Development of a code for the isotopic analysis of Uranium

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1. Introduction

To strengthen the national nuclear nonproliferation regime by an establishment of nuclear forensic system, the techniques for nuclear material analysis and the categorization of important domestic nuclear materials are being developed. MGAU and FRAM are commercial software for the isotopic analysis of Uranium by using γ-spectroscopy, but the diversity of detection geometry and some effects – self attenuation, coincidence summing, etc. – suggest an analysis tool under continual improvement and modification. Hence, developing another code for HPGe γ- and x-ray spectrum analysis is started in this study.

2. Methods and Results

2.1 Material and equipment

Uranium isotopic certified reference material CRM U100 with ^{235}U enrichment 10 mass% is used in the study. It contains 1 g of highly purified U_3O_8 powder encased in a 1.5-dram glass bottle with internal dimensions Ø 20 mm. Front wall thickness of the container is 1mm and the source is inserted into 1 mm-thick PE carrier. The certified isotopic abundances of the reference sample are shown in Table 1.

ORTEC planar HPGe detector GLP-36360 (S=1000 mm^2, d=13 mm, FWHM=585 eV at 122 keV) is used in the study. Be window of the detector is 0.25 mm thick. CRM U100 is mounted in front of HPGe detector, and source-to-detector distance is 5 cm.

2.2 γ- and X-ray peak fitting

The 87- to 100-keV energy region of Uranium spectrum contains peaks from all of the isotopes of interest. The region has three peaks due to ^{238}U, a number of ^{235}U peaks and the two strong uranium Kα_1 x-ray peaks [1]. The more than 13 x-rays and γ-rays of this region form a very complex spectrum. A new fitting code written in MATLAB which can analyze

Table 1. Certified isotopic composition of CRM U100

	^{234}U	^{235}U	^{236}U	^{238}U
Atom percent	0.0676	10.190	0.0379	89.704
Weight percent	0.0666	10.075	0.0376	89.821

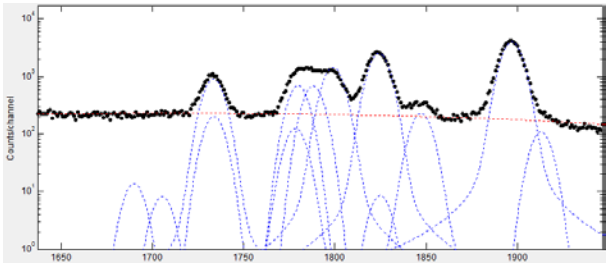

Fig. 1. The Uranium spectrum from 87-101 keV region.

overlapped γ- and x-ray peaks is developed in this study. γ-ray shape is mainly described by a Gaussian function; however, it does not accurately describe the much broader x-ray peak. The Lorentzian distribution of a uranium Kα_1 x-ray emitted has an FWHM of about 43.87 eV [2]. Fig. 1 shows the fitted γ-ray profile of the ^{238}U peaks and the much broader Voigt x-ray profile of the ^{235}U/Th daughter and the uranium x-rays. The user can fix the number of peaks in the spectrum and edit initial fitting parameters like peak center, height, width, etc. Fitting parameters are searched for the optimum value, and also can be fixed by the user.

2.3 The intrinsic efficiency function

The basic method for determining the relative abundance of uranium isotopes is to measure the intensity of several peaks from γ-rays of similar energy, but emitted from different isotopes [3]. The energy region is narrow enough to assume that three physical processes – γ-ray interactions with the detector, attenuations caused to the peaks by absorbers, sample self-attenuations – of all peaks in this region are same, and hence the relative detection efficiency as a function of energy can be shown as follows:

$$A_j = \sum_{k=1}^{3/4}\left(B_{jk} \times X_k\right) \times \text{eff} \quad (1)$$

where A_j is an area of peak j, $B_{j,k}$ is γ-ray branching probability of the peak j of the component k, X_k is disintegrations per unit time of the component k, eff is estimated detector efficiency obtained from a "standard" efficiency curve. The fitted curves based on component-response are shown in figure 1.

3. Conclusions and further works

The analysis of the 87-101 keV region of Uranium spectrum is attempted based on the isotopic responses similar to those developed in MGAU. The code for isotopic analysis of Uranium is started from a fitting

code for γ-ray and x-ray. In the future, coincidence effect and attenuations caused by absorbers and sample itself will be considered and the algorithm for the calculation of isotopic ratio will be developed.

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