

STANDARDIZATION OF Tl-201 RADIOACTIVE SOLUTION

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ABSTRACT

The standardization of ²⁰¹Tl, using the 4 π (PC)-NaI(Tl) coincidence system, is presented. The disintegration rate was determined by the extrapolation technique, using two methods: electronic discrimination and external absorbers. A Monte Carlo simulation program, developed in our laboratory, which predicts the behavior of the extrapolation curve, was applied and the results were compared with experimental values.

1. INTRODUCTION

The Nuclear Metrology Laboratory (LMN) at the IPEN São Paulo, in Brazil, has developed standardization methods for radionuclides, such as ⁵¹Cr, and ¹⁵³Sm [1, 2], used in nuclear medicine, by means of a 4 π β - γ primary system. In this paper, the procedures applied to ²⁰¹Tl radioactive solution are shown.

The radionuclide ²⁰¹Tl is produced in cyclotrons and its importance relies on its use for diagnosis in coronary exams and tumor visualization in different organs, especially in the brain. It decays by electron capture process, having a half-life of 3.04 days, emitting two gamma rays of 135 keV and 167 keV [3]. The ²⁰¹Tl decay scheme is shown in Fig. 1.

The disintegration rate was determined by the 4 π β - γ coincidence method by applying the extrapolation technique. The beta efficiency was altered by electronic discrimination and using external absorbers. The events were registered by a method developed by the LMN, using a Time Amplitude Converter (TAC), associated with a Multichannel Analyser [4].

The ESQUEMA code [5], which uses the Monte Carlo technique for simulating the detection events in the coincidence system, was applied and the results were compared with experimental values.

3.0408 (42) d
²⁰¹Tl

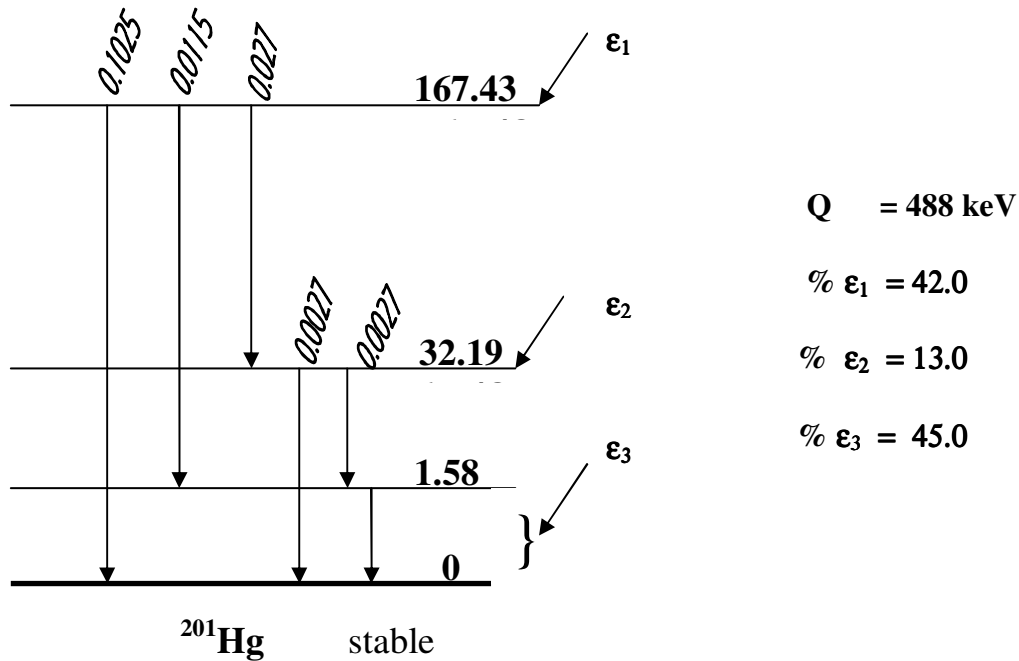


Figure 1. Decay scheme of ²⁰¹Tl [3]

2. EXPERIMENTAL METHOD

2.1. Source Preparation

The ²⁰¹TlCl solution was produced in the IPEN Cyclotron 30, by the reaction ²⁰³Tl(p,3n)²⁰¹Pb → ²⁰¹Tl and it was obtained from the IPEN Radiopharmaceutical Center. The radioactive sources to be measured were prepared by dropping small amounts of the solution on a 20 μg cm⁻² thick Collodion film. This film had been previously coated with a 10 μg cm⁻² gold layer, in order to make the film conductive. A seeding agent (CYASTAT SM) was used to improve the deposit uniformity and the sources were dried in a desiccator. The mass determination was performed using the pycnometer technique [6], in a Sartorius balance model MC 21S.

