Spectra of Cs-137 and Co-60 Using NaI Detector

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Abstract

Spectra for samples of ^{137}Cs and ^{60}Co were obtained using the sodium-iodide detector. The 0.667 MeV line from Cesium-137 was used to determine the two lines seen from the sample of Cobalt-60. These two lines were found to be 1.161 0 0.02 MeV and 1.325 ± 0.02 MeV respectively. Known values for the energies of gamma rays emitted from the ^{60}Ni nucleus after beta decay from ^{60}Co are 1.17 MeV and 1.33 MeV.

Introduction

Spectra are often obtained from photons with energies associated with the optical range of the electromagnetic spectrum. These spectra are from the outermost electrons in atoms and molecules. It is, however, possible to sample spectra from anywhere else in the electromagnetic spectrum.

Gamma ray spectroscopy deals with photons corresponding to energies on the order of 10^6 times greater than those from the visible range of the spectrum and are emitted from the nuclei of atoms as opposed to the outer electrons. This drastic difference in energies is due to the strength of the strong nuclear force between nuclides when compared to the electrostatic interaction between the nucleus and the orbiting electrons. The electromagnetic force is 1/137 the strength of the strong nuclear force.(1)

An energy of a given photon is expressed in the equation:

$$E_n = n * h * \nu$$

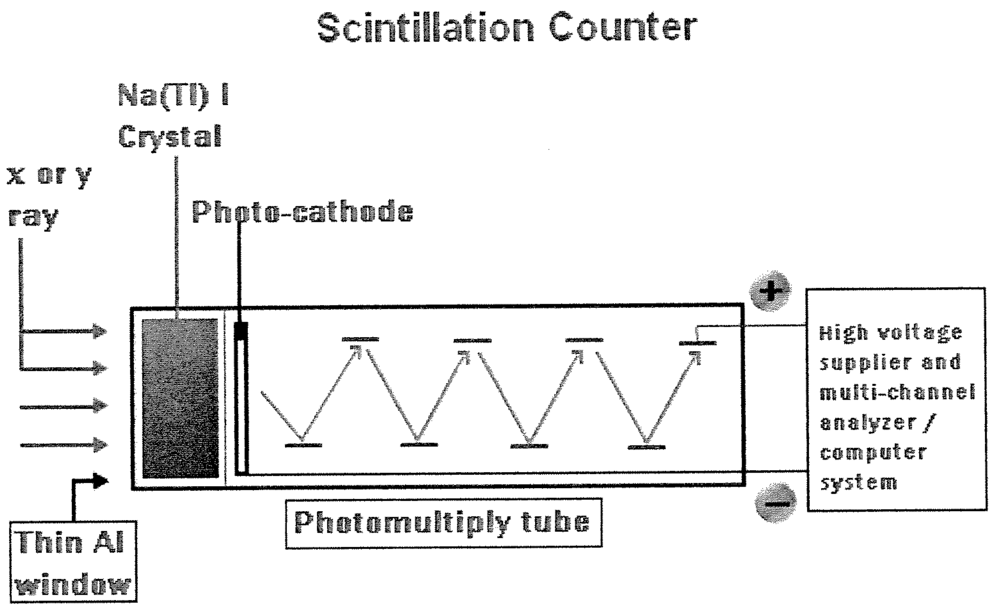
In the analysis of a spectra for a given sample, the 'peaks' or 'spectral lines' seen correspond to a resonance frequency. This resonance is caused by two quantum mechanical stationary states in one system being coupled by an oscillatory energy source, most commonly a photon. Coupling is at a maximum at the point where the difference energy between the two quantum mechanical stationary states is equal to the value of the source energy. (2)

The lines that are centered on specific frequencies each represent the resonance between two quantum mechanical states. The series of peaks makes up the spectra.

Experimental Apparatus

The Thallium doped Sodium Iodide detector was used for sampling the spectra of Cesium-137 and Cobalt-60.

Sodium Iodide detectors are scintillation detectors. They are made of a material that exhibits a property of luminescence called scintillation when excited by ionizing radiation. When these scintillators are struck by an incident particle, they absorb the energy and re-emit it in the form of a photon. The re-emitted photons are sent into a photomultiplier tube, where the photon is re-emitted once more in the form of electrons due to the photoelectric effect. The amplified electrical signal from the original source is what comprises the spectra.[3]



This particular setup of the thallium doped sodium iodide scintillator produces the spectra by counting the number of photons detected at a given channel number. These photon counts are plotted as a function of the channel number (which corresponds to the actual energy of the photon). The peaks are then identified once the noise has been sufficiently removed from the spectra.

Procedure

A sample of ^{137}Cs and ^{60}Co were placed directly in front of the NaI detector. Detector was left to collect data for a period of fifteen minutes. This collection time was used to filter out as much background noise as possible and to get a sufficient count for the known 0.667 MeV Cesium line and the two undetermined Cobalt lines.

The count for specific photons was plotted against their corresponding channel (energy). The Cobalt lines were determined by the linear relationship of the channel number listed at the approximate center of the 0.667 MeV Cesium-137 peak and the two undetermined Cobalt-60 peaks.

