Standardization of Ca-45 Radioactive Solution by Tracing Method

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The procedure followed by the Laboratório de Metrologia Nuclear (LMN) at the IPEN, in São Paulo, for the standardization of the ^{45}Ca is described. The activity measurement was carried out in a $4\pi\beta$-γ coincidence system, by the tracing method. The radionuclide chosen as the β-γ emitting tracer nuclide was ^{60}Co because of its end-point beta-ray energy which is close to ^{45}Ca. Six sources were prepared using a 1:1 ratio (β-pure and β-γ) dropped directly on the Collodion film, and other two solutions of ^{45}Ca + ^{60}Co were mixed previously using a 1:1 and 1:2 ratio before making the radioactive sources. The activity of the solution was determined by the extrapolation technique. The events were registered using a Time to Amplitude Converter (TAC) associated with a Multi-channel Analyzer.

1 Introduction

This paper describes the procedure followed by the Laboratório de Metrologia Nuclear (LMN) at the IPEN - CNEN/SP, in São Paulo, for the standardization of ^{45}Ca radioactive solution by tracing method.

This method consists of using $4\pi\beta$-γ coincidence method [1,2] for the standardization of a pure β-emitter mixed with another radionuclide which decays by simultaneous emission of two radiations such as β-γ, α-γ to be used as tracer. The tracer is standardized separately by means of conventional $4\pi\beta$-γ coincidence method.

In the tracing method [3,4] a series of sources containing aliquots of the pure β-emitter and a suitable β-γ emitter are prepared. The observed disintegration rate of β-emitter and the tracer β-efficiency ϵ_{β_t} are measured within a range of ϵ_{β_t} by using external absorbers.

The results are plotted against (1-ϵ_{β_t}) and the intercept corresponds to the disintegration rate of the pure β-emitter.

Radionuclide ^{45}Ca decays with half life of (163 ± 1) days [8] by beta transition, 0.0017% populating the excited state of ^{45}Sc and 99.9983% to the ground state with maximum beta energy of 256 keV. Due to the low gamma ray emission probability per decay it may be considered a pure beta emitter radionuclide. ^{45}Ca decay is presented in Fig. 1.

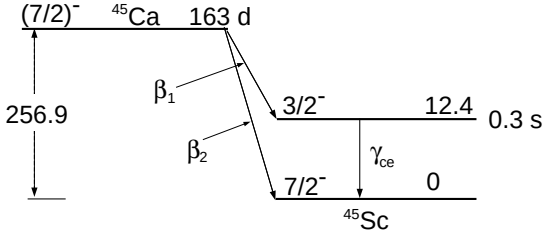

Figure 1. Decay scheme of ^{45}Ca. All energies are in keV.

Radionuclide ^{60}Co was chosen as tracer because of its end-point β-ray energy (317.89 keV) which is close to ^{45}Ca. It decays with half-life of (5.271 ± 0.002) years, by β^- emission populating the excited levels of ^{60}Ni and proceeds to ground state by emission of two main gamma rays (1173.24 and 1332.51 keV)[8].

2 Experimental Method

2.1 Source Preparation

^{45}Ca solution was obtained by means of ^{44}Ca (n,γ) ^{45}Ca reaction in a thermal neutron flux at the IPEN 2 MW research reactor. The sources were prepared by dropping known aliquots of the solutions on a 20 $\mu g/cm^2$ thick Collodion film. Six sources were prepared using a 1:1 ratio (β-pure and β-γ) dropped directly on the Collodion film and other two solutions of ^{45}Ca + ^{60}Co were mixed previously using a 1:1 and 1:2 ratio before making the radioactive sources.

The Collodion film was previously coated with a 10 $\mu g/cm^2$ gold layer in order to turn the film conductive. A seeding agent (Cyastat SM) was used to improve the deposit uniformity and the sources were dried in a warm (45 degrees Celsius) nitrogen jet. The accurate source mass determination was performed using the picnometer technique.[5] The β-γ tracer was standardized previously by measuring several sources prepared by the same procedure.

2.2 $4\pi\beta$-γ coincidence measurement

A conventional $4\pi\beta$-γ coincidence system was used, consisting of a 4π proportional counter filled with 0.1 MPa P-10 gas mixture, coupled to a pair of 3" x 3" NaI(Tl) crystals. The events were registered by a method developed at LMN which makes use of a Time to Amplitude Converter (TAC) associated with a Multi-channel Analyzer.[7] The gamma

window was set by gating the gamma-rays of tracer (1173 keV + 1332 keV).

The number of detected events in the proportional counter is given by:

$$N_{\beta(Ca+Co)} = N_{0Co}\epsilon_{\beta Co} + N_{0Ca}\epsilon_{\beta Ca} \qquad (1)$$

where:

$\epsilon_{\beta Co}$ is the tracer efficiency in the mixed source;

$N_{0(Ca+Co)}$ is the counting rate of proportional counter due to the mixed source;

N_{0Co} is the activity of ^{60}Co tracer of the mixed source;

N_{0Ca} is the ^{45}Ca beta-branch disintegration rate;

$\epsilon_{\beta Ca}$ is the ^{45}Ca beta efficiency.

