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CALIBRATION OF THE SHORT IRRADIATION FACILITY FOR k_0 – NAA IMPLEMENTATION AT THE IEA-R1 REACTOR

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ABSTRACT

The short irradiation facility of the IEA-R1 nuclear research reactor at IPEN, São Paulo, Brazil, has been used for short irradiation of samples for the purpose of determining the concentration of elements of these samples through the use of the instrumental neutron activation analysis technique. With the aim of implementing the k_0-NAA method at the Neutron Activation Analysis Laboratory (LAN), the reactor parameters α and f were obtained using the bare triple method. In this method, a set of three neutron flux monitors were irradiated without Cd-cover. The efficiency curve of the gamma-ray spectrometer used were determined by measuring calibrated radioactive sources at the usually utilized counting geometries. The results obtained for the parameters α and f were respectively 0.0384 ± 0.0016 and 35.67 ± 0.26. The obtained value of f shows that the neutrons in the irradiation position are well thermalized, in other words, the value of f, means that thermal neutron flux is 35 times higher than epithermal neutron flux. It means that this irradiation position is well thermalized. The variation of these parameters was studied with time and the reproducibility was verified.

1. INTRODUCTION

The neutron activation method k_0[1], developed by the Institute for Nuclear Sciences in Gent, Belgium, is a quasi-absolute neutron activation analysis technique which, because of its excellent accuracy and practicality, emerged as an alternative and complementary technique to the comparative method, which has been used successfully in numerous experiments carried out by the IPEN Neutron Activation Analysis Laboratory (LAN)[2-7].

In this k_0 method there is a need for the precise characterization of the irradiation facility and characterization of geometry conting. For the caracterization of irradiation system it is necessary to determine the ratio between the thermal and epithermal neutron fluxes (f) and the parameter (α) related to the distribution of epithermal neutron flux, approximately given by $1/E^{1+\alpha}$. These parameters are characteristic of the irradiation position

in the nuclear reactor[8]. For the characterization of geometry counting it is required a precise determination of detector efficiency curve.

The main objective of the present work was to determine the parameters α and f in the irradiation channel of the pneumatic station of the IEA-R1 reactor using the bare triple monitor method and the bi- monitors [9]. A precise characterization of this position of irradiation will enable the implementation and use of the k_0 method of neutron activation in the Activation Laboratory for short duration irradiation.

2. METHODOLOGY

The detector used for the acquisition of the gamma spectra was a semiconductor detector of the Germanium hyperpure type (HPGe), Canberra model GX3018, cylindrical geometry and relative efficiency of 30% for the energy of 1332.5 keV of the ^{60}Co, for this energy, the resolution was 1.8 keV. The associated electronics is the conventional one for simple spectroscopy. The detector is connected to a Canberra DSA-LX multichannel analyzer integrated into a microcomputer available from IPEN's neutron activation laboratory. Gamma ray spectra were collected and processed using the Genie 2000 software.

The efficiency curve for the spectrometer was determined at the reference position (approximately 100 mm - distance source-detector) using the following standard sources of ^{133}Ba,^{60}Co, ^{137}Cs, ^{152}Eu and ^{22}Na, with energies ranging from 121 keV to 1408 keV, applying equation 1.

$$\epsilon_p(E) = \frac{N_p}{I_\gamma A_0 t_m DC}. \tag{1}$$

where:

N_p is the area under the peak of total absorption for the considered energy range;

I_γ is the probability of the gamma emission by decay of the line considered;

A is the source activity;

t is the measurement time;

D is the decay factor - correction in the activity of the radioactive source for the aquisition date of the gamma spectrum. t_d is the decay time, as shown : $D = e^{\lambda t_d}$;

C is the factor of counting - correction for the decay during the measurement time t_m, as shown : $C = \frac{1-e^{-\lambda t_m}}{\lambda t_m}$;

The corrections for the cascade effect, in this position, were assumed in this work as negligible. The target materials used as monitors were ^{198}Au, ^{95}Zr and ^{97}Zr, the relevant

nuclear data of these monitors can be seen in Table 1.

