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Absolute peak-efficiency calibration of a well-type germanium detector using multiple gamma-emitting nuclides with the iteration algorithm based on maximum likelihood estimation

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Content

The high efficient germanium detectors are powerful tool for low-level radioactivity measurement. Full energy peak efficiencies of these germanium detectors are in general calibrated using a set of gamma-ray emitting reference sources preferably of single gamma-ray emitting nuclides. In order to get such peak efficiency curves for higher energy region, however, we have to use inevitably some nuclides which emit two or more gamma-rays such as Co-60 or Y-88 which may cause dominant coincident summing effects especially for high-efficiency detectors like a well-type detector. Among some methods to solve this problem, analytical method of efficiency calibration was developed and employed in some of commercially available software packages. This is useful for the practical radioactivity measurements, but it is difficult to avoid the inaccuracy arising from the ambiguity of the source-to-detector configuration and also the possible change of active volume or thickness of dead layer in time [1]. As an another approach, Blaauw developed a novel empirical calibration technique using the spectra obtained with a multiple gamma-emitting nuclide having three or more excited states such as Br-82 to obtain the peak and total efficiency functions [2][3]. In the present study, we tried the absolute peak efficiency calibration of a well-type germanium detector along similar idea of Blaauw, but Cs-134 was used in place of Br-82. From measured spectrum, each peak area can be expressed by an equation in terms of source activity, peak efficiency, total efficiency and gamma-ray emission probability. Given the function form for the efficiency curve (e.g. polynomial in log-log expression), the unknown parameters other than the source activity are the coefficients of each term of the efficiency function. In order to determine unknown parameters appeared in the non-linear simultaneous equations, we developed a special iteration algorithm using the maximum likelihood estimation (MLE). The results of activity measurements of non-summing nuclides such as Cs-137 and Mn-54 using the peak efficiency curve thus obtained were consistent with each reference value within 3%. In case of a well-type germanium detector, a reliable peak efficiency curves for an energy-range over 240keV were obtained using Cs-134 reference source. However, efficiencies in an energy range below 240keV cannot be obtainable by use of only one nuclide of Cs-134. Therefore another multiple gamma-emitting nuclide such as Ba-133 might be useful to obtain efficiency curves for lower energy region. The results of these experimental verification will be useful in the radioactivity measurements of low level environmental samples with a high efficiency germanium detector especially with a well-type germanium detector.

Reference [1]Sima O. and, Lépy M-C., Appl. Radiat. Isot. 109, 493-499, 2016. [2]Blaauw M., Nucl. Instrum. Methods in Phys. Res. A 332, 493-500, 1993. [3]Blaauw M. and Gelsema S.J., Nucl. Instrum. Methods in Phys. Res. A 505, 311-315, 2003.

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