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STANDARTIZATION OF ^{166m}Ho IN A COINCIDENCE SYSTEM BY SOFTWARE AND DETERMINATION OF ITS GAMMA EMISSION PROBABILITIES

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ABSTRACT

This works presents a new standardization of the radionuclide ^{166m}Ho that was carried out at Nuclear Metrology Laboratory (LMN) at IPEN. ^{166m}Ho decays with 1133 years of half-life by beta emission followed by a cascade of gamma-rays in a range of 73 to 1427 keV, and these characteristics makes it a good secondary standard to the calibration of gamma spectrometers. Previously calibrated with a standard 4π(PC)β–γ coincidence system, the same samples were now measured in the Software Coincidence System (SCS), where the data analyses can be done after the measurements, using a software developed at LMN as well. The SCS is composed of a 4π geometry proportional counter operated at 0.1MPa coupled to one NaI(Tl) crystal, positioned above the PC counter, and to a HPGe detector, positioned below the PC counter. The signals from all detectors are digitalized and their pulses height and time of occurrence are recorded on computer files. After the standardization, the emission probabilities per decay of the most intense gamma-rays in the ^{166m}Ho decay were determined by means of a HPGe spectrometer system, which was calibrated with standard sources previously calibrated in the 4π(PC)β–γ coincidence system, and the results were compared with the literature. All the uncertainties were treated by the covariance analysis method.

1. INTRODUCTION

The knowledge with good accuracy of the gamma-ray emission probability per decay of radionuclides is important in many applications. Between the radionuclides which well known decay parameters and usually used as standards, the radionuclide ^{166m}Ho is very important in gamma spectrometry due of its huge range of energies, from 73 keV to 1427 keV, and because two intense gamma radiations as 184.4107 keV and 810.286 keV.

The samples of ^{166m}Ho used to develop this work were previously calibrated with a standard 4π(PC)β–γ coincidence system consisting of a pair of 3” x 3” NaI(TI) crystals and a 4π geometry proportional counter operated at 0.1MPa [1]. The preparation of the samples were done by dropping well know aliquots of the ^{166m}Ho solutions on thin films of Collodion, previously stuck on the aluminum rings and metalized with Au on both sides.

2. STANDADIZATION OF THE RADIONUCLIDE ^{166m}Ho IN THE 4π(PC)β–γ SCS

The 4π(PC)β–γ Software Coincidence System [2] from LMN is composed of a 4π geometry proportional counter operated at 0.1MPa coupled to one NaI(Tl) crystal, positioned above the PC counter, and to a HPGe detector, positioned below the PC counter. The signals from all detectors are digitalized and their pulses height and time of occurrence are recorded on computer files.

The standardization of the ^{166m}Ho was done measuring the sample by 9000 seconds. After the measurement the data were analyzed by means of the code SCTAC [2] which reads the information about the pulses recorded and calculate the spectra and the beta-gamma coincidences, generating the points to construction of the extrapolation curve which can be seen at the figure 1.

The code also makes the due corrections about dead time, background radiation, accidental coincidences and resolution time, according to the Cox-Isham formalism [3]. The uncertainty obtained on the activity calculation was 0.55%.

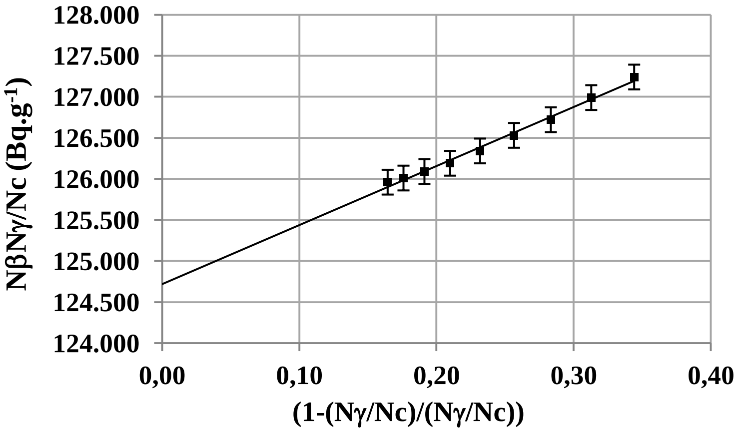

Figure 1. Extrapolation curve to determination of the ^{166m}Ho activity. The sample activity is determined by means of the extrapolation of the parameter (1-(Nγ/Nc)/(Nγ/Nc)) to zero [1].

3. MEASUREMENT OF GAMMA EMISSION PROBABILITIES

The emission probabilities per decay of the most intense gamma-rays in the ^{166m}Ho decay were determined by means of a HPGe spectrometer system, which was calibrated with a standard sample previously calibrated in the 4π(PC)β–γ coincidence system.

3.1. Determination of the calibration curve of the HPGe spectrometer

Several factors may affect the quality of measurements made on a gamma spectrometer, like the geometry of the experimental arrangement or how is the preparation of the sources etc.

However, these measures invariably depend on the accuracy of the calibration curve of the efficiency and in the accuracy of the decay parameters of the nuclides used as standard [1].

For the determination of the HPGe calibration curve was necessary to measure a ^{152}Eu standard sample, previously calibrated at LMN. After the measurement, the spectrum obtained was calibrated in energy versus spectrum channel, in order to provide the correct information about the peaks location to the analyses code. This linear adjustment was done by means of the LINFIT [4] code.

To obtain the efficiency calibration curve, first the spectrum was analyzed with the ALPINO1 [5] code, developed at LMN. Then, logarithmical relationship between the energies and the efficiency results obtained was determined by means of the code LOGFIT [6] and the result is presented in the figure 1. The same code provided the efficiencies for the ^{166m}Ho gamma emissions, by interpolation, which is necessary for the calculation of the gamma emission probabilities.

