01
Unknown	5.27095253e+02	2e-4			5.69716530e-02	2.545232379e-4	5.44898143e-0

Here, u(H) is the uncertainty associated with measuring the centroid value.

u(E) is the uncertainty associated with the known energy value.

The resolution (r) describes how good a gaussian distribution curve is. The broader the distribution, the larger the value of r. The narrower the distribution the smaller the value of r. A large value of r implies a bad distribution, a small value of r, implies a good (or better) distribution. R = FWHM/(centroid value)

FWHM is the Full width at half maximum. The width the points whose height is half the maximum height of the gaussian.

The Area is the area of the gaussian distribution

Sigma is the standard deviation of the distribution