Critical Limit for Analysis of Single Escape Peak of 1173 keV Gamma-Rays from Co-60

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1. Introduction

Cs-137 with relatively long half-life is representative radionuclide fission product. Without nuclear fission, there are so few ways to produce the Cs-137 isotope. So, the detection of Cs-137 is very important in the evaluations of nuclear facility accident [1] and waste disposal. Since Cs-137 emits the gamma-rays with almost unique energy of 661.660 keV, it is also very important isotope in the calibration of the gamma-ray detection system.

Co-60 is also widely used isotope in the calibration of gamma-ray detection system, and it is produced in the significant amounts by neutron activation in nuclear reactor. It emits the prevailing two gamma-rays with energies of 1173.238 and 1332.502 keV which are larger than 1022 keV. Therefore, the single escape(SE) and double escape(DE) peaks can appear on the gamma-ray spectrum of Co-60. There are very few measurements of these escape peaks because of very low pair production probability of Co-60 gamma-rays.

However, accidentally, the centroid energy of SE peak of 1173.238 keV gamma-rays is very near to that of gamma-ray peak from Cs-137. Considering the energy resolution of detection system, the uncertainty of energy calibration and the Doppler broadening of SE peak [2], it is highly probable that the SE peak of 1173 keV gamma-rays from Co-60 gives the misjudgement for the existence of the Cs-137 and the interference for peak area of Cs-137 gamma-rays.

In this work, we measured the Co-60 gamma-ray spectra with various full energy peak areas by using the HPGe detector, and we set the critical limit by which we can decide whether the net count of 662 keV peak would be significant or not.

2. Experimental Methods

The detector used in this work is a closed-ended coaxial HPGe detector, and its specifications are given in Table 1. The gamma-ray spectroscopy system was set up as shown in Figure 1, and the shaping time of the amplifier was set at 6 μsec.

Table 1. Specifications of the HPGe detector.

Relative efficiency	15 %
Resolution	1.80 keV(FWHM) at 1.33 MeV 0.825 keV(FWHM) at 122 keV
Peak to Compton ratio, Co-60	44
Crystal diameter	55.0 mm
Crystal length	37.2 mm
Al end cap thickness	1.27 mm
Inactive Ge thickness	700 μm
End cap to crystal	3 mm
Detector bias voltage	+2600 V

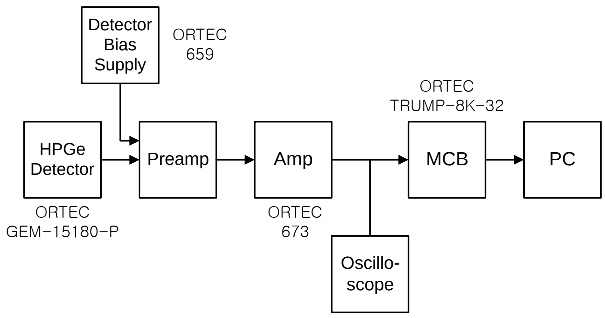

Fig. 1. Block diagram of the gamma-ray spectroscopy system.

The Co-60 gamma-ray spectra with various full energy peak areas were obtained by using the HPGe detector and standard source, and one example of the spectra is shown in Figure 2. The source-to-detector distance was 25 cm.

The peak area is calculated as follows [3],

$$A = \sum_{i=L}^{U} C_i - n\left[\sum_{i=L-m}^{L-1} + \sum_{i=U+1}^{U+m}\right] / 2m \,, \qquad (1)$$

where, C_i are the counts in the ith channel, and n is the number of channels within the peak region. In order to estimate the background beneath the peak, m channels beyond each side of the peak region are used.

The critical limit by which we can decide whether the net count of peak is significant or not, for 95% confidence, is given by:

$$L_C = 1.645[B(1 + n/2m)]^{1/2} \,, \qquad (2)$$

where, B is the background count.

In the analysis of 662 keV peak, n and m are equal to 21 and 3, respectively.

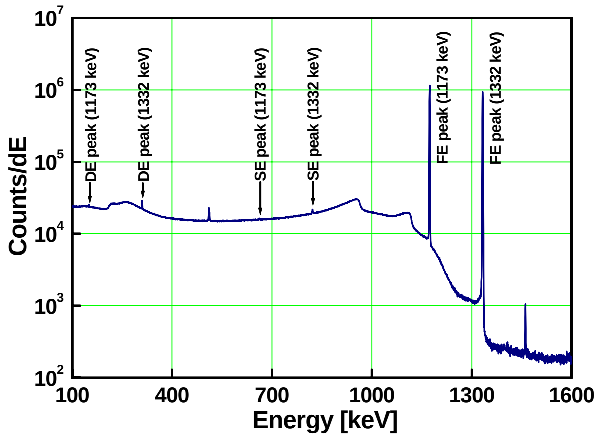

Fig. 2. Photon spectrum of Co-60 obtained by using the HPGe detector.

3. Results

Figure 3 shows the portion of interest in two spectra with different full energy peak area at 1173 keV. Through the long-term detection of background, it was confirmed that the effect of natural background was negligible. From the figure, we know that when the full energy peak area is several million, the SE peak of 1173 keV gamma-rays from Co-60 looks like a single peak which is statistically significant.

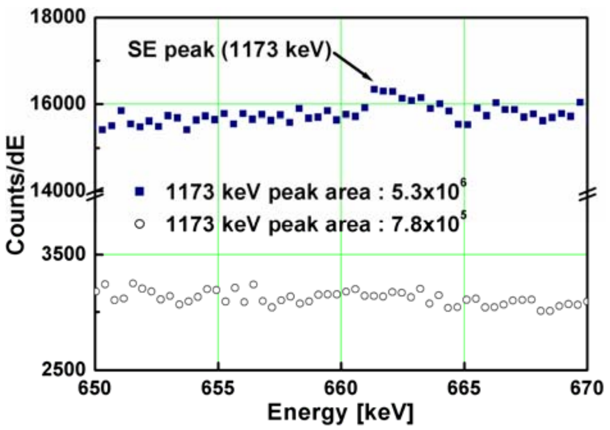

Fig. 3. A portion of the Co-60 gamma-ray spectra showing the region of SE peak of 1173 keV gamma-rays.

Table 2 shows the critical limit calculated by using the measured Co-60 gamma-ray spectra. The the ratio of the areas of SE and full energy peaks is determined and also shown in the table [4].

Table 1. Critical limit calculated by using the measured Co-60 gamma-ray spectra and the ratio of the areas of SE and full energy peaks.

1173 keV peak area	662 keV		Critical limit	Ratio of peak areas
	Gross	Net		
313350	25335	485±241	550	0.001548
782848	62601	671±381	869	0.000857
1755004	107136	669±499	1139	0.000381
3758085	307918	2172±875	1930	0.000578
4741680	373273	3573±930	2122	0.000754
6318229	497531	4278±1074	2451	0.000677
9400921	663275	5848±1240	2830	0.000622

From the table, we know that when the area of full energy peak is larger than 4.5 million, the single escape peak of 1173 keV gamma-rays from Co-60 can be regarded as the single significant peak with considering the uncertainty of net area. The result of this work is restricted in the detection system with the ratio of the areas of SE and full energy peaks of about 6×10^{-4}.

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