Proceedings of the Korean Nuclear Society Spring Meeting
Seoul, Korea, May 1998

Effect of Coincidence Gamma-ray Spectroscopy to the Reduction of Background Spectrum

Taewook Kim, Changsoo Yoou, Chongmook Park, and Byungtae Kim

Nuclear Environment Technology Institute
Technology Development Group
Duckjin-dong 150, Yusung-gu
Taejon, Korea, 305-600

Abstract

A coincidence gamma-ray spectroscopy method was applied to reduce the background radioactivity for measuring the activity of radioisotopes in a sample in the presence of environmental natural radioactivity. A HPGe detector was used for the coincident spectrum as a main detector and a NaI(Tl) scintillation detector for gating purposes as an associated detector. For coincidence spectroscopy the whole energy spectrum of associated detector was used instead of gate signals. The coincident events obtained from the gating spectrum was evaluated by a coincidence computer program in this study instead of timing circuit.

In this work, the background of detection environment was reduced to factor 100 and peaks to be determined was reduced to factor 30 using the coincidence gamma-ray spectroscopy.

Background

In general, environmental samples or radioactive samples containing various radioisotopes emitting gamma-rays can be analyzed by using a gamma-ray spectrometer without complex pretreatment. In case of analyzing low radioactive isotopes, however, the spectrum analysis is not simple because low-intensity peaks are obscured by the background spectrum of Compton continuum.

To effectively analyze the low radioactive samples, the background spectrum should be reduced al low as possible. There are several methods to reduce the background spectrum, but two methods, Compton suppression and coincidence spectroscopy, are described belows.

The Compton continuum is due to Compton scattering photon which is originated from the incomplete deposition of photon energy in detector crystal. The suppression of the Compton continuum is possible by anti-coincidence technique with guard detectors in order to reduce the background spectrum[1,2]. The guard detector detects the Compton scattering photon escaped from the detector and then the scattered photon is suppressed by electronic anti-coincidence circuit. Such a method is called as Compton suppression. This method is not used in this work.

Many radioisotopes emitting gamma-rays emits more than one gamma-ray in coincidence. Most of the gamma-rays except specified gamma-rays can be removed by the anti-coincidence circuit and in turn the background can be reduced[3]. The specified gamma-rays emitted in coincidence can be detected by coincidence techniques with combination of two Ge detectors or Ge and NaI(Tl) scintillation detectors.

The coincidence spectroscopy needs a main detector for coincident spectra and an associated detector for coincident gate, and coincident electronic circuits. In most case, the signals of main and associated detectors are amplified by fast timing amplifiers and transferred to TAC. The TAC analyzes time difference between main detector signals and associated detector signals and produces logic pulses if their time difference is within coincidence time. The TAC signals are transferred to ADC and the ADC transfers main detector signals with energy information to a computer as coincident events. Such a coincident technique requires a tremendous job, if there are many nuclides emitting gamma-rays in coincidence and will be called as a hardware coincident method in this paper to be distinguished from another coincident method such as a software coincident method.

The software coincident method does not use fast timing amplifiers. The signals of main and associated detectors are transferred directly to ADCs. Judgement of whether those signals are coincident or not is accomplished by a computer software in a MPA(Multi-Parameter Analysis) system(which was provided by Fast Comtec). In MPA system, all data including time informations are saved in a computer memory and the time information can be analyzed at once or later. In a hardware coincident method, coincident gate setting is needed to each nuclide, while in a software coincident method, coincident gate setting is accomplished just by typing gating-channels on the spectrum window of the computer.

Experiment

A coincident gamma ray spectroscopy was performed using a HPGe detector, a NaI(Tl) detector, two ADC, and MPA system which were included in a circuit as shown in Figure 1.

The efficiency of the HPGe detector is 100% compared with that of 3"x3" NaI(Tl) detector and the size of the NaI(Tl) detector was 3"x3". Radioisotopes used were a ^{60}Co standard source with activity of $3.7x10^4$Bq and natural radioactivities around the spectroscopy laboratory. The two detectors were set as shown in Figure 2.

The HPGe detector was located at 150cm apart from the ^{60}Co source and the NaI(Tl) detector was at 10cm apart.