When the β-emitter and the β-γ tracer are combined in a single source, a functional relationship exists between the detection efficiencies. This relation can be defined by a polynomial function G where:

$$(1 - \epsilon_{\beta Ca})/\epsilon_{\beta Ca} = G((1 - \epsilon_{\beta Co})/\epsilon_{\beta Co}) \qquad (2)$$

Since the tracer efficiency, $\epsilon_{\beta_{C}o}$ may not always be accurately obtainable from coincidence counting data, is convenient to use the expression involving only observed β-γ and coincidence counting rates.

The expression can be rewritten as:

$$\frac{N_{\beta(Ca+Co)}N_{\gamma Co}}{N_{cCo}} - N_{0Co}$$

$$= N_{0Ca}\left[1 + G^{'}((1 - \frac{N_{cCo}}{N_{\gamma Co}})/\frac{N_{cCo}}{N_{\gamma Co}})\right] \qquad (3)$$

The function $G^{'}$ was fitted by weighted least squares using code LINFIT [9] and the extrapolation $(1 - N_c/N_\gamma)/N_c/N_\gamma = 0$ gave the expected N_{0Ca} value. Suitable corrections for background, decay, dead time and accidental coincidences were included in calculation.

3 Results and Discussion

Figure 2 shows the extrapolation curves obtained for the three different methods of preparing sources: mixing solutions with ratios 1:1 and 1:2 and by drops with 1:1 ratio. The β efficiency was varied using external absorbers.

The extrapolated value for the two mixing solutions were in agreement with each other, namely (154.3 ± 1.9) kBq/g and (154.3 ± 2.5) kBq/g, respectively. However, for the other preparation method (drops 1:1), the extrapolated value was (150.3 ± 1.3) kBq/g, 3% lower. The possible causes for this difference are being investigated.

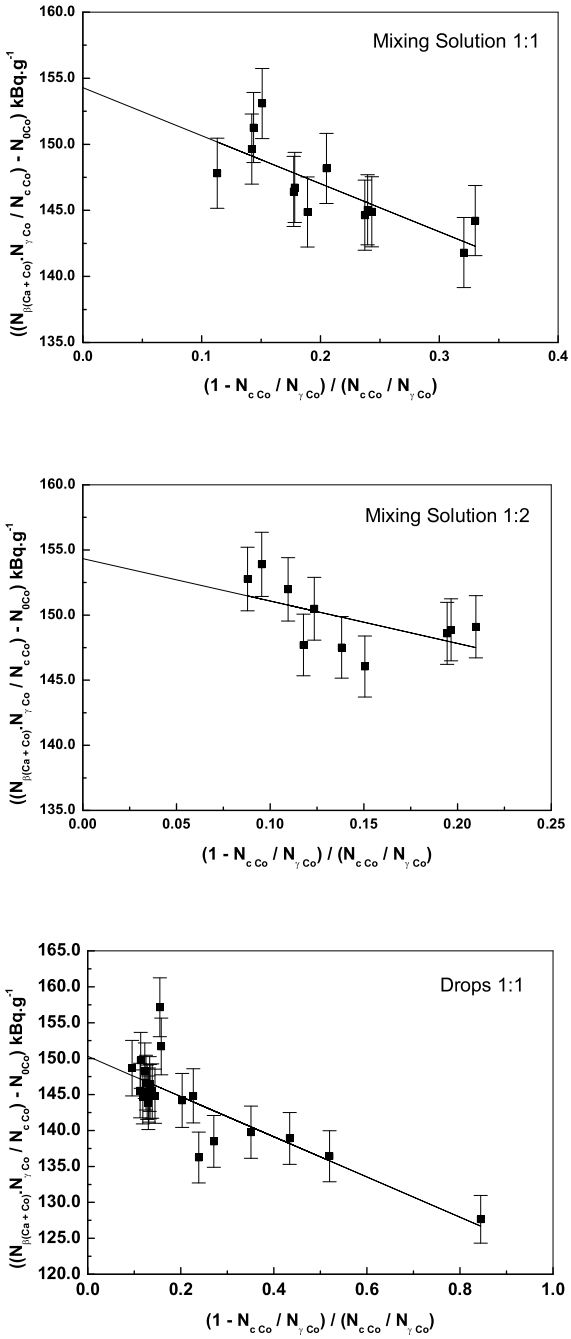

Figure 2. Extrapolation curves of $\frac{N_{\beta(Ca+Co)}\cdot N_{\gamma Co}}{N_{cCo}} - N_{0Co}$ as a function of $\frac{1-N_{cCo}/N_{\gamma Co}}{N_{cCo}/N_{\gamma Co}}$.

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