Measuring the Gamma Decay Energy of Cs-137 Using Co-60 As a Reference

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We calculate the gamma decay energy of ^{137}Cs by measuring the average channel location of the peaks of ^{60}Co on the graphs generated by a spectrometer, converting the channel locations to energy units using the known energy values of the gamma decay for ^{60}Co, and comparing the position of the peak of ^{137}Cs on the spectrometer output to the respective energy for that position on the ^{60}Co graph. We obtain a value for the gamma decay energy of ^{137}Cs of 0.657 ± 0.105 MeV.

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I. INTRODUCTION

Some atomic nuclei have a combination of protons and neutrons such that the binding energy cannot hold the nucleus together. Such a nucleus is unstable and will ultimately undergo radioactive decay, where the nucleus emits either subatomic particles, as in alpha and beta decay, or electromagnetic radiation, as in gamma decay, to shift to a more stable state [2].

Gamma decay usually occurs after other types of radioactive decay. When the nucleus emits particles, it often is left in an excited energy state. The nucleus then emits a photon to reduce its energy to a lower, more stable state [1–3]. This process is known as gamma decay.

One example of gamma decay is the decay of $^{60}_{27}$Co into $^{60}_{28}$Ni. The initial process of beta decay, given by

$$^{60}_{27}Co \rightarrow {}^{60}_{28}Ni + e^- + \overline{\nu}_e \tag{1}$$

[3, 5], leaves the $^{60}_{28}$Ni in an excited state. The $^{60}_{28}$Ni then goes through two gamma decays, emitting photons of 1.173 MeV and 1.333 MeV, respectively [3–5]. A photomultiplier tube measuring the gamma decay energies of a ^{60}Co source will output these two energy values as peaks on the resulting image plotted by the spectrometer.

II. EXPERIMENTAL SETUP

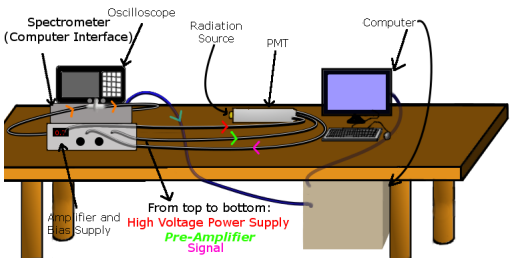

Figure 1: A diagram of the apparatus.

A radiation source is taped to the photomultiplier tube (PMT) at a location fixed by two strips of tape. The PMT records the number of photons entering it and those photons' wavelengths.

An amplifier and bias supply is connected to the PMT by three cables. The first cable provides the PMT with the voltage that powers it. The second cable boosts the PMT signal to remove noise and distortion and to make the signal strong enough to be processed by the amplifier. The third cable sends the signal to the amplifier, where it is boosted a second time.

The signal is then sent from the amplifier to the spectrometer, which sorts the photon data by wavelength into 2048 channels. This sorted data is then sent to the computer for analysis and calibration.

The oscilloscope, by displaying impulses received by the PMT, makes clear that the PMT is functioning and recording data.

III. PROCEDURE

We place two strips of tape on the flat end of the PMT to form a right angle, allowing us to place the source at the same location on the PMT for each trial by aligning it with the edges of the tape. We begin by measuring the background radiation of the room, with no source on the PMT. This background plot is intended to help us better choose the peaks of the measurements of the radiation sources by showing which of the peaks, if any, might be artifacts of ambient radiation rather than the radiation from the source.

We then measure the radiation from a ^{60}Co source. The resulting plot of the data has four distinct peaks, as can be seen in Figure 2:

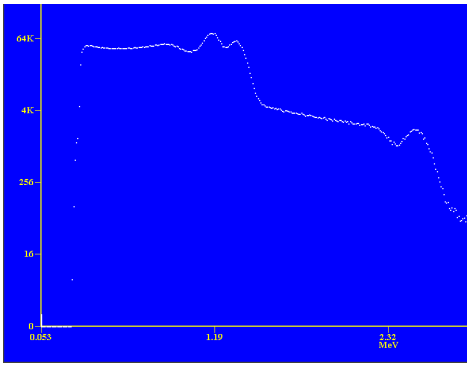

Figure 2: A plot of ^{60}Co gamma decay energies.

We perform 15 distinct trials for ^{60}Co, each time placing the source at the same position on the PMT using the pieces of tape as a guide.

