XVIII IMEKO WORLD CONGRESS
Metrology for a Sustainable Development
September, 17 – 22, 2006, Rio de Janeiro, Brazil

PRECISE DETERMINATION OF GE DETECTOR EFFICIENCY CURVE FOR OBTAINING ACTIVITIES IN RADIONUCLIDES GAMMA-EMITTERS

Jose U. Delgado [1], *Maria Cd. M. de Almeida*[2], *Roberto Poledna* [3]

[1] *LNMRI/IRD/CNEN, Rio de Janeiro, Brazil , delgado@ird.gov.br*
[2] *LNMRI/IRD/CNEN, Rio de Janeiro, Brazil, marcandida@yahoo.com.br*
[3] *LNMRI/IRD/CNEN, Rio de Janeiro, Brazil , poledna@ird.gov.br*

Abstract: An efficiency curve obtained in a gamma-ray spectrometric system using a high purity germanium detector and radioactive standards of ^{133}Ba, ^{152}Eu and ^{166m}Ho in an energy range of 50 to 1400 keV was established for metrological purposes. To do this, the efficiency response of the detector was used considering 29 different energies. This allowed calibrating various gamma-emitter radioactive point sources, within of a 50 kBq to 550 MBq activity range, with expanded uncertainties below 2.5% at two-sigma confidence level (k=2). The obtained activity value for ^{22}Na was validated by sum-peak coincidence method.

Keywords: efficiency curves, gamma-emitters, Ge detector.

1. INTRODUCTION

Many radionuclides and their applications are ground of great researches in nuclear technology as medical activities (therapy and diagnose - ^{99m}Tc for example) as industrial activities (irradiators - ^{137}Cs). However, there are other interesting radionuclides as ^{22}Na and ^{139}Ce.

Due to the fact of ^{22}Na has approximately 2.6 years of half-life ($t_{1/2}$)[1], it is important to make ^{18}F ($t_{1/2}$=110 min) calibration, which is used in Positron Emission Tomography (PET) in nuclear medicine, because both nuclides are positron emitters.

Even has not a long half-life, ^{139}Ce ($t_{1/2}$=137 days)[1] can be used as a gamma monoenergetic calibration standard in order to establish efficiency curves for Ge detectors in energy range of 100 – 200 keV. Indeed, there are few radionuclide standards in this range of energy.

The determination of the activity of a radioactive source needs the detector efficiency response knowledge in function of the energy. The efficiency calibration establishes the relationship between photopeak area and the nuclide activity as:

$$\varepsilon_f(E) = \frac{S(E)}{[A.I(E).t]} \qquad (1)$$

Where $\varepsilon_f(E)$ is the total absorption efficiency at E energy, A is the activity (Bq), $S(E)$ is the peak area (counts), $I(E)$ is the absolute probability emission of the energy considered for the specific nuclide and t is the counting time. The total absorption efficiency determination can be done from geometric considerations and interaction probabilities or using a semi-empirical relation[2]. A third way of determining a detector response is using standards with a large energy range, or a multi-gamma standard like ^{166m}Ho (80 to 1000 keV) [1,3], ^{152}Eu (100 to 1400 keV)[1,4] and ^{133}Ba (40 to 400 keV)[1], according to region of interest.

The efficiency curve depends on radiation energy[5], sample geometry, photon attenuation (sample absorption and material absorption between sample-detector), dead time and sample-detector position. This curve is obtained from the acquisition of reference spectra considering the photopeak areas corresponding the standard activities.

When the calibration of gamma-ray spectrometry using Ge detector is required for determination of the high-activity and/or multi-gamma emitter samples, a large source-detector distance, around 20 cm, can be used [6]. This reduces dead-time and true coincidence summing effects enormously [7].

2. PURPOSES

From a high-resolution germanium detector and its well-fitted efficiency curve in a defined geometry and a determined range of energy (50 – 1410 keV) is possible to do a sample calibration in activity. Also the gamma-ray impurities present in the samples can be identified and quantified precisely. Besides, this procedure can be applied as a support to absolute calibration system in the metrological laboratory. By other hand, when the laboratory of calibration or essay does not own a standard of same nature of the sample, or when the available standard owns an activity which size differs in relation to the sample, the

efficiency curve method should be used instead of the commonly comparative method [3]. If the calibration has been made in accordance with this last method, then the activity results could be determined with low accuracy and precision.

In this work, it was used the experimental arrangements for measuring precisely the activity of gamma-emitter point sources using the efficiency curve method to the samples of ^{137}Cs, ^{139}Ce, ^{99m}Tc and ^{22}Na.

3. METHOD

For this was determined one efficiency curve in a set source-detector distance with multi-gamma point source standards of ^{152}Eu, ^{133}Ba and ^{166m}Ho with traceability to the international reference system[3]. This methodology normally requires correction factors due to pile-up losses (< 0.1%), source geometry effects (< 0.2%), and gamma-gamma summing coincidence effects [4]. However, here it was adopted a 20 cm distance between detector-source in order to minimize such effects. A schematic view of gamma-ray spectrometric system with Ge detector is shown in Figure 1.

