Gamma Spectrometry results for the ^{134}Cs nuclear parameters

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ABSTRACT
^{134}Cs are produced directly as a fission product (low yield) and too obtained by neutron capture from ^{133}Cs non-radioactive. The National Laboratory for Ionizing Radiation Metrology (LNMRI/IRD/CNEN) of Rio de Janeiro performed standardization of this radionuclide. A solution of ^{134}Cs radionuclide was purchased from a commercial supplier for nuclear parameters determination such as activity and emission probabilities of some of its energies. ^{134}Cs is a beta gamma emitter with 754 days of half-life. This radionuclide is used as a standard in environmental, water, and food control. It is also important to germanium detector calibration The gamma emission probabilities were determined mainly for some energies of the ^{134}Cs by the efficiency curve method and the most uncertainties obtained were around 1.5 %.

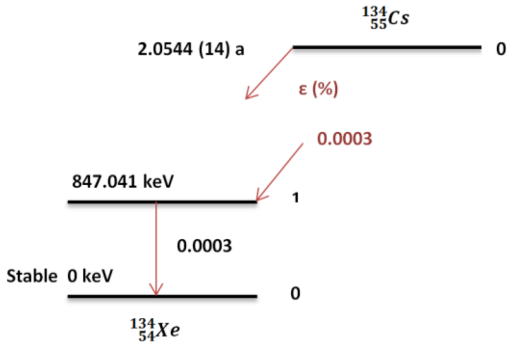
Keywords: Gamma emission probability, ^{134}Cs, HPGe, efficiency curve.

1 INTRODUCTION

^{134}Cs is a radioisotope of extreme importance for the calibration of HPGe spectrometers, among others. The determination of nuclear parameters beyond the absolute supply activity should be considered a factor of relevance.

The determination of the gamma emission probabilities, for example, allows improvements in the characterization of this radioisotope depending on the accuracy of the measured values and serves as a quality indicator of the spectrometry system and the methodology used in the determination of this parameter.

Another factor that highlights the use of ^{134}Cs is that through the determination of efficiency, one can use this radioisotope as a plotter to measure ^{137}Cs.



^{134}Cs has a radioactive half-life of 2.06 years and it has two mechanisms by which it can disintegrate.

One mode is by β- emission which is the most likely occurrence option being responsible for 99.9997% of the disintegrations. Only 0.0003% of the disintegrations occur by electronic capture and positron emission (β +).

In the event of a nuclear accident, such as the leakage or explosion of a reactor as happened in 1986 in Chornobyl, Ukraine, some radioisotopes produced in the ^{235}U nuclear fission reaction are released into the atmosphere, such as ^{131}I, ^{137}Cs, ^{134}Cs, and ^{90}Sr [1].

After this accident, Brazil worried about the importation of foods that could have the presence of radioisotopes ^{137}Cs, ^{134}Cs, and ^{90}Sr.

These radioisotopes are absorbed by the plants that are consumed by the animals resulting in the possible contamination of imported beef and milk. [2]. The ^{134}Cs and ^{137}Cs ratio determination is important to failed fuel exposure estimation [3].

2 METHODOLOGIES

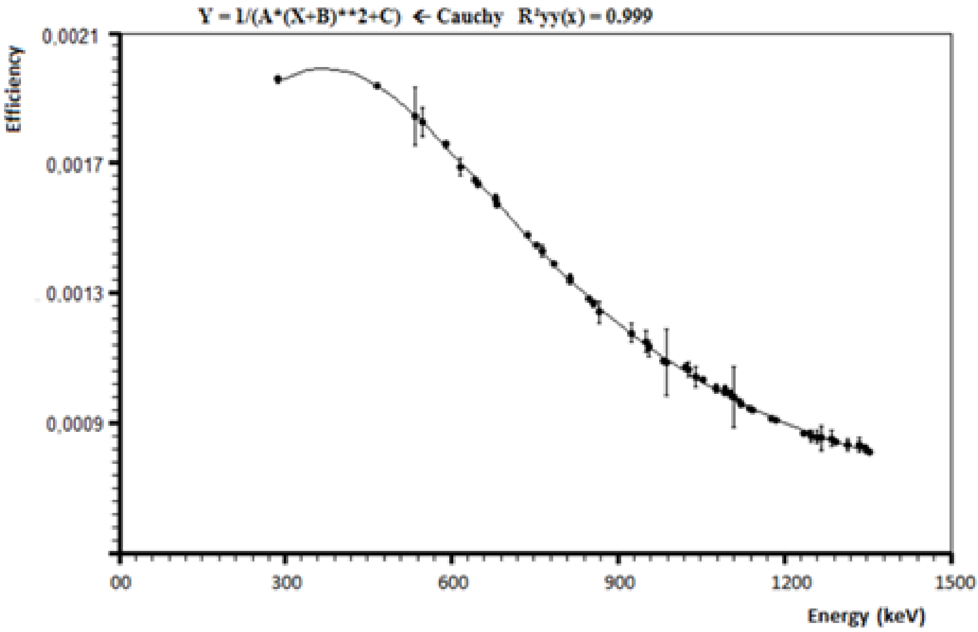
2.1 RELATIVE EFFICIENCY CURVE METHOD

The efficiency curve was obtained using various radionuclidic standardized sources such as ^{166m}Ho, ^{152}Eu, ^{137}Cs, ^{134}Cs, ^{241}Am, and ^{65}Zn totaling 59 energy points and the graphic can be observed in Figure 1.