The signals of HPGe and NaI(Tl) detectors are transferred to the MPA system via

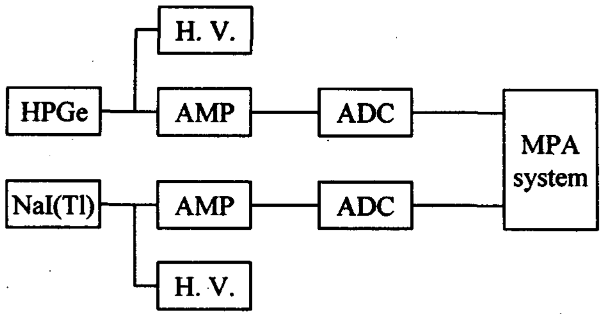

Fig. 1. Software coincident circuits of this experiment

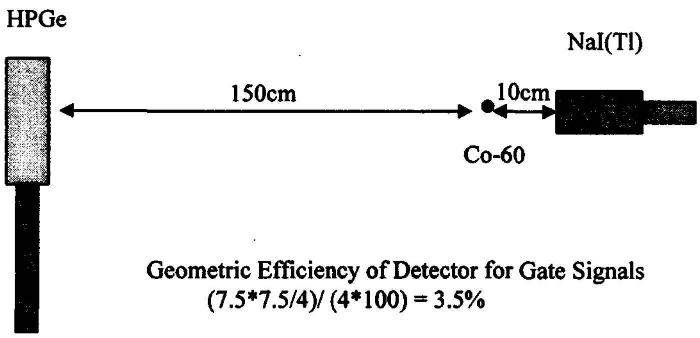

Fig. 2. The geometry of detectors in this experiment

amplifier and ADC. In coincident-spectrum measurement, the whole energy spectrum of main detector HPGe has to be used, but the signals of associated detector NaI(Tl) could be set to many types such as whole energy spectrum type, gating pulse type, or mixing of both types. When the spectrum of associated detector is set to the gating pulse type, many peaks of the spectrum could be set to gating pulses at the same time just by typing the channel numbers of gating peaks of the MPA system in the computer window. After all conditions are set, analysis is executed by a computer program.

The ^{60}Co transforms to ^{60}Ni undergoing β^- decay as shown in Figure 3. The ^{60}Ni transformed from ^{60}Co is very unstable and promptly transformed to a stable state by emitting two consecutive gamma-rays, so called coincident gamma rays. The energy of the first emitted gamma-ray is 1173.2keV and the second one is 1332.5keV.

The angle between the emitting directions of two gamma-rays depends on deformed type of ^{60}Ni nuclei and is around 2π. So if one of two gamma-rays were emitted to the HPGe detector, then the other one would be emitted to the opposite direction. Because of such reasons, the NaI(Tl) detector was set on opposite direction against the HPGe detector.

In general, the detection efficiencies of lower energy gamma rays are larger than those of higher ones. Two gamma-rays emitted from ^{60}Ni, 1173.2keV and 1332.5keV, have the same yield of 100% per β^- decay of ^{60}Co. But in energy spectrum of ^{60}Co, the peak of 1173.2keV gamma ray is higher than that of 1332.5keV ones.

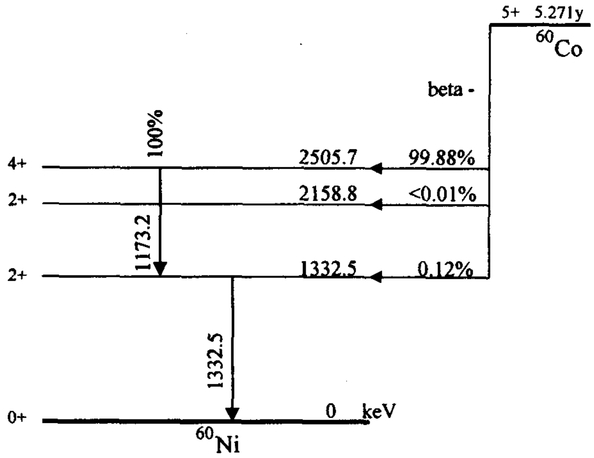

Fig. 3. The decay scheme of ^{60}Co

In this experiment, a coincident gate was set to 1173.2keV peak of NaI(Tl) detector spectrum and the energy spectrum of ^{60}Co was measured with HPGe detector in coincidence with and without gate signals of NaI(Tl) detector.

The HPGe detector was not shielded by any shielding material such as ordinary lead, namely open to the atmosphere. Therefore the more background activity of the gamma-ray spectrometer was increased, the activity of ^{60}Co was more decreased comparing with the background of the spectrum. Nevertheless, still the activity of the ^{60}Co was high comparing the natural radioactivity.

Two measurements were carried out at the same time. One was for a measurement of single gamma spectrum and the other was for coincident gamma spectrum. The coincident spectrum would be analyzed by the MPA system without using the timing circuits of TAC or by using hardware timing circuits. In general, when using hardware timing circuits, a timing circuit is needed to each peak for making a detected gamma-ray peak to a coincident-gate signal, so that if there are many different peaks matching to coincident-gate signals, then many electronic circuits are required. However, for analysis of the results of this coincident experiment, a software coincident method was used, which are embedded in the MPA system.

The signals of HPGe detector and NaI(Tl) detector are transferred through amplifiers and ADCs and accumulated in a MPA card register or memory of the MPA system. Timing coincidences of two detector signals are analyzed with a window program of the MPA system. This process is very simple. With appearance of the energy spectrum of associated detector signals, peaks associated to coincident gate are merely selected by typing the channels and a coincident time.

