2009년도 춘계 학술발표회 논문집
대한방사선방어학회

A Simple Correction Method for Cascade Coincidence Summing Effects for ^{60}Co

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Keyword : Cascade Summing, ^{60}Co, HPGe

Introduction

In general, we use mixed gamma ray sources to calibrate the detection efficiency of gamma ray spectrometers for volume sources. Most of the commercial mixed gamma sources contain ^{60}Co. ^{60}Co can produce the coincidence summing effects due to two gamma rays (1173.24 keV and 1332.50 keV) in sequence within the resolving time of the preamplifier of the detector. The magnitude of the effects depends on the total efficiency. And the total efficiency is affected by the source-to-detector distance and the source geometry. In addition, it can be affected by incidence photons after scattering due to surrounding materials of the detector crystal. The summing effects can be corrected with peaks to total efficiency ratio obtained by using mono gamma ray sources. However, it might be complicate and inaccurate to compute the total efficiency for volume geometries. In previous other works, as an alternative to the experimental method, theoretical calculations or Monte-Carlo techniques have been suggested. However, the methods might require special skills.

In this paper we demonstrate an simple correction method for the cascade coincidence-summing effects in the measuring conditions required by standard radioactive sources.

Materials and Methods

Theoretical approach

The calculation of the correction factor for coincidence summing can be illustrated by considering a radioisotope with the decay scheme of ^{60}Co. For the simple calculation, we assume that the β radiation is absorbed into the detector window, bremsstrahlung can be neglected, and there is no angular correlation between gamma rays producing the summing effect. In the presence of coincidence summing, the peak count rate , n_1 and n_2 in the full-energy peak for γ_1 and γ_2 are

$$n_1 = Ap_1\epsilon_1(1-\epsilon_{t2})$$

$$\text{and } n_2 = Ap_2\epsilon_2[1-(\frac{p_1}{p_2})\epsilon_{t1}] \qquad (1)$$

with A = source activity, p_i = emission probability of γ_i, ϵ_i=full energy peak efficiency at E_i. When ϵ_{t1} and $\epsilon_{t2} \ll 1$, we can get

$$\epsilon_1 \cong \sqrt{\frac{p_2 n_1 n_3}{Ap_1^2 n_2}} \text{ and } \epsilon_2 \cong \sqrt{\frac{n_2 n_3}{Ap_2 n_1}}. \qquad (2)$$

Validity of the methodology

The applicability of this method was evaluated by using Monte Carlo simulation and experimental methods with radioactivity analysis of IAEA-300 and KCl as reference materials. First, we compared n_{10}/n_{20} and n_1/n_2 as various source geometries. Monte Carlo Simulation and a gamma spectrometer were used to determine n_{10}/n_{20} and n_1/n_2, respectively. For the purpose, the commercial standard radioactive source was diluted in U8 vial (∅2.4 × 6 cm^3) and Marinelli beaker (1 L) with 2 M HCl. The cylindrical sources have geometries with the identical diameter of 2.4 cm and varied heights of 0.2, 1, 2, 3, 4 and 5 cm. We used a p-type coaxial HPGe detector with a relative efficiency of 30 %. MCNPX code was used for the Monte Carlo Simulation. The gamma ray peaks were measured within relative counting uncertainty of 2 %. The full energy peak count rates measured were used to directly calculate the detection efficiency for ^{60}Co using Eq. (2). In order to validate this methodology, we analyzed radioactivity of ^{40}K contained in soil sample as IAEA reference material.

Results and Discussion

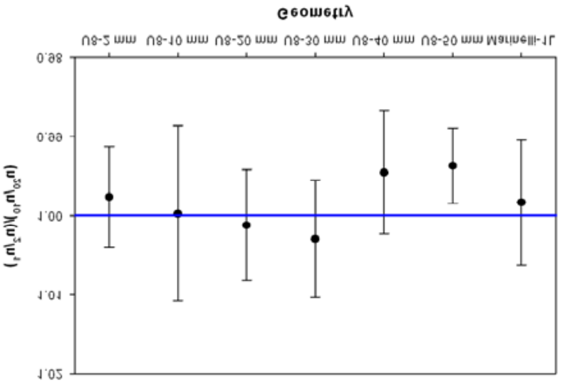

Fig. 2. The peak count ratios of n_{10}/n_{20} and n_1/n_2 with the geometries.

As shown in fig. 2, n_{10}/n_{20} and n_1/n_2 determined by MCNP code and experiment agreed well with each other for interest of source geometries. The maximum difference from 1 was about 0.3 %. The result shows that the approach of the Eq. (2) is reasonable.

Table 1. The calculation results of detection efficiency ϵ_1(1173.24 keV) and ϵ_2(1332.5 keV).

Sample	ϵ_1			ϵ_2		
	This study	MCNP	Diff. (%)	This study	MCNP	Diff. (%)
U8 -2 mm	0.0277	0.0282	0.9	0.0248	0.0253	1.1
U8 -10 mm	0.0228	0.0229	0.5	0.0205	0.0206	0.5
Mar. -1 L	0.00925	0.00923	0.2	0.00839	0.00839	0.01

The detection efficiency for the two gamma rays shown in table 1 was calculated by using Eq. (8). And the radioactivity analysis results with efficiency corrected by this method agreed within the range of the recommended values.

Conclusions

We obtained the simple semi-empirical method to determine the detection efficiency for ^{60}Co without cascade summing effects. The equations applied to the method could be validated by using Monte Carlo Simulation method. The radioactivity analysis results agreed well with the reference values. In this study we could determine the detection efficiency for the radioactivity sources containing ^{60}Co without peak to total ratio. Furthermore, this method can be applied to the cascade correction for ^{60}Co independently of strong attenuation effects.

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