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FEPE calibration of a HPGe detector using radioactive sphere source

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Abstract

The calibration of hyper pure germanium detectors is required to calculate the activity of radioactive sources. To determine the activity, the detector full-energy peak (photopeak) efficiency is required. The full–energy peak efficiency gamma-ray HPGe detector for spherical sources is obtained by the use of direct analytical expressions. In addition, the source self-absorption and its effect on the full–energy peak efficiency has been studied.

Keywords: Closed-end HPGe detector, gamma-ray spectrometry, full-energy peak efficiency, spherical source;

1. Introduction

The calculation of the efficiency for germanium detectors has been performed by several authors (Hnatowicz, 1977, Debertin, and Grosswendt, 1982 and Wang et al., 1997). In the present work, we will illustrate how to calibrate HPGe detectors used to determine the source activity for radioactive gas spheres. In this paper, the experimental efficiencies are compared to the calculated ones using an analytical method based on the direct mathematical approach reported by Selim and Abbas (1994, 1998, 2000 and 2001); and Abbas (2010a, 2010b and 2010c). The effect of the source self-absorption on the discrepancies of the calculated efficiencies is also included.

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Nomenclature

μ	=	the attenuation coefficient of the detector material
d	=	the effective rays path length through the detector crystal active volume
R	=	the detector radius
L	=	the detector height
h	=	the source – detector distance
ρ	=	the lateral distance

2. Experimental setup

The full-energy-peak efficiency curve was determined for an n-type GMX Ortec HPGe detector, model 10180-S, with a relative efficiency of 9%. This detector had an active volume of 51 cm^3 at a given source-to-detector distance. The radioactive source was a 32 cm^3 Pyrex sphere with a 3.9 cm inner diameter and a 0.2 cm wall thickness containing ^{85}Kr and ^{133}Xe radioisotopes with activities of $(4.725 \pm 0.059) \times 10^7$ Bq and $(1.969 \pm 0.016) \times 10^7$ Bq, respectively (Pibida et al., 2007).

3. Mathematical viewpoint

In this paper, we compared the measured efficiency values (Pibida, 2007) with theoretical calculations using a new simplified method based on the direct mathematical approach reported by Selim and Abbas (1994, 1998, 2000 and 2001); and Abbas (2010a, 2010b and 2010c) for a point source - cylindrical detector geometries. The absolute efficiency, ε, for an arbitrarily positioned radiating point source placed at any distance from the detector can be represented conceptually in Figure 1 and shown by the following equation:

$$\varepsilon = \frac{1}{4\pi}\int_{\phi}\int_{\theta} f_{att}(1-e^{-\mu\, d})\sin\theta\, d\theta\, d\phi \qquad (1)$$

where θ and ϕ are the polar and the azimuthal angles, respectively. μ is the attenuation coefficient of the detector material (Hubbell and Seltzer, 1995). The effective rays passing through the detector crystal active volume traverse a distance d until it emerges from the detector crystal.

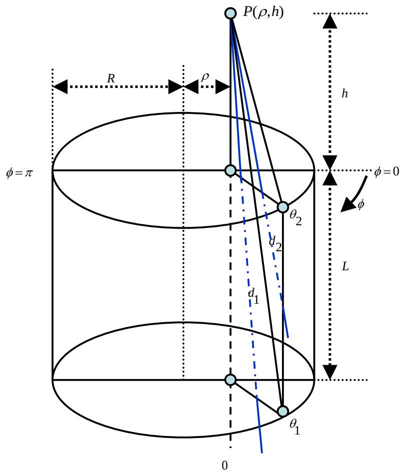

Figure 1. The possible cases of the photon path lengths through the detector active volume.