PERGAMON

Radiation Physics and Chemistry 61 (2001) 437–438

Radiation Physics and Chemistry

www.elsevier.com/locate/radphyschem

A simple method for efficiency calibration of HPGe detectors in γ-spectrometric measurements

J.P. Pérez-Moreno, J.P. Bolívar*, R. García-Tenorio, E. San Miguel, J.L. Aguado, J.L. Mas, F. Vaca

Department of Fisica Aplicada, University of Huelva, EPS La Rabida, 21819-Palos, Huelva, Spain

Abstract

In this paper a simple, rapid and general method for γ-ray efficiency calibration of Ge detectors for environmental samples is presented. This method is based on the use of an active natural solid sample with several γ-emissions (in our case, ^{226}Ra) as the calibrating matrix for determining the full energy peak efficiency (FEPE) ε_c vs γ-emission energy E_γ and the sample height h in a counting cylindrical geometry. The ^{226}Ra activity concentration is determined by α-particle spectrometry, a method that has previously been validated.

Keywords: Gamma-spectrometry; Efficiency-calibration; Self-absorption; Sample-height

1. Introduction

In γ-measurements of solid samples using Ge detectors, it is interesting to obtain the full energy peak effciency (FEPE) in the calibrating matrix ε_c curve as a function of the γ-emission energy E_γ and the sample height h, in the special case of a cylindrical geometry. The objective of this paper is to design a simple, rapid and general method to find the FEPE curve in the calibrating matrix as a function of E_γ and h. For this, the only requirement is an active solid calibrating matrix with several γ-emissions in the energy range of interest; in our case 150–1800 keV.

The FEPE in the calibration sample for a γ energy E_γ and height h is given by the expression $\varepsilon_c = \varepsilon'/a$, where $\varepsilon' = N/(P_\gamma TM)$; a is the activity concentration of a specified radionuclide; P_γ, the probability of γ-emission; T, the counting time; M, the mass of the sample; N, the net counts under the full energy peak; and ε' (which we refer to as the "normalised efficiency").

*Corresponding author. Tel.: +34-959017583; fax: +34-959017304.

E-mail addresses: bolivar@uhu.es (J.P. Bolívar).

2. Present investigation

Obviously, ε' has the same functional relation on E_γ and h that ε has, since the activity concentration a is constant for every h, that is to say, the γ-emitter radionuclide is homogenously distributed in the matrix. Our method consisted of finding the function $\varepsilon' = f(E_\gamma, h)$ using a sample which contains a radionuclide with several γ-emissions in the energy interval of interest.

For the calibrating sample we used phosphate rock, containing mainly $Ca_{10}(PO_4)_6F_2$ and having an apparent density of 1.60 g cm^{-3}. For this mineral we can suppose that ^{226}Ra, ^{214}Pb and ^{214}Bi are in secular equilibrium if the counting is done at least one month after filling and sealing of the sample container, the latter being a cylinder of 6.5 mm diameter and variable sample height. The content of ^{226}Ra in the mineral was measured by α-particle spectrometry using a method previously validated (Aguado et al., 1999), yielding an activity concentration $a = 1152 \pm 54$ Bq ^{226}Ra/kg. γ-spectrometric measurements from 1 to 5.0 cm, in increments of 5 mm, were also done. A total of nine spectra were collected. The measurements were performed using a coaxial Ge detector XtRa model GX3518 (Canberra Industries, Meriden, USA), 38% relative efficiency and

0969-806X/01/$ - see front matter
PII: S0969-806X(01)00290-0

Table 1
Uncertainties at a confidence level of 1σ, due to countings statistics and fitting of parameters

Radionuclide	^{152}Eu	^{133}Ba	^{60}Co	^{137}Cs
Certified (Bq/kg)	1338 ± 36	1053 ± 51	620 ± 10	2025 ± 39
Our calibration (Bq/kg)	1262 ± 43	988 ± 49	674 ± 34	1988 ± 72

shielded with 10 cm thick lead. For each energy, the best simple relation for ε' vs E_γ was an exponential function $\varepsilon' = \varepsilon_o' e^{bh}$, where the parameters ε_o' and b depend on the energy. An empirical energy-dependency relation for these parameters (ε_o' and b) was found. A reduced chi-square (χ^2_R) of around unity and a regression coefficients of higher than 0.99 were obtained for all fittings.

Including the parameter fittings in the previous equation, and noting that $\varepsilon_c = \varepsilon'/a$, we find

$$\varepsilon_c = 18.08 E_\gamma^{-0.972} \exp(-0.417 h E_\gamma^{-0.138}). \quad (1)$$

This expression relates the FEPE in the calibration sample with the γ-emission energy E_γ (keV) and its height h (in cm). This calibration was validated, including the necessary self-absorption corrections (Bolívar et al., 1996), via a certified aqueous calibration standard containing ^{152}Eu, ^{137}Cs, ^{133}Ba and ^{60}Co. The results are shown in Table 1.

References

Aguado, J.L., Bolívar, J.P., García-Tenorio, R., 1999. ^{226}Ra determination in phosphogypsum by alpha-particle spectrometry. Czech. J. Phys. 49, 439–444.

Bolívar, J.P., García-Tenorio, R., García-León, M., 1996. A method for determination of counting efficiencies in γ-spectrometric measurements with HPGe detectors. Nucl. Instrum. Methods A. 382, 495–502.