Data

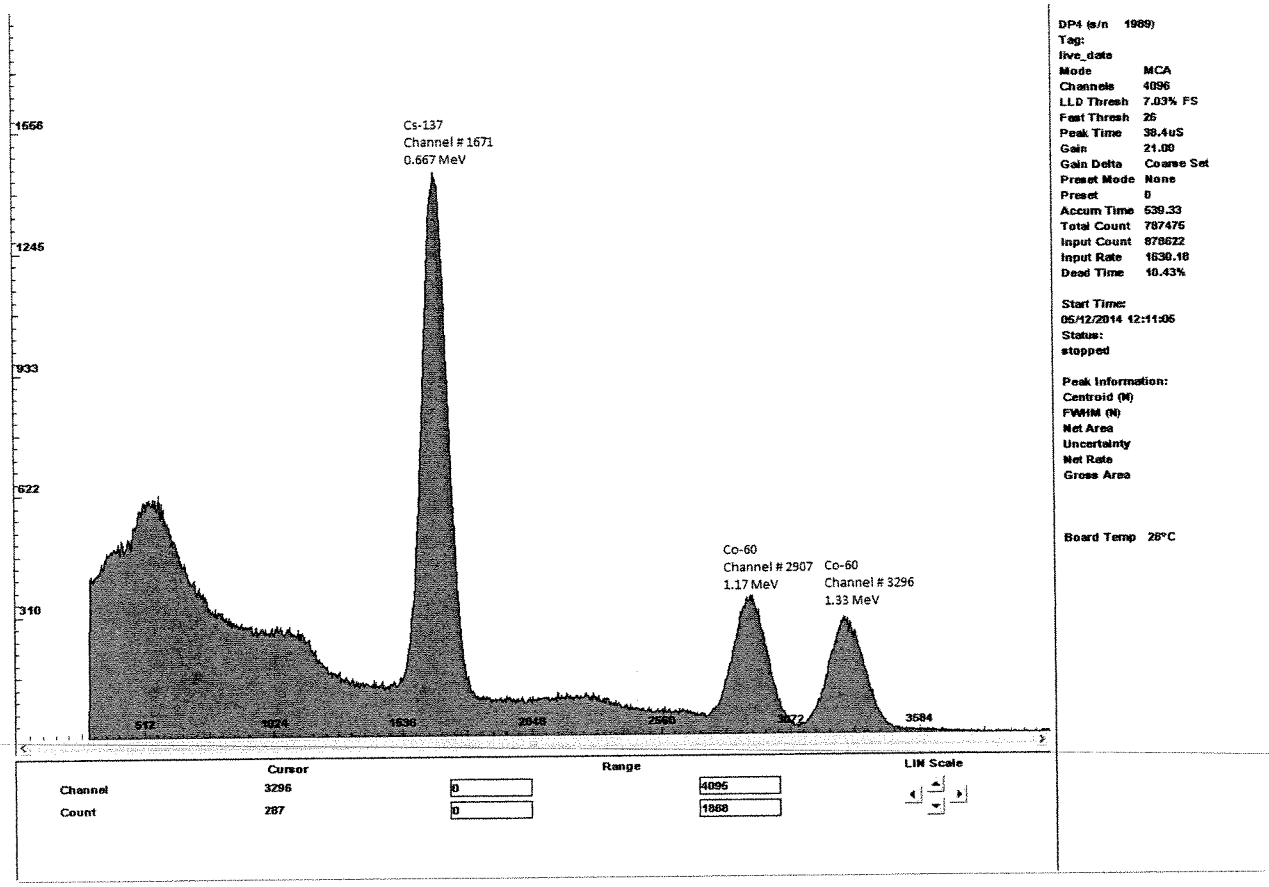
Using the known value for the 0.667 MeV Cesium-137 line, the two undetermined Cobalt-60 lines were calculated from the factor relating the channel numbers to energy.

The 0.667 MeV line was measured at channel number 1671. Using:

0.667=1671*x

The other two energy levels were calculated. The first Cobalt-60 line at channel 2907 was determined to be 1.161 ± 0.02 MeV and the second at channel 3296 was determined to be 1.325 ± 0.02 MeV.

labels



Analysis

The uncertainties in these measurements come from both the resolving power of the NaI detector and the necessity to estimate the center of each peak to find the proper channel number for calculating the energy of the two undetermined Cobalt-60 lines.

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Measurement of the undetermined Cobalt-60 lines were found at 1.161 ± 0.02 MeV and 1.325 ± 0.02 MeV compared to known values of 1.17 MeV and 1.33 MeV. These lines are a result of the gamma rays emitted by the ^{60}Ni atom that decays from ^{60}Co and the ^{137}Ba atom that decays from ^{137}Cs.[4] The actual equation for the mechanism is:

^{59}Co + n -> ^{60}Ni + e^- + ν_e + gamma ray

The noise seen before the 0.667 MeV Cesium line is a result of the Compton distribution. This distribution comes from Compton Scattering via primary gamma rays within the Sodium Iodide crystal itself.[5] While it is possible to reduce this, it is difficult to do so in NaI detectors.

Anticoincidence shielding can be used to reduce primary gamma rays but they are more common in the smaller and more expensive Germanium detectors.

Conclusion

The thallium doped sodium iodide detector was used to take spectra of ^{137}Cs and ^{60}Co. Using the known value of 0.667 MeV for Cesium-137, the two undetermined lines of Cobalt-60 were found to be 1.161 ± 0.02 MeV and 1.325 ± 0.02 MeV. This is a 0.77% and 0.38% deviation from the known values of 1.17 MeV and 1.33 MeV respectively.

NaI detectors are advantageous for applications in both gamma ray and x-ray spectroscopy. The ability to create large, efficient sodium iodide crystals is a huge advantage. The sodium iodide also produces more intense bursts of light compared to other scintillation devices. The convenience and ease of use of this type of detector also allows for out-of-laboratory uses such as identifying unknown materials for purposes of law enforcement.[2]

References

(1) - http://hyperphysics.phy-astr.gsu.edu/hbase/forces/funfor.html
(2) - http://en.wikipedia.org/wiki/Gamma_spectroscopy
(3) - http://en.wikipedia.org/wiki/Scintillator
(4) - http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/betaex.html
(5) - http://en.wikipedia.org/wiki/Compton_effect