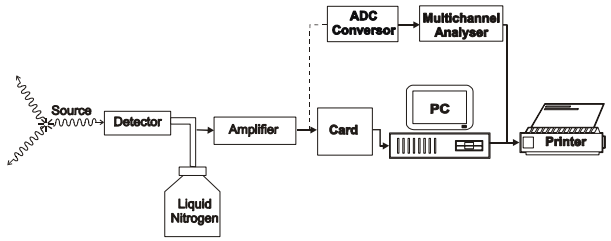

Fig. 1. Gamma-ray spectrometric system with germanium detector.

The detector consists of an Ortec Coaxial Ge detector (GEM50P4), with a volume of 260 cm^3, a resolution (FWHM) of 1.90 keV at 1332.5 keV and a 66:1 Peak-Compton ratio.

The sources to be analysed were prepared by dropping the original solution on acrylic disc. After drying, these samples were covered with other disc and sealed. These acrylic sources have the following dimensions: 25.4 mm of external diameter, 5.0 mm of height, 1.0 mm of thick for deposition area and 1.0 mm of covering.

4. RESULTS

This work shows the efficiency curve (Figure 2) obtained as well as the results related to activity determination with associated uncertainties for the following radioactive samples: ^{137}Cs, ^{139}Ce, ^{22}Na and ^{99m}Tc (Table 1). Weighted means of two measurements were adopted and the main uncertainty contributions come from the efficiency interpolation (~1.3%) and peak area determination (~0.2%).

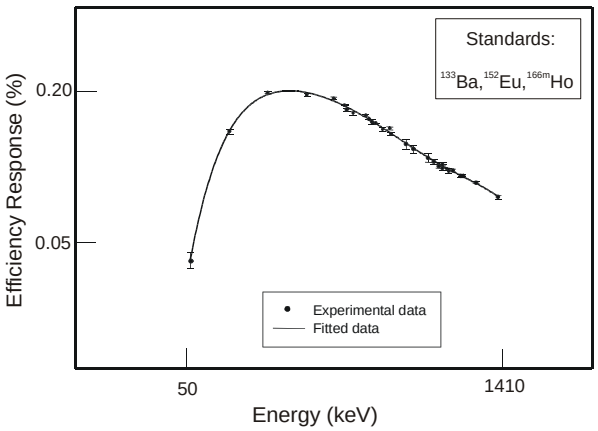

Fig. 2 Efficiency curve obtained with ^{133}Ba, ^{152}Eu and ^{166m}Ho standard sources, and a 20 cm source - Ge dectetor distance to gamma-spectrometer system.

Table 1. Activities and uncertainty values for radionuclide point sources measured. The expected and measured activity are in the same date

Nnuclide	Expected Activity (kBq) ± U (%) (k = 2)	Measured Activity (kBq) ± U (%) (k = 2)
^{137}Cs	unknown	65.40 ± 1.6
^{139}Ce	269.63 ± 0.96	270.31 ± 2.3
^{99m}Tc	*529607.00 ± 1.84	541690.00 ± 2.5
^{22}Na	**252.80 ± 0.97	245.26 ± 0.8

* Radionuclide calibrator method; ** Ionization chamber method

During the unknown source measurements was identified the ^{137}Cs gamma peak (Ey=661.6 keV) and its activity was determined from the area counting related to this energy and the efficiency curve. There were not observed any significant impurities.

The activity (quantity) of ^{139}Ce was determined from the area counting of 165.85 keV (Eγ). This result is in good agreement with the expected activity value (0.25% of deviation).

The activity result of ^{99m}Tc (Eγ=140,47 keV) by gamma spectrometry showed 2.3 % of deviation in comparison with expected value. This radionuclide can be contained ^{99}Mo (Eγ =140.51 keV) as impurity, due to the inherent characteristics of decay scheme, is equal to ^{99m}Tc. In this case it was not possible to differentiate between the countings attributed to ^{99m}Tc and ^{99}Mo [6] and may be this is the one of reasons from this deviation.

The spectrum of ^{22}Na has two gamma peak energies. It was used 1274.54 keV to activity determination because the line at 511.00 keV is the same energy of the positron annihilation phenomenon. The activity results showed 3.0% of deviation from expected value**.** In this case, the ^{22}Na standard activity was checked by sum-peak coincidence method and then it was used to obtain ^{22}Na activity by comparative method and the result was 245.56 kBq with 0.4 % of uncertainty. This result is according with the activity efficiency value (Table 1).

5. CONCLUSION

This work allows obtaining results for some radioactive point sources of high activity by means of a Ge detector using the efficiency curve method. The total uncertainties reached values below 2.5 % in a confidence level of 95 %.

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