Activity measurement of a ^{57}Co source for NIST

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In October 2009, Ryan Fitzgerald of the Radioactivity Group at NIST asked us to determine the activity of a ^{57}Co source with our well-calibrated HPGe detector. He had determined the activity of the source based on β-γ anticoincidence measurements but his new calibration was "significantly different" from NIST's old calibration from 1978. He was seeking another activity determination based on an independent technique. Since the absolute efficiency of our γ-ray detector is known to ±0.2%, we were in a position to measure the activity by observing the decay rate of γ rays emitted from ^{57}Fe, the daughter of ^{57}Co, and we agreed to do so.

The source supplied by NIST, which reached Texas A&M on 4 November 2009, was described as being prepared as follows: "2 drops of cobalt chloride solution (in 1 mol/L HCl) and 1 drop of dilute Ludox solution were deposited on the sticky side of a piece of polyester tape, approximately 0.006 cm thick, that had been mounted on a 0.05-cm-thick aluminum annulus with 3.8-cm inside diameter and 5.4-cm outside diameter. The source was dried in a desiccator overnight. The dried solids in the source consisted of 2.3 μg of $CoCl_2$ and 0.3 μg of SiO_2. The dried source was then sandwiched with a second piece of tape." We were also supplied with a radiographic analysis of the source, which showed it to be deposited in a spot with 5.5 mm diameter (full width at half maximum activity). If we assume uniform distribution of the solid material, there is no significant self-attenuation in this small amount of source material, so in our analysis of the data we only include the effect of the polyester tape.

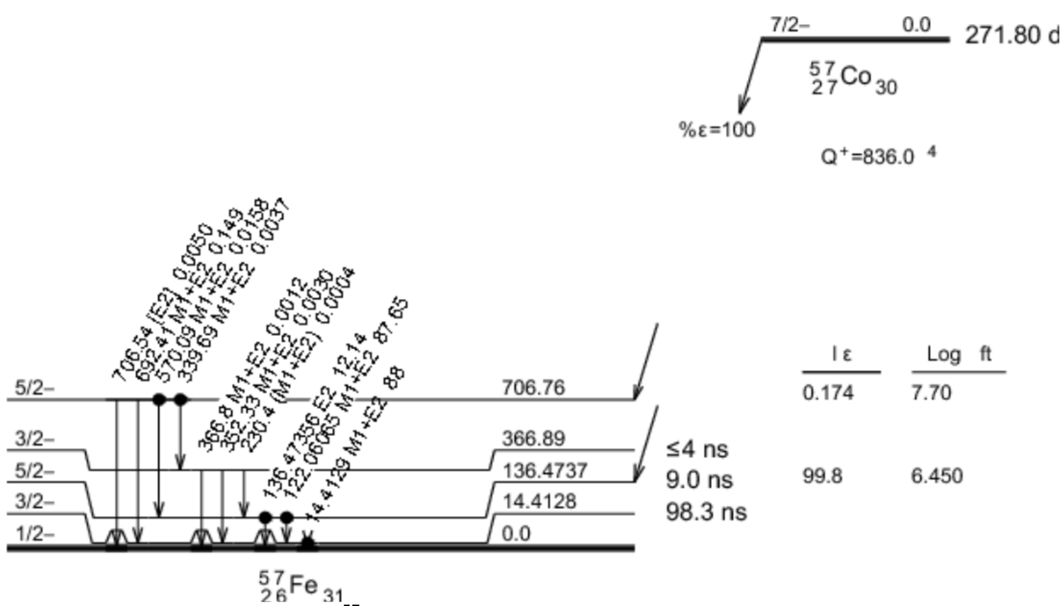

FIG. 1. Beta-decay scheme for ^{57}Co.

The decay scheme of ^{57}Co is shown in Fig. 1. The γ-ray spectrum from the decay is dominated by three γ rays: with 14.41, 122.06 and 136.47 keV. Our measurement focused on the latter two. Since we only measure the decay rate of these γ rays, we need to know the emission probability per decay, P_γ, for each in order to determine the activity of ^{57}Co itself. We take these values and the half-life of ^{57}Co from Ref. [1]: they are listed in Table 1. Note that all three of the main transitions in ^{57}Fe convert to some extent, with the 14.41-keV transition having by far the largest conversion coefficient (α = 8.56). All three are also populated by electron capture from ^{57}Co. Both processes lead to the production of x rays, so it is important in data analysis to take account of both γ-γ and γ-x-ray coincident summing.

Table 1. Properties required in the analysis (from [1]).

