Journal of the Korean Nuclear Society
Volume 7, Number 3, September, 1975

《Technical Report》

Relative Full-Energy Peak Detection Efficiency of Ge(Li) Detectors*

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(Received: September, 1975)

Abstract

The relative detection efficiency of γ-ray full-energy peaks was obtained by a pair-point method using the ^{56}Co source whose γ-ray relative emission rates were well measured. Three Ge(Li) detectors with active volumes of 43.8cc, 32.6cc, and 6cc were calibrated over the γ-ray energy energy range 800-3, 500keV.

요 약

γ-선의 full-energy peak에 대한 상대적 검출효율을 pair-point method에 의해서 결정하였다. 이때 사용된 방사선원은 γ-선의 상대적 방출율이 이미 잘 측정된 ^{56}Co이었다. 이 방법을 통해서, γ-선 에너지 범위 800-3500keV에 걸쳐, 반응체적 43.8cc, 32.6cc 및 6cc의 Ge(Li) 검출기들의 검출효율을 보정하였다.

1. Introduction

Measurements of detection efficiencies, both the absolute and relative, have been reported by many authors[1-5] for specific detectors. Some calculatins of absolute detection efficiencies have also been reported.[6,7] Total counting efficiency curves for various sizes of Ge(Li) detectors have been calculated by Hotz et al,[6] It is difficult to calculate the full-energy peak efficiency with accuracy because, except for very low-energy γ-rays, the full-energy peak receives an appreciable contribution not only from the photoelectric effect but also from Compton scattering followed by photoelectric absorption of the scattered final γ-ray. However, the full-energy peak efficiency is more useful than the total counting efficiency for the experiment analysis. More recently theoretical calculations by the Monte-Carlo techniques of the absolute photopeak and full-energy peak efficiencies of Ge(Li) detectors have been made by Faria and Levesque,[7] Only relative yields of γ-rays of different energies are usually being measured, and the relative rather than the absolute efficiency of the detector is all that is required.

In this work a pair-point method was used for obtaining the relative full-energy peak efficiency curve and demonstrated as a prac-

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Table 1. Average values of energies and intensities of γ-rays in ^{56}Co measured by J. B. Marion[8].

Energy (keV)	Relative Intensity	Energy (keV)	Relative Intensity
733.99±0.19	0.1 ±0.05	2015.49±0.20	2.93±0.16
784.92±0.15	0.4 ±0.11	2035.03±0.12	7.33±0.30
846.76±0.05	100	2113.00±0.10	0.37±0.08
977.47±0.13	1.52±0.16	2598.80±0.12	16.77±0.57
1037.97±0.07	13.02±0.35	3009.99±0.24	0.84±0.16
1175.26±0.13	1.85±0.23	3202.25±0.19	3.15±0.16
1238.34±0.09	69.35±1.47	3253.82±0.15	7.70±0.34
1360.35±0.09	4.38±0.16	3273.38±0.18	1.55±0.11
1771.57±0.10	15.30±0.53	3452.18±0.22	0.88±0.10
1964.88±0.45	0.72±0.08	3548.11±0.25	0.18±0.01

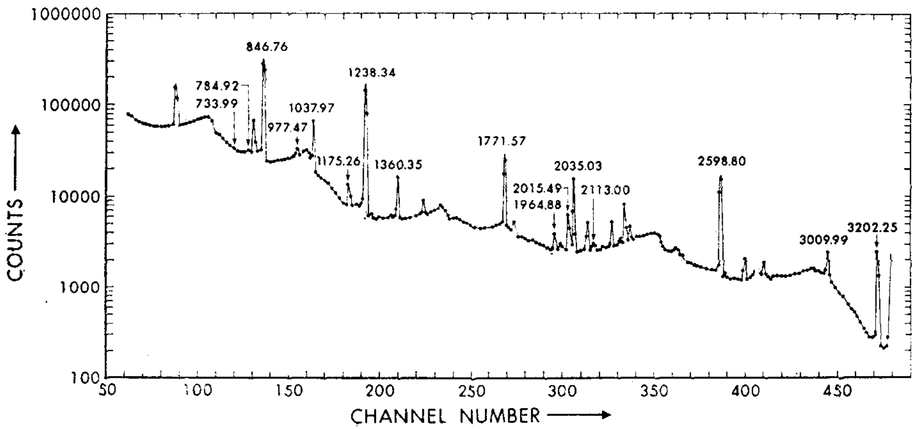

Fig. 1. A typical γ-ray spectrum of the ^{56}Co source, E_γ (keV)

tical example by determining the full-energy peak efficiencies of three Ge(Li) detectors over the γ-ray energy range 800 to 3,500keV.

2. The ^{56}Co Source

Of great usefulness in efficiency calibration would be a radioactive source with many lines with known relative intensities distributed over a wide energy range. One of the most promising sources is the ^{56}Co source. The γ-rays of the ^{56}Co source have been thoroughly studied by some authors[8, 9] Energies and intensities of γ-rays in ^{56}Co are given in Table 1.

