IMPROVEMENT IN THE MEASUREMENTS OF ACTIVITY AND GAMMA EMISSION PROBABILITIES FOR ^{235}U and ^{238}U

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Abstract: The gamma-ray spectrometry was used to determine precisely the activity and gamma-ray emission probabilities related to ^{238}U and ^{235}U decays. The values obtained here are consistents when compared with those of literature. Thus radioactive sources containing these radionuclides can be routinely prepared by LNMRI and provided to users in glass ampoule containers.

Key words: Gamma-ray Spectrometry, Activity, Uranium, Gamma Emission Probabilities, Nuclear Data.

1. INTRODUCTION

The National Metrology of Ionizing Radiation Laboratory (LNMRI) has as one of its missions to provide standard sources certified for use in research or routine work of laboratories around the country. It is expected that a given pattern of the certified values are within the uncertainty levels of accuracy and appropriate, which is not observed when referring to some practices using materials containing uranium isotopes.

^{238}U is a natural element, its average concentration in the Earth's crust is estimated to be 4x10-4% (4 grams of uranium per tonne). It is known that in nature the ^{238}U is found accompanied by ^{235}U.

The detection of gamma radiation by scintillation or semiconductor detectors is based on the process of excitation or ionization of atoms in the detector from the electrons produced by any of the three processes of interaction of gamma radiation with matter (photoelectric interaction, Compton and / or pair formation). The use of electronic devices will turn the electrical signals generated in these detectors in a spectral distribution which is a function of the energies of photons detected. In gamma spectrometry, it is important only in the interactions that have as a consequence the total absorption of gamma radiation detector. This technique aims to identify and determine the nature and activity of radionuclides present in a sample.

2. PURPOSE

This work aims to determine the activity accurately and reduce the uncertainties associated to gamma emission probabilities (Pɔ) for ^{235}U and ^{238}U, improving the radionuclide standardization by LNMRI. The sources to be calibrated are from samples containing natural uranium. Uranium is an element found in nature as a mixture of three isotopes: 99.276 % of ^{238}U, 0.7196 % of ^{235}U and 0.006 % of ^{234}U.

3. METHODOLOGY

3.1 Calculation of gamma activity

The gamma spectrometry is a nondestructive analytical technique for identifying radionuclides through the energies emitted and can also determine its activity using a calibration curve in efficiency. The general formula for the calculation of activities is indicated in EQ.1, using the efficiency curve.

$$A_0 = \frac{S(E)}{(\varepsilon \times P_y(E) \times t)} \times F \qquad (1)$$

Where:
Ů(E) is the absorption efficiency for the total energy E;
S (E) is the peak area in number of pulses ;
A is the activity in Bq ;
Pɔ (E) is the gamma emission probabilities of the power line considered;
t is the duration of the count ;
F is a correction factor for decay, attenuation, etc.

The activity of ^{235}U was determined from the energy of 185.7 keV. The activity of ^{238}U was obtained, taking into account the secular equilibrium between ^{238}U and ^{234}Pa.

3.2 Calculation of gamma emission probabilities

The gamma emission probabilities for ^{238}U are of low intensity, so its determination is complex. Furthermore, this isotope has two lines, namely, 49.6 and 113.5 keV, which interfere with other closer. It was considered that the sample containing ^{238}U was in secular equilibrium, since the half-life of the parent nuclide is long when compared with those of their descendants. The same can be said for ^{235}U. This can be verified by EQ.2. [1].

$$\lambda_1 * N_1 = \lambda_2 * N_2 = \ldots = \lambda_k * N_k \qquad (2)$$

Where:
$\lambda_{(1,2,\ldots k)}$ are the decay constants of the parent and their descendants; and
$N_{(1,2\ldots k)}$ are the numbers of elemental atoms.

Pɔ's of the most significant energy for ^{235}U and ^{234}Pa (descendent of ^{238}U) were determined experimentally, and values for their uncertainties were lower than those found in the literature, as shown in Table 2.