2.2. 4π(PC)-NaI(Tl) Coincidence system

The coincidence system used was a 4π(PC)-NaI(Tl) composed of a 4π proportional counter operated at 0.1 MPa, for detecting the X-rays and the Auger electrons coming from the electron capture process decay, coupled to a pair of 76 mm x 76 mm NaI(Tl) crystals, to detect the gamma-ray emitted. The measurements in the proportional counter were performed

in the integral mode, using a single channel analyzer to discriminate the electronic noise. The measurements in the NaI detector were performed selecting the total absorption peak of 135 keV plus 167 keV gamma-rays. The electronic system used for these measurements was presented in a previous paper [7].

The disintegration rate N_0 was obtained by the well- known coincidence formula [8].

$$\frac{N_{(X,A)}N_{\gamma}}{N_c} = N_0 \left[1 + \frac{(1 - \epsilon_{(X,A)}) (\alpha_T \epsilon_{ce} + \epsilon_{\beta\gamma})}{\epsilon_{(X,A)} (1 + \alpha_T)} \right] \quad (1)$$

Where:

- N_0 is the disintegration rate;
- $N_{(X,A)}$, N_{γ} and N_c are the electron Auger or X-ray, gamma-ray and coincidence counting rates, respectively;
- $\epsilon_{(X,A)}$ is the electron Auger or X-ray detection efficiency;
- $\epsilon_{\beta\gamma}$ is the gamma-ray detection efficiency of proportional counter;
- ϵ_{ce} is the conversion electron detection efficiency and
- α_T is the total internal conversion coefficient.

The electron Auger or X-ray detection efficiency was altered by using two methods: electronic discrimination and external absorbers of Collodion films, coated with gold, placed on both sides of the source. The efficiency ranged from 50% to 15%, with electronic discrimination and from 50 % to 13 %, using external absorbers.

3. RESULTS AND DISCUSSION

Fig. 2 presents the experimental values obtained by means of the two methods used for altering the proportional counter efficiency. The squares are the values obtained by electronic discrimination and the open circles are the values obtained, with the sources covered by Collodion films.

Table 1 and Table 2 show the $(1 - N_c/N_{\gamma})/(N_c/N_{\gamma})$ efficiency parameters and experimental values, with uncertainties obtained by electronic discrimination and using external absorbers, respectively.

