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Standardization of ^{125}I by the coincidence method and practical applications

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Abstract

A new coincidence system, based on two thin NaI(Tl) crystals, $50\times 2\,\mathrm{mm}^2$, with beryllium windows, $1.5\,\mathrm{mg\,cm}^{-2}$, positioned approximately symmetrically from the source holder (at various distances) was constructed. The electronic chains of a classical 4πPC–γ system were utilized. A multichannel analyzer was employed for energy calibration, and an oscilloscope for visualization of the pulses. After calibration, the system was used for the standardization of an ^{125}I solution. An energy window of 12–95 keV containing the entire spectrum (single and sum peak) was employed, and a simple demonstration of Taylor's equation [1967. X-ray–X-ray coincidence counting methods for the standardization of ^{125}I and ^{197}Hg. In: Standardization of Radionuclides: Proceedings of a International Atomic Energy Agency Symposium, Vienna, 1966, pp. 341–353, SM-79/65] for whole spectrum counting, was developed. The method and system were tested during the calibration of a LKB 2104 multi-gamma counter, by comparing the detection efficiency values obtained for this prepared standard solution and that utilized in the CIPM-CCRI(II) key comparison. The efficiency of the equipment was calculated as the mean of the two individual values. The result validates the method and demonstrates the accomplishment of the national traceability assurance in nuclear medicine for ^{125}I.

Keywords: ^{125}I; Standardization; Coincidence system construction; Comparison; Calibration

1. Introduction

The absolute standardization of ^{125}I is generally performed by three basic methods: sum-peak counting (Brinkman et al., 1963; Eldridge and Crowter, 1964); X–X coincidence counting (Taylor, 1967) and 4πe–X coincidence counting (Martin and Taylor, 1992). The methods have been continually developed (Schrader, 2006) and applied, with satisfactory results, in international comparisons (Ratel, 1989, 2005). The simplest method is sum-peak counting, as it makes use of a single detector. As this method requires the application of random-summing and pulse pile-up corrections (Capogni et al., 2006), we constructed an X–X, gamma coincidence system. The present paper describes the system, the experimental procedure and discusses the results. The standardized solution was used for the calibration of a commercial gamma counter used in the Radioimmunoassay (RIA) Laboratory of IFIN-HH. As calibrations performed with this solution and the solution with the activity assigned in the key comparison are in good agreement, a mean efficiency for the counter was calculated, which was used to correct the approximate value recommended by the equipment manufacturer.

2. Coincidence system

The scheme of the system is presented in Fig. 1. It consists of a new detection block, comprising two identical, thin NaI(Tl) crystals of dimensions $50\times 2\,\mathrm{mm}^2$, with beryllium windows, $1.5\,\mathrm{mg\,cm}^{-2}$. The detection probes, type TSP-50-0/B, were constructed in our electronics department, using photomultipliers type EMI 9656KR, with a photocathode diameter of 55 mm. They were placed in a position approximately symmetrical from the source holder, at various distances. The low and high voltage supplies, as well as the whole electronic chains are those

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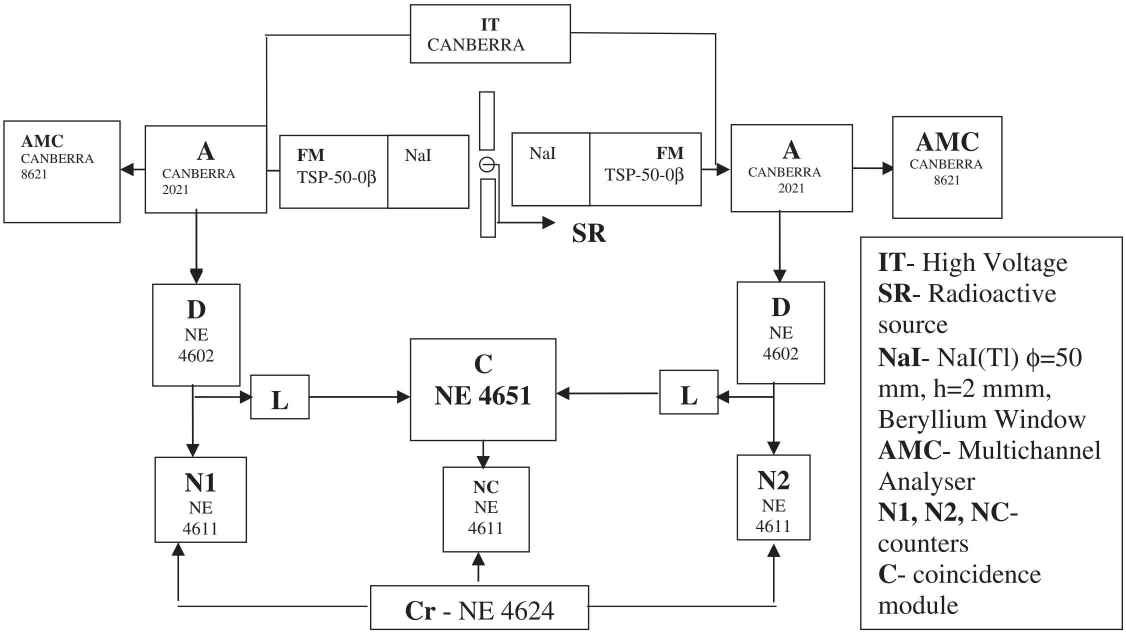