The HPGe spectrometric system has been calibrated in efficiency through the use of standard point sources [4].

The range of energy was established between 48 keV and 1427 keV originally. Then a cut was made considering only the energies above 300 keV since the low-energy region was not necessary for the calibration. The efficiency curve fitting was performed by a 5th-degree polynomial.

Figure 1. Efficiency curve with ^{166m}Ho, ^{152}Eu, ^{133}Ba, ^{137}Cs, ^{241}Am, ^{54}Mn and ^{65}Zn radionuclidic standards



2.2 GAMMA-RAY EMISSION PROBABILITY MEASUREMENTS

To associate the main peaks of the spectrum to the radionuclide, the energy-channel relation of a spectrometer needs to be obtained. Afterward, the total absorption efficiency curve is determined, as a function of energy, and the radionuclide activity may be calculated from the region of interest. The expression that represents an activity area is:

$$CPS_{corrected}/P_{\gamma}\varepsilon_{\gamma} \quad (1)$$

Where: $CPS_{corrected}$ is the count rate of full energy peak; ε_{γ} is the full energy peak efficiency for specific gamma energy; and $P\gamma$ is the emission probability for specific gamma energy.

However, as the source activity is known, $P\gamma$ was calculated for ranges of 475 keV, 563 keV, 569 keV, 604 keV, 796 keV, 802 keV, 1039 keV, 1168 keV, and 1365 to ^{134}Cs using the following expression, taking into account the corrections as decay, background, and positioning:

$$P_{\gamma} = CPS_{corrected}/(\varepsilon_{\gamma}.A) \quad (2)$$

Where A is the absolute activity. The $P\gamma$ determination depends on the precision achieved in the efficiency curve.

2.3 SOURCE PREPARATION AND MEASUREMENTS

^{134}Cs point source was prepared by means of the pycnometer technique, depositing drops of radionuclide solution in a polystyrene film, with a thickness of 0.05 mm, set in one acrylic ring. The ring has an external diameter of 25 mm, an inner diameter of 4 mm, and a thickness of 1 mm. Once dried, the source was covered with the same polystyrene film.

The spectrometry system used consists of HPGe detector-type a planar with beryllium window with 20% of relative efficiency (d3gem). Some appropriate electronics are composed basically of the elements: A high voltage supply, a signal amplifier, and a multichannel analyzer. The multichannel analyzer associated with the data acquisition program is responsible for subtracting background beyond managing dead time.

The conditions of ^{134}Cs source measurements are HPGe detector position- d3 gemp4 (20cm); source activity: 2820.71 Bq at noon h of date 20170601.

3 RESULTS

Table 1. Counts per second to the different energies of ^{134}Cs

Energy (keV)	**Area**	**Uncertainty u_a (area)**	**$CPS_{corrected}$ (Bq/s)**
475	16538	322	0.0476
563	82224	421	0.2366
569	149331	499	0.4297
604	854624	965	2.4591
796	630766	811	1.8149
802	62050	268	0.1785
1039	5796	92	0.0166
1168	9681	105	0.0279
1365	14951	123	0.0430

Table 2. Results of gamma emission probabilities to ^{134}Cs energies

Energy (keV)	Gamma Efficiency	Pγ	Pγ (%)
475	0.001278	0.150948	1.5095
563	0.001135	0.084462	8.4462
569	0.001115	0.156248	15.6248
604	0.001034	0.964063	96.4063
796	0.000861	0.854779	85.4779
802	0.000857	0.084399	8.4399
1039	0.000673	0.100392	1.0039
1168	0.000618	0.018273	1.8273
1365	0.000579	0.030132	3.0132

Table 3. LNHB [5] data of the gamma emission probabilities (Pγ) to 134Cs energies

Energy (keV)	Pγ
475	1.479 (7)
563	8.342 (15)
569	15.368 (21)
604	97.63 (8)
796	85.47 (9)
802	8.694 (16)
1039	0.9909 (33)
1168	1.791 (5)
1365	3.019 (8)

The gamma spectrometry system was stable throughout the measurement. During ^{134}Cs spectrum acquisition some problems can occur when considering the peaks of 563 keV and 569 keV that overlap over the 605 keV peak when using a NaI (Tl) type detector but in this case the use of the HPGe detector stands out for such use because it has a much greater resolution power and facilitates the separation of these peaks with greater ease.

The results of gamma emission probabilities to ^{134}Cs energies are near with the LNHB results [5]. The mean deviation for the 9 energies studied was 1.41 %.

4 CONCLUSIONS

The efficiency curve method is widely used for radioisotopes whose half-life is not long as in the case of the 134Cs and the efficiency curve was well adjusted providing success in analysis. Satisfactory results were obtained for the ACTIVITY AND THE gamma emission PROBABILITIES.

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