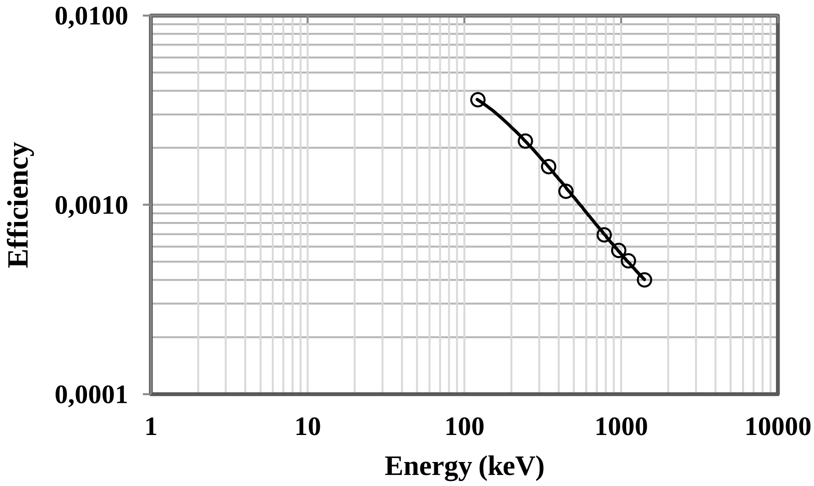

Figure 1. Efficiency calibration curve of the HPGe spectrometer between 121 keV and 1408 keV. The circles are the experimental points and the line represents the adjustment.

3.2. Calculation of the gamma emission probabilities per decay of the ^{166m}Ho

The same sample of ^{166m}Ho standardized in the SCS was measured at the HPGe spectrometer. The measurement time of was around 160000 seconds and the background radiation measurement time was 100000 seconds. In the figure 2 the spectrum of ^{166m}Ho is presented.

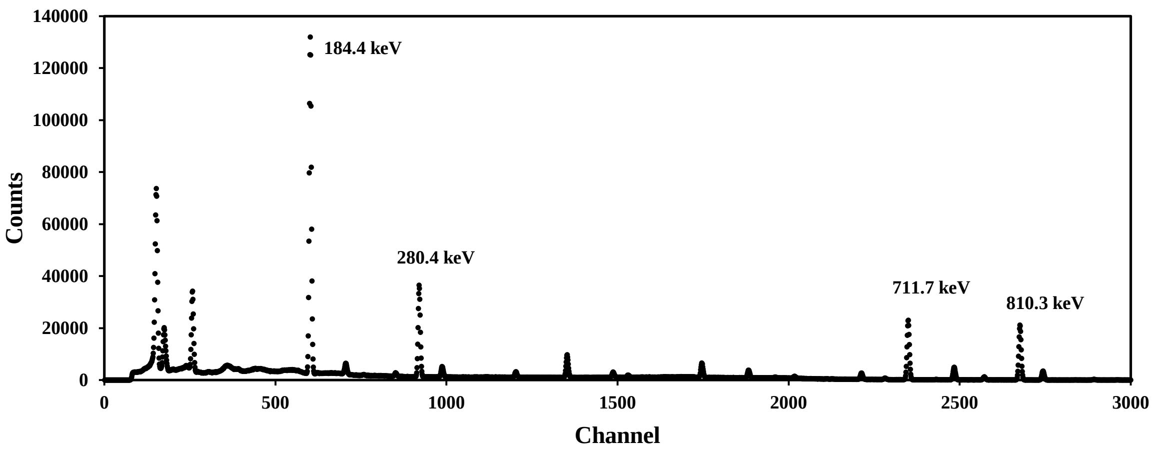

Figure 2. Gamma spectrum of the ^{66m}Ho obtained with HPGe spectrometer.

The emission probabilities per decay for the most important gamma-rays from the ^{166m}Ho decay were determined by the equation below:

$$p(E) = \frac{S(E)}{A.\varepsilon(\mathrm{E}).\mathrm{T}}$$

where ε(E) is the efficiency for the gamma-ray with energy E, S(E) is the area under the total absorption peak of energy E, A is the absolute source activity at the reference date and determined in the standardization with the Software Coincidence System and T is the measurement time [1].

The calculation was done by means of the ALPINO1 code. The due correction for ackground, dead time, geometry and self absorption were done. The results are presented in the table 1 together with some data from the literature for comparison.

Table 1: Calculated ^{166m}Ho gamma emission probabilities per decay in comparison with the literature.

Energy (keV)	This work	Recommended [7]	Bernardes et al. [8]	Hino et al. [9]
184.41	71.83(96)	72.5(3)	72.60(47)	72.4(7)
280.46	29.04(22)	29.54(25)	29.30(15)	29.7(3)
410.96	11.25(9)	11.35(17)	11.17(6)	11.39(13)
529.83	9.64(8)	9.4(4)	9.35(5)	9.63(11)
570.99	5.49(6)	5.43(20)	5.42(3)	5.54(8)
670.53	5.36(6)	5.34(21)	5.32(3)	5.65(9)
711.70	54.54(32)	54.9(9)	53.8(2)	56.0(5)
752.28	12.20(11)	12.2(3)	11.98(6)	12.27(15)
810.29	57.53(40)	57.3(11)	56.6(3)	58.2(5)
830.57	9.79(9)	9.72(18)	9.56(5)	9.77(12)

4. CONCLUSIONS

The standardization of ^{166m}Ho solution by means of the $4\pi\beta-\gamma$ Software Coincidence System succeeded and this result allowed the calculation of the gamma emission probabilities per decay for its most intense gamma-ray, whose results presented good agreement with the values of the literature within the experimental uncertainty.

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