Standardization of gamma sources using NaI(Tl) and $LaBr_3$(Ce) detectors: Measurements and Simulations

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Introduction

The activity of a radionuclide can be measured by using different methods such as absolute, relative and solid angle [1]. The absolute methods include β-γ coincidence [2], β-γ anti-coincidence [3,4], β-γ correlations [5], γ-γ coincidence [6-10], etc. The relative methods can be further divided into semi-empirical method and Monte Carlo technique [11-14]. 4π counting and 2π counting techniques are some of solid angle methods. Large amount of literature is available on activity evaluation using sum-peak method [15-17]. Most recently, Ogata *et al.*, [18] proposed modified sum-peak method which does not consider the total detected counts while estimating the activity of a double gamma emitter. The method could successfully be used in accurate determination of absolute activity for larger values of source-detector separation only. It is very well known that the calculation of absolute activity for a single gamma emitter, like ^{137}Cs, can be done by knowing the intrinsic photo-peak efficiency of the detector, counts under the photo peak, measurement time, branching ratio and solid angle [19]. However, the estimation of intrinsic photo-peak efficiency without the knowledge of activity is quite difficult and depends on location of source from the detector. Moreover, if the detector size is small and source strength is weak, then higher values of source-detector separation require longer measurement times to get the reasonable counts under the photo peak. If the source is strong, then the photo-peak counts should be corrected for dead time and pile-up. To avoid these problems, Monte Carlo techniques can be used in evaluating the intrinsic photo-peak efficiency for any value of source-detector separation and the user can choose the separation depending on the source strength. In the present work, we made detailed studies on activity of a single gamma emitter ^{137}Cs for different values of source-detector separation. The studies were made using NaI(Tl) and $LaBr_3$(Ce) detectors. Monte Carlo techniques were employed to estimate the intrinsic photo-peak efficiencies corresponding to 662 keV gamma rays. We have also made activity measurements on a double gamma emitter ^{60}Co using sum-peak method. In both cases, calibrated sources were used and the measured results were compared with the activities certified by the manufacturer (Board of Radiation and Isotope Technology, Govt. of India).

Experimental Details

We have measured activity of ^{137}Cs and ^{60}Co sources using a 2″ × 2″ NaI(Tl) detector and a 1″ × 1″ $LaBr_3$(Ce) detector separately. These measurements have been made for source-detector separations of 1 to 10 cm with an interval of 1 cm.

Simulations

In order to evaluate the activity of ^{137}Cs, we need to estimate the intrinsic photo-peak efficiency corresponding to gamma of 662 keV. For a source-detector separation of 9.3cm, the values of intrinsic pho-peak efficiency are available for NaI(Tl) detectors of different sizes [19]. Realistic Monte Carlo simulations were made to evaluate the intrinsic photo-peak efficiency using radioactive decay module and general particle source module (GPS) of GEANT4 toolkit. The simulations were performed by allowing 10^6 gamma rays to fall only on the front surface of the crystal so that we can get the intrinsic efficiencies (both detection and photo-peak). Simulations were also made by considering single gamma energies of 662 keV in order to validate the ^{137}Cs source embedded in radioactive decay module. It is found that the emission spectrum of ^{137}Cs is incorrect as already reported [20]. Considering the meta-stable state of ^{137}Ba in GPS module, however,

the results of simulated absolute efficiencies corresponding to 662 keV are found to be in very good agreement with the measured absolute efficiencies. The emission spectrum of ^{60}Co could very well be reproduced with the measured spectrum [20]. This validates the ^{60}Co source in radioactive decay module in GEANT4.

Results and Discussion

Fig.1 shows plots of intrinsic photo-peak efficiency versus source-detector separation for both detectors corresponding to E_γ = 662 keV. As mentioned earlier, the intrinsic photo-peak efficiency varies with the distance of source from the detector. These values were then used to estimate the absolute activities. Using the count rates under individual peaks, sum peak and total detected counts, the activity of ^{60}Co is measured. The results are summarized in Tables 1 and 2 for NaI(Tl) detector. The measured activities are found to be in good agreement with the certified values of 2.7μCi for ^{137}Cs and 15.12 μCi for ^{60}Co. The observed errors are due to the uncertainties associated with source size, solid angle, detector geometry. It is also verified that the simulated counts in peaks for ^{60}Co spectrum are very well reproduced.

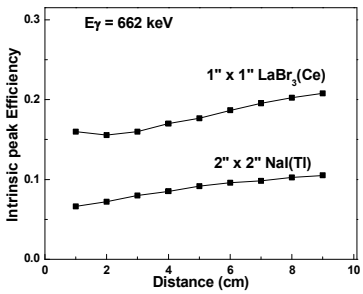

Fig.1: Variation of intrinsic peak efficiency versus source-detector separation

Table-1: Measurements with ^{137}Cs source using a 2″ × 2″ NaI(Tl) detector

Source-detector separation (in cm)	Measured activity (in micro curie)
1	2.6 (0.09)
3	2.4 (0.11)
5	2.6 (0.09)
7	2.5 (0.09)
9	2.6 (0.11)

Table-2: Measurements with ^{60}Co source using a 2″ × 2″ NaI(Tl) detector.

Source-detector separation (in cm)	Measured activity (in micro curie)
1	14.65 (0.12)
2	14.90 (0.13)
3	15.02 (0.14)
4	15.10 (0.12)

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