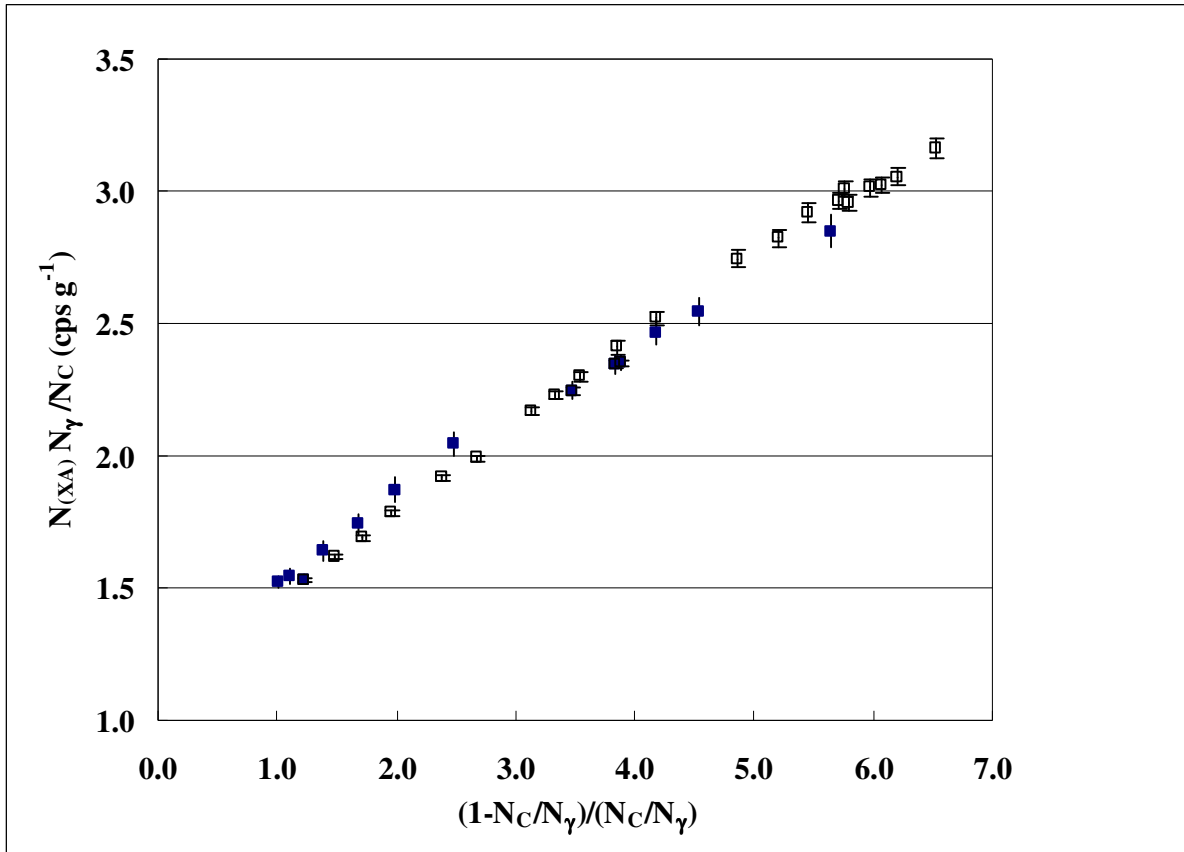


Figure 2. Experimental values of $N_{(X,A)} N_{\gamma} / N_C$, as a function of $(1 - N_C / N_{\gamma}) / (N_C / N_{\gamma})$, obtained by using external absorbers (open circles) and electronic discrimination (squares)

Table 1. Results obtained by electronic discrimination

Measurement	$(1 - N_C / N_{\gamma}) / (N_C / N_{\gamma})$	$N_{(X/A)} N_{\gamma} / N_C$ (cps/g)	Uncertainty
1	1.019	1.524	0.023
2	1.105	1.541	0.029
3	1.231	1.530	0.018
4	1.384	1.639	0.036
5	1.685	1.742	0.041
6	1.986	1.871	0.051
7	2.475	2.044	0.045
8	3.473	2.243	0.033
9	3.833	2.346	0.035
10	3.885	2.351	0.030
11	4.169	2.466	0.049
12	4.540	2.547	0.052
13	5.648	2.848	0.064

Table 2. Results obtained by external absorbers

Measurement	$(I-N_c/N_\gamma)/(N_c/N_\gamma)$	$N_{(X/A)}N_\gamma/N_c$ (cps/g)	Uncertainty
1	1.231	1.530	0.007
2	1.493	1.618	0.009
3	1.714	1.688	0.009
4	1.961	1.785	0.011
5	2.378	1.916	0.012
6	2.681	1.990	0.013
7	3.135	2.170	0.016
8	3.323	2.228	0.016
9	3.473	2.243	0.013
10	3.534	2.300	0.017
11	3.833	2.346	0.014
12	3.851	2.410	0.025
13	3.885	2.351	0.012
14	4.180	2.519	0.028
15	4.856	2.745	0.031
16	5.204	2.822	0.034
17	5.444	2.920	0.035
18	5.716	2.963	0.027
19	5.758	3.007	0.027
20	5.800	2.959	0.030
21	5.979	3.012	0.031
22	6.065	3.022	0.032
23	6.205	3.054	0.033
24	6.520	3.162	0.034

In Table 3, the activity concentration results, obtained by the least square fitting to the experimental data, with the uncertainties are presented.

Table 3 Results of activity concentration

Activity concentration (MBq g ⁻¹)	
External absorbers	1.149(6)
Electronic discrimination	1.143(44)

The results, obtained using Collodion films for alter the efficiency of the proportional counter, were compared with a theoretical calculation carried out by the ESQUEMA code. This code uses the Monte Carlo technique by means of the MCNPX code [9], for obtaining the response functions of both detectors of the coincidence system used. By simulating the experimental conditions, as the thickness of the Collodion films covering the source, it is possible, by means of the ESQUEMA code, to predict the extrapolation curve behavior for a unitary activity.