Table 1: Monitors and relevant nuclear data[10]

Index	Reaction	E_r(eV)	Q_0	$T_{1/2}$	E(keV)	$k_{0,Au}$
1	$^{96}Zr(n,\gamma)\ ^{97m}Zr$	338	251.6	16.74 h	743.3	1.24×10^{-5}
2	$^{94}Zr(n,\gamma)\ ^{95}Zr$	6260	5.31	64.02 d	724.2 + 756.7	2.00×10^{-4}
3	$^{197}Au(n,\gamma)\ ^{198}Au$	5.65	15.7	2.695 d	411.8	1

E_r: Resonance energy.
Q_0: is the ratio of the resonance integral (I_0) to the thermal neutron cross section (σ_0), that is, $Q_0 = \frac{I_0}{\sigma_0}$, where $\sigma_0(n,\gamma)$ is the cross section for thermal neutrons.
$T_{1/2}$: nuclide half-life.
E: Gamma energy.
k_0: is the factor k_0 for the analyzed isotope, with reference to the gold comparator.

The monitors were placed in polyethylene bags, sealed and their masses were obtained using a Shimadzu model AEL-40Sm analytical balance. Then the monitors were placed in polyethylene "rabbits". The masses and geometries of the monitors are listed in Table 2.

Table 2: Mass of monitors (Au and Zr)

Monitor	Features	mass(mg)
Au	IRMM 530 RC wire ϕ = 1.0 mm Alloy Al-0.1% Au	8.00
Zr	Aldrich foil 0.25 mm 99.8%	45.53

The monitors were irradiated simultaneously in the pneumatic station of the IEA-R1 reactor for 1 minute under a thermal neutron flux of $(1.90 \pm 0.15)10^{13} ncm^{-2}s^{-1}$.

This procedure was performed twice, for two sets of different samples in order to obtain a better comparison and reproducibility of the results.

The alpha parameter value was determined by the bare triple monitor method, we also used the Monte Carlo method to calculate the uncertainty of the this parameter. The ratio (f) between the thermal and epithermal neutron fluxes was determined by the bi-monitors method using the isotopes ^{97}Zr,^{95}Zr.

3. RESULTS

The efficiency curve for the HPGe spectrometer was determined using the standard sources and the efficiency curve in function of energy of the detector is shown in Fig.1.

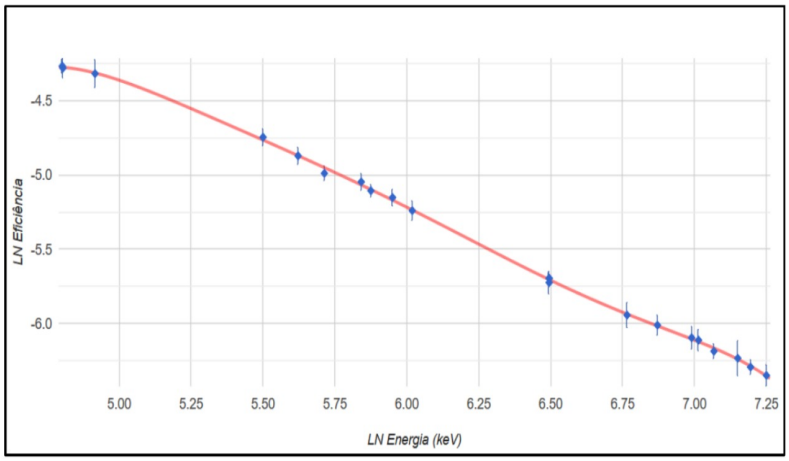

Figure 1: Efficiency curve obtained for the HPGe detector as a function of energy using 100mm as distance source-detector.

The efficiency curve was adjusted by the least squares method and the degree of the polynomial adjusted in log-log scale according to equation 2, was six and the value obtained for the reduced Chi-Square was 0.989, indicating an acceptable fit.

$$ln\epsilon_p(E) = \sum_{i=0}^{n} a_i (lnE)^i \tag{2}$$

The parameter α was obtained through the "Bare triple monitor" method using the wolframalpha software and the bisection method. The average value obtained was 0.0384± 0.0016, considering the correction factor for self-shielding and applying the Monte Carlo method to determine the uncertainty of alpha.

The parameter f was determined by the bi-monitors method. The value obtained was 35.67 ± 0.26, pointing out that this irradiation channel is well thermalized.

4. CONCLUSIONS

The values of α and f were determined over time and a reproducibility was observed in the results. The values obtained in this work are in agreement with those obtained by Semmler [11], but it is still necessary to verify the experimental parameters obtained in this work by determining the element concentrations using some standard reference material.

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