E_γ	P_γ per decay
122.06	0.8551(6)
136.47	0.1071(15)
$T_{1/2}$	271.80(5) d

Our measurements were conducted between 14 – 21 December 2009. All measurements were made with the source-to-detector-face distance of 151 mm, our standard setting at which the original calibration was made. After an initial background measurement, two spectra were obtained sequentially from the ^{57}Co source without the source being moved between measurements. Following that, the source was removed and another background spectrum was taken, after which the ^{57}Co source was replaced in position and a third spectrum recorded. Finally another background was obtained.

Following the ^{57}Co measurements, we measured several spectra with our precisely calibrated ^{60}Co source, originally provided to us by PTB with a certified precision on its activity of 0.06% [2]. This is the source upon which our absolute efficiency calibration is based [3] and we periodically use this source to check that our detector has not changed its properties. The result we obtained from the ^{60}Co source on this occasion yielded an activity that was within 0.11(22) % of the PTB-certified activity. Evidently our detector continues to maintain its calibration.

It can be seen from Fig. 2 that the ^{57}Co spectrum in the energy region between 110 and 150 keV in fact contains six peaks, none of which are in the background spectrum. In addition to the two principal peaks at 122 and 136 keV, there are the corresponding Ge-x-ray-escape peaks at 112 and 126 keV, each being ~0.1 % of the intensity of its associated photopeak, and there are the γ + *K* x-ray coincident-sum peaks at 128 and 142 keV, the former being ~0.3 % of the 122-keV peak and the latter being ~0.2% of the 136-keV peak. The γ + γ coincident sum of the 122- and 14-keV γ rays of course lies under the 136-keV peak.

We analyzed each of the three ^{57}Co spectra in two different ways: a) we summed all six peaks between 110 and 145 keV and treated the result as a measure of the total activity from the combined 122- and 136-keV γ rays, which have a combined P_γ per decay of 0.9622(16) (see table 1); and b) we analyzed the 122-keV peak and its associated escape and sum peaks independently. The first method requires no coincident summing correction, while the second requires that the γ + γ coincident sum be calculated and applied. Both methods and all three spectra gave statistically consistent results.

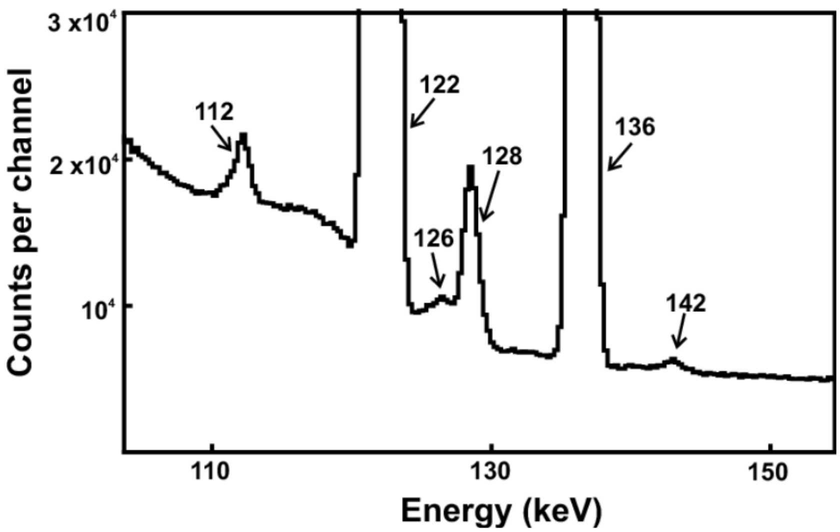

FIG. 2. Portion of the energy spectrum of γ rays from the decay of ^{57}Co in which the vertical scale has been chosen to show the weak peaks clearly. Note that the background sloping up to the left arises from γ rays Compton scattered by the aluminum annulus surrounding the source.

We were asked to provide our activity result extrapolated back to the reference time of 1200 EST 16 October 2009. Our final result for this reference time is 54.60(17) kBq. The uncertainty quoted on the result corresponds to ±0.31% and is made up of contributing factors that are listed in the uncertainty budget given in Table 2.

Table 2. Uncertainty budget for activity measurement for ^{57}Co source **.**

Source	**Uncertainty (%)**
Counting statistics	0.15
Detector efficiency	0.20
P_γ	0.18
$T_{1/2}$	0.003
Total	0.31

[1] *Update of X Ray and Gamma Ray Decay Data Standards for Detector Calibration and Other Applications, Volume 2*, IAEA, 2007.

[2] E. Schoenfeld, H. Janssen, R. Klein, J.C. Hardy, V. Iacob, M. Sanchez-Vega, H.C. Griffin, and M.A. Ludington, Applied Radiation and Isotopes, **56** (2002) 215.

[3] R.G. Helmer, J.C. Hardy, V.E. Iacob, M. Sanchez-Vega, R.G. Neilson and J. Nelson, Nucl. Instrum. Methods Phys. Res. **A511**, 360 (2003).