In this work the values of γ-ray energies and γ-ray emission rates of the ^{56}Co source were taken from the table by Marion.[8] A typical spectrum of the ^{56}Co obtained in this work is shown in Fig. 1.

3. The Relative Detection Efficiency Curve

The number of counts A in a full-energy peak is expressed as

$$A(E, d) = \eta(E, d) \cdot \alpha(E \cdot d) \cdot \Omega(d) \cdot I \cdot t \qquad (1)$$

where

E: γ-ray energy

I: γ-ray emission rate/strad

Table 2. Source-detector distances and counting times for Ge(Li) detector calibrations.

Detector	Active Volume	Source-Detector Distance	Counting Time
ORTEC 1	43.8 cc	10 cm	6 hr
ORTEC 2	32.6 cc	10 cm	4 hr
Homemade	6 cc	5 cm	2 hr

$\Omega(d)$: solid angle subtended by the detector

t: counting time

d: distance from the source to detector

$\alpha(E,d)$: attenuation factor representing the effects of absorbing layers between the source and detector

$\eta(E,d)$: fraction of γ-rays in the solid angle that are detected in the full-energy peak

The formula for the number of counts A, *Eq.* (1), is self-explaining since only η remains the unknown parameter implying fraction of γ-rays detected in the full-energy peak. Ratios of η for two peaks can be determined in terms of measurable quantities A, I, and α.

The ratio of two values of $\eta(E,d)$,

$$\varepsilon(E_1, E_2, d) \equiv \frac{\eta(E_1, d)}{\eta(E_2, d)} = \frac{A(E_1, d)}{A(E_2, d)} \cdot \frac{I_2}{I_1} \cdot \frac{\alpha(E_2, d)}{\alpha(E_1, d)}, \qquad (2)$$

is known as the relative full-energy peak detection efficiency. In fact it was found that the ratios, $\frac{A(E_1, d)}{A(E_2, d)}$, were independent of d in the range under investigation. Therefore, the expression will be written

$$\varepsilon(E_i, E_0) = \frac{\eta(E_i)}{\eta(E_0)} = \frac{A(E_i)}{A(E_0)} \cdot \frac{I_0}{I_i} \qquad (3)$$

without any absorbing layer between the source and detector, where $\varepsilon(E_i, E_0)$ represents the relative full-energy peak detection efficiency of a γ-ray energy E_i to the common reference γ-ray energy E_0. The efficiency, $\varepsilon = \frac{\eta(E_i)}{\eta(E_0)}$, was obtained for each pair of γ-rays with energies E_i and E_0 in terms of measured A's and known I's.

The 846.76keV ($=E_0$) peak of the ^{56}Co was chosen as the common reference peak with which pairs of other γ-rays were formed. The choice of the 846.76keV as the E_0 peak is due to its highest yield as shown in Table 1. The relative efficiency curves for the three Ge(Li) detectors, 43.8cc (ORTEC), 32.6cc (ORTEC), and 6cc (homemade) are shown in Fig. 2. As seen in the efficiency ε increases with increasing the active volume of a Ge(Li) detector.

An overall accuracy of 10% in the relative

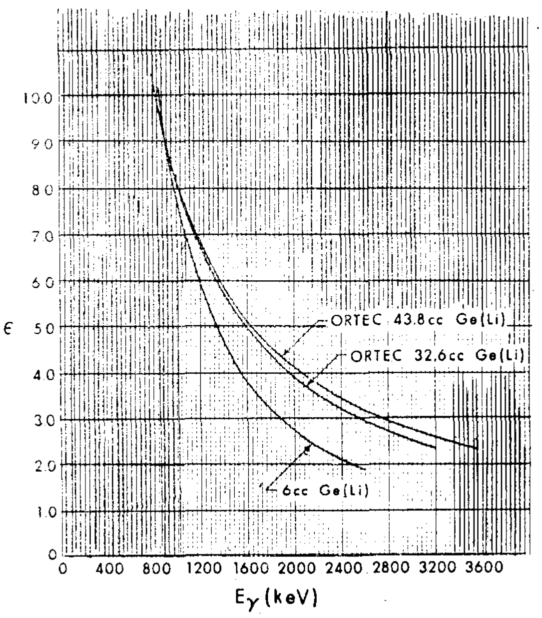

Fig. 2. Comparison of the relative full-energy Peak efficiencies for the three Ge(Li) detectors

efficiency curve was obtained. Spectra were recorded using a 4096 channel pulse-height analyzer for the ORTEC 43.8cc detector and a 512 channel pulse-height analyzer for dectectors, ORTEC 32.6cc and homemade 6cc. Source-detector distances and counting times for Ge(Li) detector calibrations are given in Table 2.

It was found that a graph of log (relative efficiency) vs log (energy) was close to a straight line. The form, log $\varepsilon=a_0+a_1 \log E$, was therefore chosen for the least-squares fit of the experimental values. In Fig. 2 all the solid lines were obtained from the least-squares fit.

I would like to thank Dr. B. Robertson for making the ^{56}Co source and Mr. H. Fodchuk for helping to arrange the detection system.

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