The normal energy spectrum and the coincident spectrum are recorded at the same time in the computer memory of the MPA system. The measured time was 10,000 seconds and the coincident time used was 4μs.

Results and Discussion

The results are shown in Figure 4. The upper spectrum shown in the figure shows a single

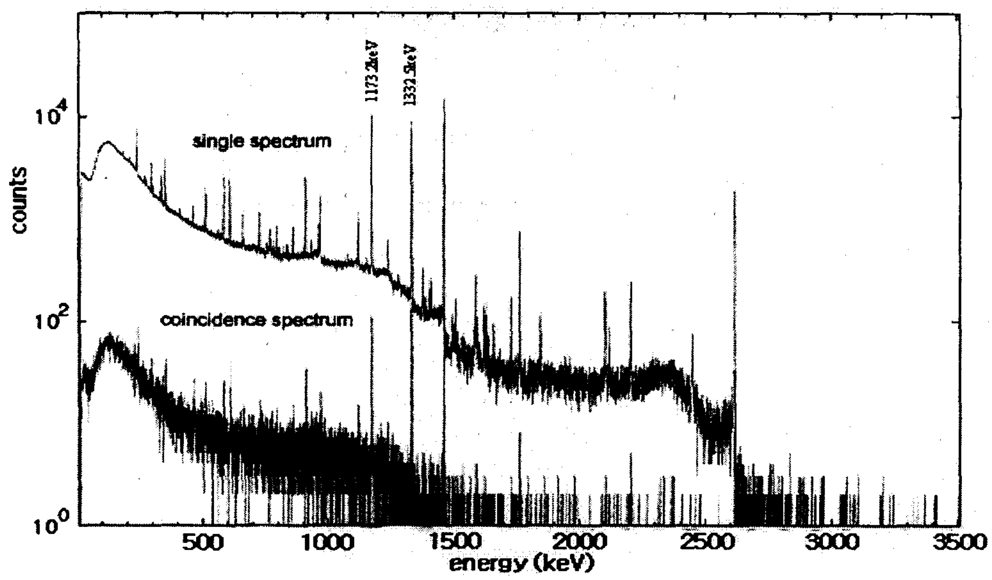

Fig. 4. A comparison between single spectrum and coincident spectrum of ^{60}Co gamma-ray

energy spectrum and the lower one does a coincident spectrum. The vertical scale of the figure is counts per channel and horizontal scale is energy in keVs.

The figure shows that the background of the coincident spectrum was about 100 times lower than that of the single one. Such a result came from the reason that any pulses not coincident with the gate pulses of 1173.2keV gamma pulse of ^{60}Co were suppressed by the coincident circuit or the coincident analysis software of the MPA system.

Theoretically at a certain channel of energy spectrum, the ratio of random coincident events to the true coincident events is proportional to the ratio of the numbers of coincident events to the total numbers of events detected by associated detector. That ratio was about 1/100 in this experiment.

The efficiency of measuring true coincident events in the coincidence spectrometer is proportional to the geometrical efficiency of associated detector and was about 3.5% in this experiment. The reduction factor of the true coincident events was about 30. So the height of coincident peak was about 3 times higher than that of non coincident peak.

The geometrical efficiency of associated detector can be raised up to more than 0.9. If then, the coincident peaks will not reduced, and in turn, the background of this counting detector will be reduced to less than about 100 times. Namely, the peaks wanted remains on the spectrums and other peaks and backgrounds diminishes clearly.

Conclusion

In this work, the background of detection environment was reduced to factor 100 and peaks to be determined was reduced to factor 30 using the coincidence gamma-ray spectroscopy.

A coincidence gamma-ray spectroscopy method is useful to measure the activity of low radioactive isotopes. In coincident measurement, the ratio of true coincident events to random coincident events is fixed, but the measurement efficiency of true coincident events is proportional to the geometrical efficiency of gate detector. So the larger the geometrical efficiency of associated detector is, the better results of the coincidence gamma-ray spectroscopy may be obtained.

The software coincident method is more convenient than the hardware coincident method , since the software coincident method has a simple operation function and can reduce a lot of work to be required by the hardware coincident method. The software coincident method could be recommended in various coincident experiments.

Reference

1. D. Masse, A. Adam and J. Laurec. "A Ge-NaI(Tl) spectrometer with Compton suppression and gamma coincidence counting : Application to ^{189}Ir and ^{101}Rh activity measurements," Nucl. Instr. and Meth. A309, 227-235 (1991).
2. L. L. Kiang, R. H. Tsou, W. J. Lin, Simon C. Lin, S. C. Kiang, P. K. Teng and S. D. Li," A study on T-shape Compton suppression spectrometer by Monte Carlo Simulation," Nucl. Instr. and Meth. A327, 427-432 (1993).
3. Cheng-Jong Lee and Chien Chung, "Determination of ^{134}Cs in Environmental Samples Using a Coincidence Gamma-ray Spectrometer." Appl. Radiat. Isot. 42(9), 783-788 (1991).