Metrological activity determination of ^{133}Ba by sum-peak absolute method

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Abstract. The National Laboratory for Metrology of Ionizing Radiation provides gamma sources of radionuclide and standardized in activity with reduced uncertainties. Relative methods require standards to determine the sample activity while the absolute methods, as sum-peak, not. The activity is obtained directly with good accuracy and low uncertainties. ^{133}Ba is used in research laboratories and on calibration of detectors for analysis in different work areas. Classical absolute methods don`t calibrate ^{133}Ba due to its complex decay scheme. The sum-peak method using gamma spectrometry with germanium detector standardizes ^{133}Ba samples. Uncertainties lower than 1% to activity results were obtained.

1. Introduction

The National Laboratory of Metrology of Ionizing Radiation (LNMRI) under the National Nuclear Energy Commission (CNEN) is the body designated by the National Institute of Metrology and Quality Technology (INMETRO) as National Metrology Laboratory for quantities associated with ionizing radiation. This laboratory participates in inter comparison in order to ensure the traceability of measurements in the worldwide network of metrology, coordinated by the Bureau International des Poids et Mesures (BIPM) and the Inter-American Metrology System (SIM). It offers various systems and calibration methods for radioactive sources in various geometries which can be absolute or relative.

The high-resolution gamma spectrometry by high purity germanium detector (HPGe) is applied to the analysis of emitting photons radionuclides [1].

This is a relative technique, by the use of standards for determining the activity of the samples is compared to a standard of the same nature or by efficiency curve which is generated by using various standard (^{241}Am, ^{152}Eu, ^{166m}Ho).

The ^{133}Ba has 10.5 years of half- life and decays by electron capture 100 % into two main branches , E1 (86.2 %) to the level of 437 keV and E2 (13.7 %) to the level of 383.8 keV for ^{133}Cs as seen in figure 1. It is a radionuclide which is in addition to the x – rays characteristics, amount 14 power lines gamma (γ) and x-ray, forming several coincidences in the search for stability [2]. These emitted energies in its excited state cover a range of great interest to analyze, this makes it a standard for laboratories.

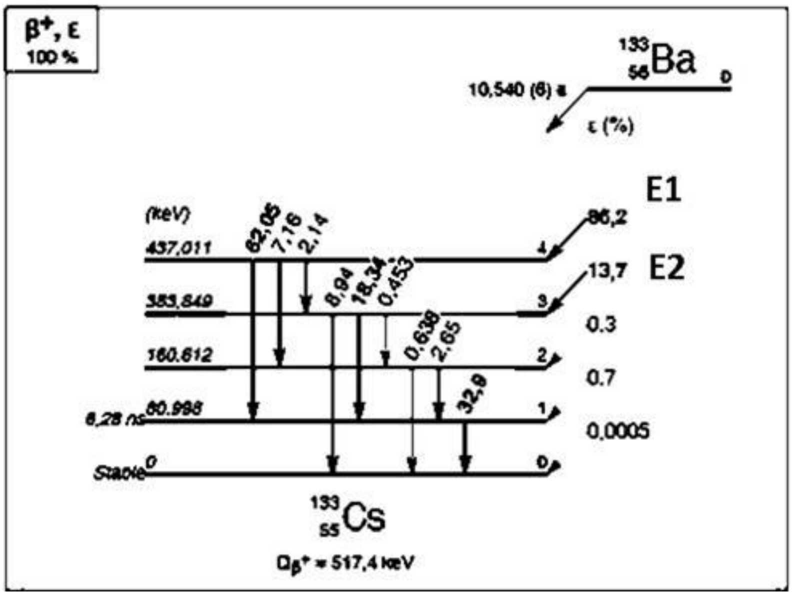

Figure 1. ^{133}Ba scheme decay simplified

The sum-peak method was developed by Brickman [3] and their collaborators presenting a calibration by means of two coincident radiation, X and γ rays. Over several years articles were published in which it is used HPGe [4,5] . This method allows a direct measurement and uses the same principle of coincidence counting by gamma spectrometry with a single detector.

His equation is:

$$[(A_1 \,.\, A_2) \;/\; A_{12}] + T = N \tag{1}$$

where:

A_1 and A_2 represent the areas of photopeaks range of energies observed in coincidence.

A_{12} represents the energies area of photopeaks observed in sum.

T counts of full spectrum.

N is the absolute activity of the source.

The objective of this work is the calibration of the ^{133}Ba using the sum-peak method, showing speed and providing direct calibration values comparable to literature.

2. Methodology

Five sources of ^{133}Ba were made in point form geometry in thin film and the approximate activities were calculated according to the distance source - detector to avoid pile-up effect during measurement.

It used a planar germanium detector coupled to a voltage divider that allows the spectrum energy range of 300 keV to 1200 keV , allowing full spectrum display of ^{133}Ba .

The distance of the sources in relation to the detector are 0 cm (top) and 10 cm. Uncertainties recommendations follow the ISOGUM [6].

