



STANDARDIZATION OF ^{65}Zn BY SUM-PEAK METHOD

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Abstract:

Due to the difficulty in the calibration of this nuclide by $4\pi\beta\text{-}\gamma$ coincidence method, the proposal of this work was to realize the standardization with a simplest method: Sum-peak Method.

According to its decay scheme, ^{65}Zn disintegrates by electron capture to the 1115 keV excited level and by electron capture and β^+ for the ground state of ^{65}Cu . Then, this nuclide was standardized in the sum-peak method using the coincidence with 8 keV X-ray and 1115 keV γ -ray, forming the 1123 keV (sum-peak). For this, the sources were measured directly on the crystal in a planar HPGe detector using a LNMRI stock solution.

The activity results obtained by sum-peak method were compared with measurements made with a well type $4\pi\gamma$ ionization chamber, which is traceable to BIPM.RI (II) - K2.Zn-65 key comparison performed in 2002. The sum-peak value was $42.794 \text{ kBq/g} \pm 0.25 \%$ and the ionization chamber value was $42.744 \text{ kBq/g} \pm 0.85 \%$, both in the reference date and $k=1$. The difference between the two methods was 0.12 %. The results showed that Sum-peak Method can be used in ^{65}Zn standardization and this method is easier, simpler and more practice than the $4\pi\beta\text{-}\gamma$ coincidence method.

Key words: sum-peak method, standardization, absolute activity measurements, ^{65}Zn .

1. INTRODUCTION

The most useful method to standardize ^{65}Zn is the $4\pi\text{PC-}\gamma$, but there are some difficulties to do this, related by some authors [7, 8, 9 and 12]. The principal difficulty is due to the fact that the PC counts both positron and Auger electrons.

It is interesting to LNMRI standardize this nuclide in a simple and fast method.

The ^{65}Zn is practically a monoenergetic radionuclide very useful as a reference source in the gamma spectrometry and in the industry [10]. According to its decay scheme, ^{65}Zn disintegrates by electron capture to the 1115 keV excited level and by electron capture and β^+ for the ground state of ^{65}Cu (Figure 1) [2 and 3].

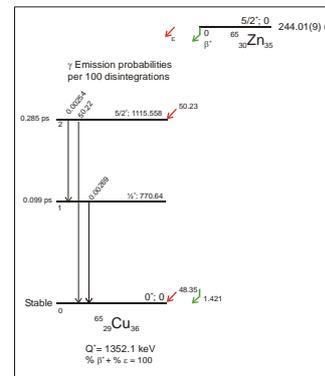


Figure 1. ^{65}Zn Decay scheme

The K-X photons arising from the two electron capture and beta emission in the ^{65}Zn decay is showed in Table 1.

Table 1. K-X photons in the ^{65}Zn decay scheme.

X-Ray emission	Energy (keV)	Photons per 100 disintegrations
$\text{K}_{\alpha 2}$	8.02792	11.76 (13)
$\text{K}_{\alpha 1}$	8.04787	22.91 (22)
K_{β}	8.90539	4.82 (7)

2. METHODOLOGY

2.1. Sum-peak Method

Sum-peak Method was proposed by Brinkman [4 and 5]. This method is very simple, using just a single NaI(Tl) detector or a HP(Ge) detector. To be measured by sum-peak method, the nuclide should be present two or more electromagnetic radiation. The two radiation may be two gamma rays in coincidence, as ^{60}Co and β^+ emitters, or one X-ray followed by one gamma ray, as ^{65}Zn and ^{51}Cr [1]. The Equation 1 expressed the fundamental equation of the sum-peak method.

$$\frac{A_1 \cdot A_2}{A_{12}} + T = N \quad (1)$$

where, N is the source activity, T is the number of total rate interactions on the spectrum, A_1 and A_2 are photopeak counting rates and A_{12} is the sum-peak counting rate, which

results from the simultaneous interaction of the two radiations on detector.

The photon spectrum of a ^{65}Zn source placed on the top of a planar germanium detector presents three photopeaks that are used in the sum-peak method: the 8 keV X-ray (A_1), the 1115 keV γ -ray (A_2) and the sum-peak originated from the sum of 8 keV with 1115 keV photopeaks (A_{12}). Then, for the ^{65}Zn , the fundamental sum-peak equation is:

$$N = T + R \quad (2)$$

with

$$R = \frac{A_{8\text{keV}} \cdot A_{1115\text{keV}}}{A_{1123\text{keV}}} \quad (3)$$

where

$A_{8\text{keV}}$ count rate on the 8 keV photopeak

$A_{1115\text{keV}}$ count rate on the 1115 keV photopeak

$A_{1123\text{keV}}$ count rate on the 8+1115 keV sum-peak

2.2 Uncertainties

The statistical components were evaluated using the Equation 2. In this equation there are not nuclear parameters involved, then the principal components that affect the A-type is the calculation of photopeaks net areas, the extrapolation to zero energy (0 keV) and background counts. From the derivation of Equation 2, it is possible to evaluate the statistics uncertainties, according to the Equation 4.

$$(\Delta N_0)^2 = \left(\frac{\partial N_0}{\partial N_T} \right)^2 (\Delta N_T)^2 + \left(\frac{\partial N_0}{\partial N_R} \right)^2 (\Delta R)^2 \quad (4)$$

Besides the A-type uncertainties derived from N_0 , others uncertainty components also affect the accuracy of the activity of ^{65}Zn solution (sample weight, dilution factor and decay correction) considered in this work. According to the masses used to prepare ^{65}Zn sources for sum-peak method, the sample weighting component was 0.05 %, and the dilution factor component may be neglected. The decay correction component (half-life) is evaluated by the Equation 5.

$$S_{T_{1/2}} = \frac{\ln 2 \cdot \Delta t \cdot \mu T_{1/2}}{T_{1/2}} \quad (5)$$

where,

Δt difference between counting date and reference date.

