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Coincidence summing corrections in HPGe gamma-ray spectrometry for Marinelli-beakers geometry using peak to total (P/T) calibration

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ABSTRACT

The coincidence summing corrections for an HPGe spectrometer with Marinelli-beaker geometry were calculated using the peak-to-total (P/T) calibration method in combination with the algorithms implemented in the Genie 2000 software. The P/T ratios were calculated for different energies and three types of beaker contents: air, powder milk and soil. The validity of the correction was tested against a standard sample and showed excellent agreement with the certified data. The corrections were also in good agreement with published data in the literature.

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1. Introduction

Gamma ray spectrometry using Ge detectors is a widely used technique for the detection of low activity in environmental samples. Such measurements require typically close geometry arrangement with volumetric sources such as discs, cylindrical cups, or the Marinelli beakers. This close distance arrangement increases the chance of coincidence summing effects for complex decay-scheme nuclides (for e.g. radium-226, ¹³⁴Cs which is present in environmental samples as a result of accidental release during the nuclear weapon testing.) Corrections due to these effects are not generally easy to account for especially for volume sources. Thus, for added

accuracy in gamma-ray spectroscopy, the corrections for the coincidence summing effects are highly desirable.

Several algorithms and empirical equations have been developed in the literature to take into account these effects (Arnold & Sima, 2004; Blaauw & Gelsema, 2003; Dias, Koskinas, & Takeda, 2002; Tomarchio & Rizzo, 2011; Vidmar, Kanisch, & Vidmar, 2011) The peak-to-total ratio (P/T) is an established method for coincidence summing effects corrections in the gamma-ray spectrometry field (ANSI, 1999). However, the method is not used in routine measurements due to the elaborate work involved in its implementation, especially for close geometry measurements (Lee, Park, & Woo, 2008).

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In the present study, we used the peak-to-total (P/T) calibration method for evaluating corrections to the gamma ray spectra due to coincidence summing effects for HPGe spectrometer using 0.5 L Marinelli beaker. The coincidence summing corrections are calculated using the peak-to-total (P/T) calibration method which is performed using a set of point sources ^{109}Cd , ^{57}Co , ^{137}Cs , ^{54}Mn and ^{65}Zn . Subsequently, the corrections were applied for standard samples of the same geometry, as well as for the point sources ^{133}Ba and ^{60}Co . Validation of the coincidence summing corrections was also tested against a standard bulk sample.

2. Materials and methods

2.1. Measurement of the gamma-ray spectra

The measurements of activities were made using a coaxial HPGe detector (which has been described elsewhere (Ababneh, Masa'deh, Ababneh, Awawdeh, & Alyassin, 2009) with active volume of 105.7 cm^3 , relative efficiency of 25% at 1.33 MeV ^{60}Co line and a resolution of 1.9 keV at the same line (Canberra, USA). The system was initially calibrated for energy and efficiency using the Multi Gamma Ray standard MGS-5, (Canberra, USA). The detector is shielded with 10 cm lead layer. Gamma-ray spectra of point sources were measured in order to calculate peak-to-total efficiency ratio. The following point sources ^{109}Cd , ^{57}Co , ^{137}Cs , ^{54}Mn and ^{65}Zn were used. To perform the peak-to-total calibration the 0.5 L Marinelli beaker was divided into four regions (I, II, III and IV) (Fig. 1) and nine (9) positions within the beaker were specified which map the four regions of the beaker. The volume of each region was calculated and the point sources were fixed at each position using a piece of sponge and polyester. The background spectrum for the beaker with the sponge and polyester was

obtained and used later for background subtraction. The spectrum of each point source was measured at each of the nine (9) positions one at a time to obtain distinct energy peaks and the average peak-to-total ratio was calculated for each region by averaging over the different positions within that region. The counting time was adjusted to record at least 40000 counts for each full-energy peak in order to minimize the statistical counting error. The calibration was carried out for an empty beaker (air filled) as well as for beakers filled with soil or powder milk. The point sources used in the case of soil and milk were: ^{109}Cd , ^{57}Co , ^{137}Cs and ^{54}Mn .

2.2. The peak-to-total ratio and the efficiency calculations

For a point source, the total efficiency $\epsilon_t(E)$ at gamma-ray energy E may be computed, provided the full peak efficiency $\epsilon_p(E)$ and the peak-to-total ratio (P/T) are known using (Martin, 2004):

$$\epsilon_t(E) = \frac{\epsilon_p(E)}{P_T(E)} \tag{1}$$

The peak-to-total ratio P_T is defined as the ratio between the number of counts in the full-energy peak and the total number of events in the spectrum. For volume sources, $\langle P_T \rangle$ are given by (Park and Jeon, 1994):

$$\langle P_T \rangle = \frac{\int \epsilon_p(E, r, z) P_T(E, r, z) r dr dz}{\int \epsilon_p(E, r, z) r dr dz} \tag{2}$$

where $\epsilon_p(E, r, z)$ is the full-energy peak efficiency, $P_T(E, r, z)$ is the peak-to-total ratio and (r, z) are the position coordinates of the point sources. Since it is rather complicated to apply the above integration for the Marinelli beaker geometry, the

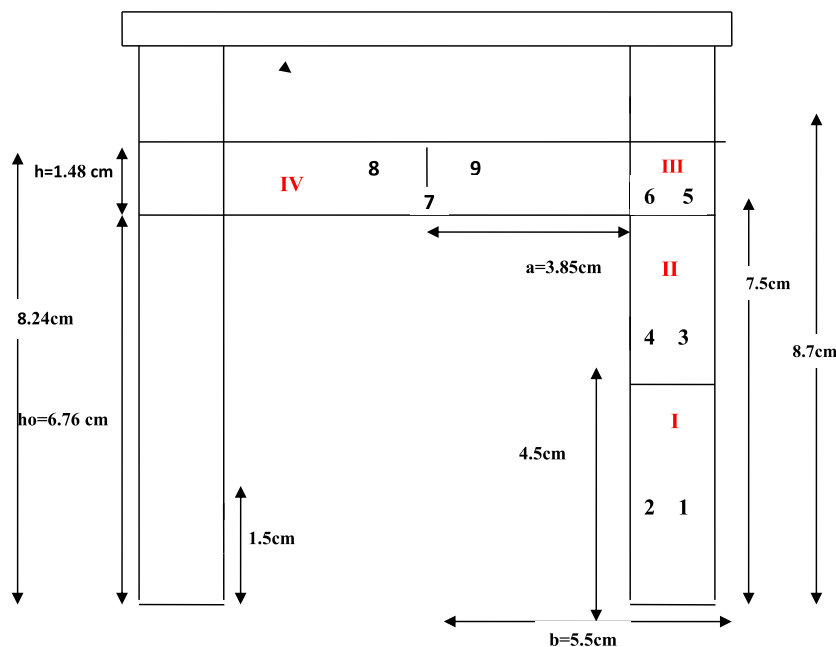


Fig. 1 – Schematic diagram showing the positions of the point sources and the regions of volume integration for the 0.5 L Marinelli beaker.

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