Fig. 1. Coincidence installation scheme.

used in a classical 4πPC–γ system. Additionally, a 4096 channel analyzer, type CANBERRA 8621, was used for energy calibration, which was performed utilizing ^{133}Ba (31; 81 keV), ^{137}Cs (32 keV) and ^{241}Am (60 keV) sources. A fast digital LeCroy 6000A oscilloscope was used to characterize the pulses present in the electronic chains. These pulses exhibited a rise time of 0.5 μs, a duration of 8 μs and were presented to amplifiers, of maximum amplification 3k and a formation time 0.25 μs, and then used to feed discriminators. The two discriminators (single-channel analyzers) provide TTL, 5 V amplitude impulses of length 1 μs. The HV and electronic amplification were chosen to ensure that the main K X-ray 27 keV peak was situated at 2 V amplitude for both detectors. In this manner, the sum peak is expected at about 4 V, and the entire spectrum may be positioned within the region (0.5–7.0) V.

3. Experimental procedure

3.1. Preparation of sources

As presented in Fig. 1, the sources are placed in a vertical position, and to ensure the non-detection of Auger and internal conversion electrons, the sources were sandwiched between two 1 mg cm^{-2} Mylar aluminized foils. Seven sources, with droplet masses between 11 and 39 mg were prepared and measured, after treatment with a solution of AgNO$_3$.

3.2. Adjustment of the measurement conditions and method

Due to the low X-ray and gamma-ray energies (maximum 35 keV), gamma correlations and Compton effects are negligible and a close distance of about 10 mm was used with an energy window of 12–95 keV. The influence of drift in the electronic amplification was minimized by the use of this large window. A unique dead time, $\theta = (10.0 \pm 0.5)$ μs, and a coincidence resolution time $\tau = (1.060 \pm 0.005)$ μs were used in the measurements.

The theoretical basis of the X–X, gamma coincidence method was developed by Taylor (1967), who developed the basic coincidence equations for the cases of (a) whole spectra counting using identical detectors (Eq. (7)) and (b) single-peak counting (Eq. (13)).

As described above, our measurements were performed in the condition (a), whole spectrum counting. Eq. (7) of Taylor is

$$N_0 = \frac{4K}{(1+K)^2}\left[N_1 + \frac{N_c(1-N_c/(2N_2))}{2(1-N_c/(2N_1))}\right] \times \left[N_2 + \frac{N_c(1-N_c/(2N_1))}{2(1-N_c/(2N_2))}\right]\frac{1}{2N_c},$$

where N_0 is the activity in Bq, N_1, N_2 and N_c are the counting rates in s^{-1} and K is the ratio of emission probabilities of the decay branches (gamma plus internal conversion) and electron capture.

This equation may be obtained as follows.

The detection efficiency ε for a cascade emission, capture i and (gamma + conversion) j, including the sum peak, is

$$\varepsilon = [P_i\varepsilon_i' + (1 - P_i\varepsilon_i')P_j\varepsilon_j'],$$

where ε_i' and ε_j' refer to the intrinsic efficiencies (incorporating solid angle effects), while P_i and P_j are the relevant emission probabilities.