# Beta Spectrum Lab

## ENPH 453

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## Abstract

## Introduction

## Beta Decay

Beta decay is a form of radioactive decay involving the transformation of a neutron into a proton or vice versa. Beta decay emits a high-energy electron or positron, known as beta rays. There are three types of beta decay: β+ decay, β- decay, and electron capture. β+ decay involves that transformation of a proton into a neutron, emitting a positron and neutrino. Β- occurs when a neutron transforms into a proton, emitting an electron and anti-neutrino. Electron capture is the process of an inner electron being captured by a proton in the nucleus, transforming it into a neutron and emitting a neutrino. Several factors contribute to beta decay; mainly, the total number of nuclides and the number of protons. If there is a large number of protons in an atom the Coulomb repulsion between them increases the energy, in which case it would be favourable to transform proton into a neutron, resulting in β+ decay. If there is a large number of protons in a nucleus then, based on Pauli’s exclusion principle, neutrons will be forced into high energy states, in which case β- decay may occur. This lab will be studying the β- decay of 128I. A method of inducing β- decay is to enrich a stable source with additional neutrons. The added neutrons will likely decay to protons, depending on the source. The energy of the process is termed the Q value. The Q value is the difference between the mass of the reactants and products. The Q value of 128I β- decay was calculated to be 2121 keV by subtracting the mass excess of 128Xe from the mass excess of 128I. The kinetic energy of the emitted electron, mass of the emitted neutrino, and kinetic energy of the neutrino sum to the Q value. The mass of the emitted neutrino can be calculated by subtracting both kinetic energies from the Q value.

## Beta Spectrum

The beta spectrum is a histogram plot of the energy of the electron emitted in β- decay. The energy of the electron can be used to determine the kinetic and mass energy of the emitted neutrino. At the maximum possible electron energy, the neutrino would theoretically have no kinetic energy. If the neutrino has no kinetic energy, then the energy that is not accounted for in the electron kinetic energy is the mass energy of the neutrino. The maximum kinetic energy of the electron is the x-intercept of the beta spectrum. The β- spectrum shape is that of a gaussian distribution skewed towards low energies. The distribution is skewed because of the Coulomb force slowing the electrons down to lower energies as they are emitted. For β+ decay the spectrum is skewed to high energies for the same reason. The spectrum can be linearized into a Kurie plot which clearly shows the intercept. The spectrum data is linearized by plotting the square root of the counts divided by the respective Fermi function versus energy.

Experiment

## Apparatus

The apparatus consisted of a sodium iodide source and detector connected to a photomultiplier tube (PMT). The signal from the PMT was amplified and was passed to an oscilloscope for qualitative analysis and to a computer through a multichannel analyser (MCA) for quantitative analysis. A diagram of the apparatus if shown in Fig \_\_. The sodium iodide crystal used was a Bicron 3M3/3 NaI crystal. The crystal was used as a source of beta decay and as a scintillator detector and as encapsulated in lead to isolate it from external sources of radiation. The PMT used to capture the signal from the crystal was biased at 800V with a Ortec 459 0-5 kV bias voltage supply. An Ortec 572A amplifier was used to amplify the signal output from the PMT. A Tektronix TDS3012B 2 channel oscilloscope was used to monitor the signal from the amplifier. The data was collected on the computer using the Maestro32 MCA software. The data collected in Maestro32 was then saved as SPE files. The SPE files were imported into both MATLAB and Excel for analysis.

Experimental Procedure

Setup

Calibration

Initially the computer, oscilloscope, and amplifier were turned on and the voltage bias was set to 820V. The bias remained at 818 +/- 4V for the duration of the experiment. The Maestro32 program collected data in a histogram of 2048 bins with no initial units or calibration. The system needed to be calibrated such that the Q-value of the decay was in the higher bins for greater resolution of data collection. The amplification gain was adjusted using a known gamma decay source to calibrate the system. 60Co has two known peaks at \_\_\_\_\_\_\_ which combine to a peak at 25\_\_ keV which is slightly above the Q-value. The amplification was adjusted until the 25\_\_ keV peak was at the end of the histogram. The 25\_\_ keV peak was not amplified past the limit of data collection so it could be used later in bin calibration and resolution calculation. The optimal gain was set at \_\_ and locked for the duration of the experiment.

To confirm the calibration and linearity of the bins, five gamma decay sources with peaks of varying energies were used. Each source was placed directly against the detector surrounded by lead if they had a low activity. If the source had very high activity it was placed 30cm away from the detector surrounded by lead to reduce dead time. The sources, their peaks, and placements are shown in Table \_\_.

The spectrums of each source were saved as SPE files for analysis.

Background Radiation and Noise

Despite to lead encapsulation, background radiation and noise would affect data collection. To negate this issue, longer periods of background radiation and noise were recorded to be normalized and subtracted from the data. Due to the detector in this experiment being the source as well the background was tested before the source was activated. The first background data was collected for 45 hours with no source present. A second set of background data was collected for 117 hours after a later lab period. Both datasets were saved as SPE files and imported into MATLAB. The data was normalized and save in a MATLAB workspace to be subtracted from the final beta spectrum.

Data Collection

## Analysis

## Discussion

## Conclusion