Pɔ's for the most significant energies in the ^{235}U decay were referred to the line of 185.72 keV [2]. Equation 3 was used as the basis for the calculation.

$$P\gamma = \frac{A(E)}{(\varepsilon \times N_0 \times t)} \times F \qquad (3)$$

Where:
Ů(E) is the total absortion efficiency for energy E;
A(E) is the peak-area in numbers of pulses;
N_0 is the Activity in Bq;
$P_ɔ$ is the absolute emission intensity for the considered energy;
t is the time of counting ;
F is a correction factor for decay, attenuation, etc.

From equation 3, it was obtained the following equation, that is responsible by the calcul of P(ɔ) [3].

$$P_{\gamma 8} = \left(\frac{c_{(8)}}{c_{(5)}}\right) * \left(\frac{A_{(5)}}{A_{(8)}}\right) * \left(\frac{\varepsilon_{\gamma(5)}}{\varepsilon_{\gamma(8)}}\right) * P_{\gamma 5} \qquad (4)$$

Where:
c is the peak counting of each energy;
A is the peak-area in numbers of pulses;
Ů is the total absortion efficiency ;
$P_ɔ$ is the absolute emission intensity;

The nomenclature used for the parameters is as follows: subscript (5) to express the parameters related to the ^{235}U; subscript (8) to express the parameters related to the ^{238}U.

3.3 Uncertainties

The uncertainties presented in tables are expanded (k = 1) and estimated according to the ISO GUM [4].

4. RESULTS AND DISCUSSION

The values for activity and associated uncertainties below 2% can be seen in Table 1.

Table 1. Activities and uncertanties for ^{235}Uand ^{238}U

Nuclide	Activity (Bq)	Unc. (%)
^{235}U	1.5	1.5
^{238}U	32.8	1.7

In Table 2, the values of Pɔ's obtained here are compared with the published values by NNDC [5]. Thus, it can see that the uncertainties are compatible or even lower.

Table 2. Comparison of Pɔôs for ^{235}U with data published by NNDC [5]

Nuclide	Energy (keV)	$P_ɔ$ NNDC Table	Unc (%)	$P_ɔ$ This work	Unc. (%)
^{235}U	140.7	0.0022	9.091	0.0023	3.2
	143.7	0.1096	0.730	0.1057	0. 68
	163.3	0.0508	0.787	0.0513	0.71
	182.6	0.003	5.882	0.0037	2.3
	185.7	0.572	0.874	0.5726	0.68
	194.9	0.0063	1.587	0.0060	1.5
	202.3	0.0108	1.852	0.0102	1.1
	205.3	0.0501	0.998	0.0524	0.72

The Table 3 shows the results of P_γ obtained here and the data provided in the literature for ^{238}U and ^{234m}Pa.

Table 3. Pɔ's for ^{238}U and ^{234m}Pa determined by this method compared with the data published by NNDC and LARA [6]

E (keV)	$P_ɔ$ NNDC	Unc. (%)	$P_ɔ$ LARA	Unc. (%)	$P_ɔ$ This work	Unc. (%)
49.52 U238	0.00064	12.50	0.000697	3.76	-	-
113.01 U238	0.00010	14.71	0.000174	27.0	-	-
786.22 Pa234m	0.00210	14.29	0.0033	1.90	0.00331	1.68
1001.06 Pa234m	0.00590	13.56	0.00839	1.43	0.00844	1.56

5. CONCLUSION

The methodology presented here for calculating the activity of a sample under the conditions described, allowed us to obtain this parameter with simplicity and versatility.

The calculation of the probability of issuance under the conditions described for the natural ^{238}U, is compromised when use it all straight lines decay, requiring deconvolution program. with the results presented it is proved thus, the laboratory expanded the capacity to provide radioactive standards for different users, including now ^{235}U and ^{238}U with smaller uncertainties.

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