3. Results and discussion

In activities determining were used the x-ray, kα= 30.8 keV and kβ= 35.5 keV of ^{133}Ba decay, and their sum-peaks of gamma energies.

The uncertainties are basically type A, namely counts. The relative combined standard uncertainty associated with any result obtained by gamma-ray spectrometry provides: type A - peak area; type B - mass, decay, half-life, source position.

Figure 2 introduces gamma spectrum between 270 keV to 450 keV showing these energies and sum-peaks with x - rays. Peaks not identified come from background radiation (Bg). They are well evident the simple sum-peak of the γ with X- rays, suggesting the application of equation 1.

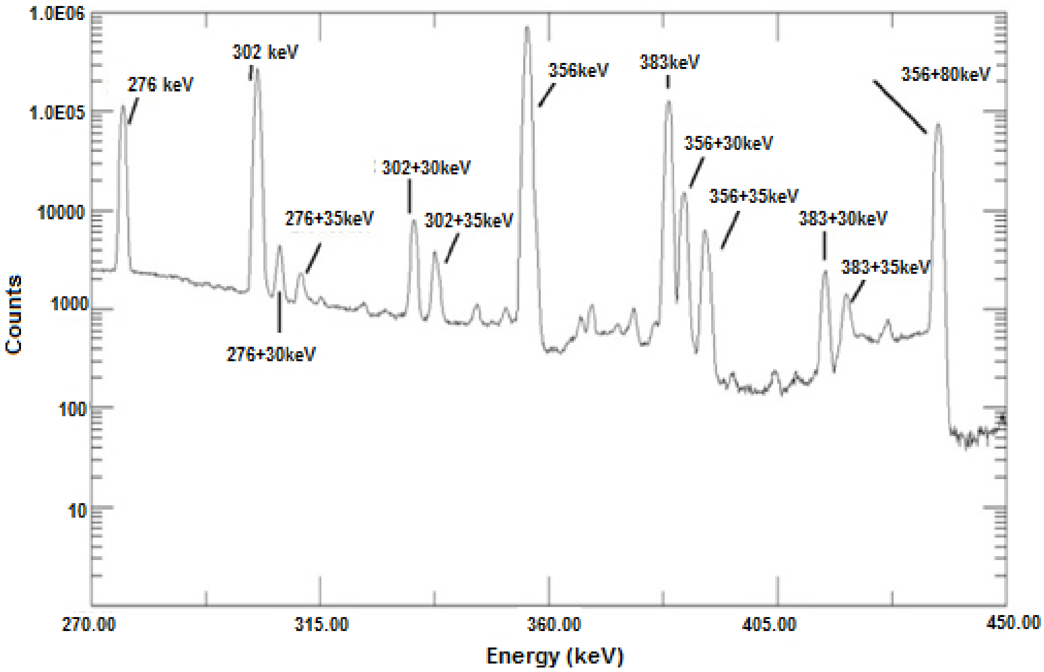

Figure 2. Energy spectrum between 270 keV to 450 keV of ^{133}Ba decay and their sum-peaks with the source on the top of detector

Table 1 shows the results from different sources in the 10 cm position detector by comparative method with the BIPM standard.

Table 1. Results of ^{133}Ba activities by comparative method using BIPM standard (2015/03/25)

Source	Activity kBq/g	U_a	U_b	U_t (K = 2)
1	156.46	1.2	0.48	1.30
2	156.79	0.92	0.48	1.04
3	156.96	0.93	0.48	1.05
4	157.37	1.2	0.48	1.30
5	157.66	0.49	0.48	0.69

The table 2 shows the values obtained at the sum-peak method and the table 3 shows the decay in the source that generated the five samples, all calibrations are referenced to the 12:00 h of 2015/03/25.

Table 2. Results of ^{133}Ba activities by sum-peak method (2015/03/25)

Source	Activity kBq/g	U_a	U_b	U_t (K=2)
1	156.13	0.51	0.48	0.70
2	156.21	0.51	0.48	0.70
3	156.24	0.51	0.48	0.70
4	156.23	0.51	0.48	0.70
5	156.25	0.51	0.48	0.70

Table 3. Some calibration methods for ^{133}Ba sources (2015/03/25)

Method	Activity kBq/g	U_a	U_b	U_t (K=2)
Sum-peak	156.21	0.51	0.48	0.70
Decay	156.28	0.06	0.66	0.66
Comparative	157.05	0.95	0.48	1.06

They were only analyzed the sum-peaks of the characteristic x-ray and γ energies, and some of these suffer interference and require deconvolution in order to obtain consistent results.

4. Conclusion

The values found among the methods presented here are compatible. The ^{133}Ba analysis can be performed of the absolute sum-peak method with the advantage of being fast, simple and to present low uncertainty results. The continuing search must be performed to ^{133}Ba calibrate by this method due to peaks relating to the sums and , they should be better observed due to the possible generation of other peaks relating to the triple sums , changing the final result.

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