Analysis of γ ray spectra with MCA

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I. Introduction

In this experiment, we perform γ ray epectroscopy using a scintillation detector and then measure the pulse heights using a multi channel analyser. In the previous experiment we used a single channel analyser by varying the window and baseline to measure pulses within the window. The Multi Channel Analyser(MCA) measures all the pulses in all the windows at the same time.

II. Theory

We lay out, in brief, the theory behind the decay of the radioactive sources that produce the γ rays in our interaction, and the Multi Channel analyser.

II.1. Decay Scheme of $^{137}_{55}$Cs and $^{137}_{55}$Co

We detail the γ ray decay scheme of the $^{137}_{55}$Cs and $^{60}_{27}$Co, both of which we will use in the experiment.

II.1.A. Decay scheme for $^{137}_{55}$Cs

Caesium-137 ($^{137}_{55}$Cs) or radiocaesium, is a radioactive isotope of caesium that is formed as one of the more common fission products by the nuclear fission of uranium-235. The decay scheme for the $^{137}_{55}$Cs is given in the schema below.

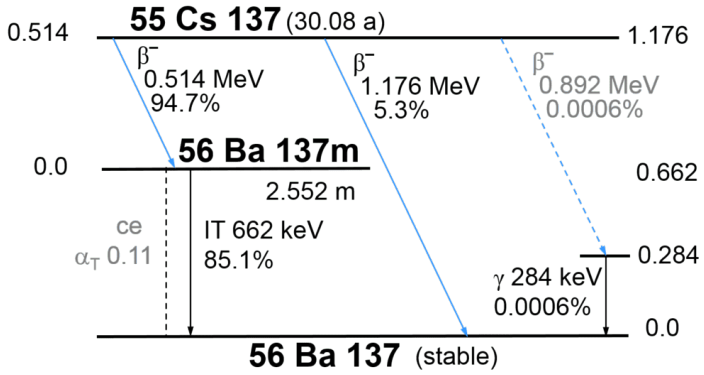

Figure 1 :: Decay scheme of $^{137}_{55}$Cs into $^{137}_{56}$Ba (Source: The Internet)

There are three decay schemes for $^{137}_{55}$Cs decaying into $^{137}_{56}$Ba. The most observed ones are the β decay into $^{137m}_{56}$Ba and then γ decay into $^{137}_{56}$Ba, and the direct β decay into $^{137}_{56}$Ba. We are observing the γ ray spectrum for the γ ray emitted on transition from $^{137m}_{56}$Ba to $^{137}_{56}$Ba. The 'm' in $^{137m}_{56}$Ba stands for metastable or unstable. The third decay scheme occurs only 0.0006% of the time, so, we can safely ignore that.

The decay leaves 94.7% of the parent Caesium nuclei into the metastable $^{137m}_{56}$Ba nucleus via a β^- ray interaction and the release of an anti-neutrino. Then a γ ray decay of energy 662 keV converts the metastable nuclei into the the ground state $^{137}_{56}$Ba. The nuclear reactions are written below.

$$^{137}_{55}\text{Cs} \longrightarrow {}^{137m}_{56}\text{Ba} + e^- + \overline{\nu}_e \longrightarrow {}^{137}_{56}\text{Ba} + e^- + \overline{\nu}_e + \gamma(661.65keV) \qquad [1]$$

II.1.B. Decay scheme for $^{60}_{27}$Co

Cobalt-60 ($^{60}_{27}$Co) is a synthetic radioactive isotope of cobalt with a half-life of 5.2714 years. It is produced artificially in nuclear reactors.

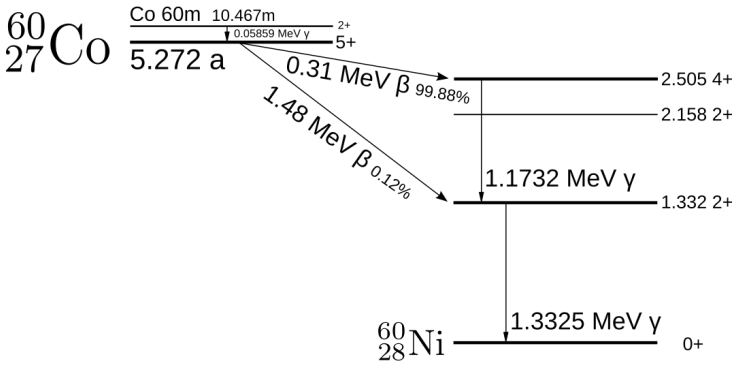

Figure 2 :: Decay scheme of $^{60}_{27}$Co into $^{60}_{28}$Ni (Source: The Internet)

This is produced on activation of $^{59}_{27}$Co via neutron activation. The dominant interaction here is a β^- decay to a intermediate state and then two consecutive γ ray decays to get to $^{60}_{28}$Ni. Then we get a multistep decay from $^{59}_{27}$Co to $^{60}_{28}$Ni. We observe a multistep decay due to some selection rules that do not allow transitions to certain states to take place. We thus get the following decay processes

$$^{59}_{27}\mathrm{Co} + n \longrightarrow {}^{60}_{27}\mathrm{Co} \quad [2]$$

$$^{60}_{27}\mathrm{Co} \longrightarrow {}^{60}_{28}\mathrm{Ni}^* + e^- + \overline{\nu}_e \longrightarrow {}^{60}_{28}\mathrm{Ni}^* + e^- + \overline{\nu}_e + \gamma(1.173MeV) + \gamma(1.333MeV) \quad [3]$$

II.2. Multi Channel Analyser

In this experiment we use a Multi Channel Analyser (MCA) to measure the energy spectrum of the particles emmitted in the nuclear decay process for C-137 and Co-60. The MCA is connected to a Scintillation detector which produces low energy photons which go through a photo multiplier tube (PMT) to amplify the signal. The number of electrons produced is proportional to the energy of the incident gamma ray. An MCA is used to analyse an input signal consisting of voltage pulses. As evident from the title, it can scan for voltage pulses accross different voltage channels. In our experiment, we had 1024 channels, each corresponding to a certain window of energy with a fixed window size. We calibrated the MCA using the known values for the energy peaks for the decay of a Co-60 nucleus.

A multichannel analyser stores information in one of two ways:

II.2.A. Pulse-Height Analysis

In pulse-height analysis mode (PHA), incoming pulses are characterised by their voltage ampitudes, and hence, the output spectrum is a histogram, corresponding to number of pulses counted within a certain window corresponding to each of the channels of the MCA. In this experiment, we used the MCA in PHA mode to get a energy spectrum for the gamma ray emmision from the nuclear decay process.

II.2.B. Multichannel Scaling Mode

In Multichannel scaling (MCS) mode, the MCA doesn't differentiate between pulses of different voltage amplitudes. Hence, we only get a pulse count rate over time as an output. The MCA records the number of pulses in a given channel first, for a fixed time interval, and then starts counting for the next channel for the next time interval and so on.

III. Data

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VI. Conclusion