We attempt to determine which peaks on the plot give the values for the gamma decay energies of ^{60}Co by comparing the locations of peaks on the background plot with those on the ^{60}Co plot. Using this method, we determined that the two peaks on the ^{60}Co plot not accounted for by the background plot were the first and second peaks. However, further analysis, described in section IV, shows that the actual two peaks on the plot corresponding to the ^{60}Co gamma decay energies are the second and third peaks. Using a computer program to calibrate the plots so that the channel numbers are converted to energies, we are able to obtain the corresponding energy for each channel.

We then measure the radiation from a ^{137}Cs source. The procedure is the same as that for measuring the ^{60}Co source, except that we only perform 10 trials instead of 15. The resulting plot only has a single peak, which matches the number of gamma decay energies of ^{137}Cs, so there is no need to choose among peaks. We compare the resulting channel location of the peak to the corresponding energy on the ^{60}Co plot to determine the gamma decay energy of ^{137}Cs.

IV. ANALYSIS

The average location of the ^{60}Co peaks across the 15 trials is

$$peak\ 2 = channel\ 125 \pm 9 \tag{2}$$

and

$$peak\ 3 = channel\ 143 \pm 10 \tag{3}$$

The positions of the two peaks are correlated, with the average distance between them being 18 ± 2 channels. We thus take the larger of the standard deviations of the two channel locations as the overall error in channel location.

The two gamma decay energies for ^{60}Co are 1.173 MeV and 1.333 MeV [3–5], as stated above. Using these values and the channel locations of the ^{60}Co gamma decay peaks, we calibrate the data on the computer to turn the channel locations into energy values. The width of each channel comes out to be

$$0.009 \pm 0.001\ MeV \tag{4}$$

The average location of the ^{137}Cs peaks across the 10 trials is

$$channel\ 67 \pm 6. \tag{5}$$

The corresponding energy, according to the ^{60}Co plots, is

$$0.657 \pm 0.105\ MeV \tag{6}$$

The global value for the gamma decay energy of ^{137}Cs is

$$0.662\ MeV \tag{7}$$

[4], which matches the result from our experiment.

When we originally used the two peaks with no equivalent peaks on the background plot, the channel width was calculated to be

$$0.005 \pm 0.001\ MeV \tag{8}$$

and the gamma decay energy of ^{137}Cs was calculated to be

$$1.049 \pm 0.081\ MeV \tag{9}$$

a value more than nine standard deviations from the global value. For this reason, we concluded that we attributed the wrong peaks to the ^{60}Co gamma decay energies. We therefore determine the correct ^{60}Co through trial and error by comparing the resulting ^{137}Cs gamma decay energies to the global value and picking the ^{60}Co peaks that produce the ^{137}Cs energy closest to the global value.

V. CONCLUSION

The attempt to determine the two relevant peaks in the ^{60}Co plot using the background failed, as the resulting gamma decay energy diverged greatly from the global value. One of the ^{60}Co decay energy peaks has what appears to be a corresponding peak in the background plot. The ambient radiation may include radiation ^{60}Co, as cobalt is often used to make steel, and ^{60}CO is a naturally occurring isotope. Alternatively, the ambient radiation may include a separate element with a gamma decay energy close to that of ^{60}Co, as the error margin allows for a range of possible substances to have a peak in the same location.

Further improvements to the experiment can be made through three methods. The first is to better determine the error in average peak location. In taking the error of one peak to be the error in both peaks, we assume that the two peaks are perfectly correlated, when in fact there is some amount of variation between their respective locations. Accounting for this variation would allow more precise calculation of the error.

The second method is to reduce the error from placing the radiation sources on the PMT. Repeated placing of the sources on the PMT for different trials changes the location of the peaks by an amount significantly greater than the corresponding peak location variance from statistical error. At least part of this error may result from our lack of accounting for the rotational orientation at which we place the source on the PMT. We insure that the source is placed at the same physical location on the PMT and that the same side of the source faces the PMT, but we do not make sure that the rotational orientation of the source is uniform throughout the trials. As the radioactive part of the source is likely not directly at its center, the resulting variation in the rotational orientation of the face of the source would create additional error in the channel locations of the resulting peaks.

Finally, performing more trials would reduce the standard deviation of the peak locations by the square root of the number of trials performed.

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