$\mu T_{1/2}$ uncertainty in the half-life value [3]

$T_{1/2}$ half-life [3]

3. EXPERIMENTAL PROCEDURES

3.1 Sum-peak measurements

Three sources were prepared from the ^{65}Zn original solution by dropping deposition of known masses onto a cavity in the center of an acrylic disk fixed in a 0.05 mm thick polystyrene film. The masses were determined in a

micro analytical balance using the picnometer differential weighing technique. After drying the sources were covered by the same polystyrene film as show in the Figure 2.

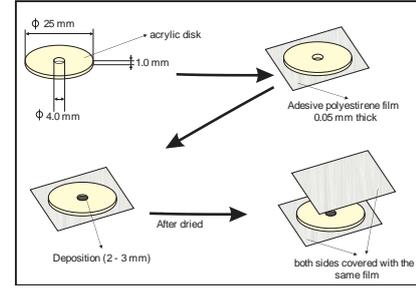


Figure 2. Preparation of the ^{65}Zn sources.

The nuclide was standardized in the sum-peak method using the coincidence with 8 keV X-ray and 1115 keV γ -ray, and 1123 keV (sum-peak). The photon spectrum is shown in Figure 3. The spectrum exhibits three peaks which are used for the activity determination.

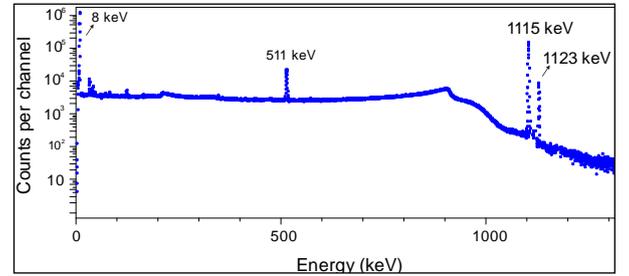


Figure 3. ^{65}Zn spectrum obtained

For this, the sources were measured directly on top of the crystal in a planar HPGe detector using an LNMRI solution. The source count time varied from 32000 to 96000 seconds. The peak area evaluation was done using a data acquisition software [11].

The germanium detector used in this work is optimized to operate in the X or γ -ray detection between 3 and 300 keV. To measure the 1115 and 1123 γ -rays, a device voltage divider was introduced in the pre-amplifier exit. The device is composed by a 50 Ω and 1.2 k Ω resistors [6]. This device allowed to achieve energy around 1200 keV which efficiency responses are adequate to operate with high energies for standards and samples. The device arrangement is shown in Figure 4.

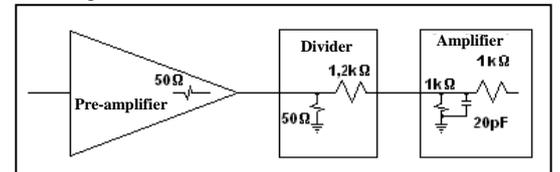


Figure 4. Device voltage divider used to extend the energy range in the planar detector.

3.2 Ionization Chamber Measurements

One ampoule was prepared for the measurements in a Centronic IG11/20A high pressure well type $4\pi\gamma$ ionization chamber, which is traceable to BIPM.RI (II)-K2.Zn-65 key-comparison performed in 2002. The radioactive source was a ^{65}Zn solution of about 2.7 g in IRD standard ampoule

geometry, with carrier concentration of 20 µg/g ZnCl₂ in 0.1 mol/l HCl.

4. RESULTS

The results are given in the Table 2. The reference date is March, 14th, 2010 – 12 h. The sum-peak method final activity value obtained on the reference date was evaluated as the weighted mean of the nine measurements for the three sources prepared. No γ-impurities were found in the planar HPGe spectrometer.

Table 2. Results of ⁶⁵Zn measurements.

Method	Activity per unit mass (kBq/g)	U (%) k=1
Sum-peak Method	42.794	0.25
Ionization Chamber	42.744	0.85

The difference between the two methods was 0.12 %, and the sum-peak method uncertainty is very small when compared with ionization chamber.

The uncertainties components are listed in Table 3.

Table 3. Uncertainty components, in %, for the sum-peak method.

Uncertainty Component	Type	(%)
Weighting	B	0.05
Live time	B	0.01
Decay corrections	B	0.0017
Statistical counting*	A	0.24
Combined uncertainty (k=1)		0.25

*including background and extrapolation to zero keV uncertainties.

5. CONCLUSION

The results of two methods are in good agreements and the uncertainty is consistent, showing that sum-peak method may be used in ⁶⁵Zn absolute standardization because this method is not only easy, but also simple and practical. So, this method can be seen as an alternative in relation to others methods.

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