Fig. 3 shows the extrapolation curve behavior of $N_{(X,A)} N_{\gamma}/N_C$, as a function of $(1 - N_C/N_{\gamma}) / (N_C/N_{\gamma})$, obtained by using external absorbers, compared to the normalized Monte Carlo calculation simulating the experimental conditions.

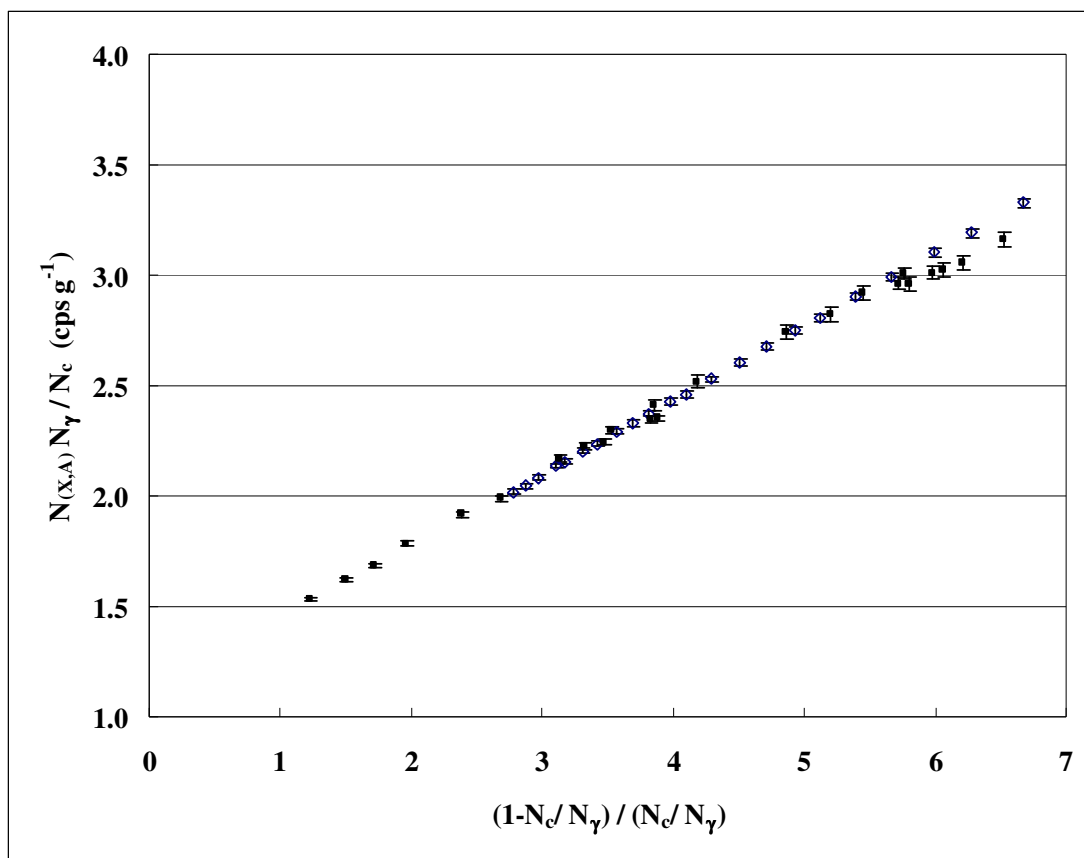


Figure 3. Behavior of the extrapolation curves of $N_{(X,A)} N_{\gamma}/N_C$, as a function of $(1 - N_C/N_{\gamma}) / (N_C/N_{\gamma})$, obtained by using external absorbers, compared to the Monte Carlo calculation. The open circles are the theoretical values and the squares are the experimental data.

Conclusions

As it can be seen in figure 3, the extrapolation curve behavior obtained with the Monte Carlo calculation is in agreement with the experimental data obtained with external absorbers. The predicted extrapolation curve behavior, simulating the electronic discrimination, is ongoing and will be compared with experimental values. The activity concentration results presented in Table 3 concerning the measurements of ^{201}Tl using external absorbers are in agreement with those obtained with electronic discrimination, showing that both methods for altering the proportional counter efficiency can be used.

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