Determination Of I131 And Lu177m Activity By Spectrum Deconvolution.

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Additional Key Words and Phrases: Spectrum deconvolution, datasets, spectroscopy, Lu177m, I131

1 INTRODUCTION

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2 MATHEMATICS

Mathematically, spectrum deconvolution can be described as follows. The count rate y in each channel i of the measured spectrum of a mixture of n radionuclides is given by the following equation:

$$y_i = \sum_n c_n S_{n,i} \tag{1}$$

where:

y_i = counts in channel i
n = radionuclide
c_n = unknown true count rate of nuclide n
$S_{n,i}$ = content of the corresponding channel i of the pure (reference) spectrum of nuclide n

$S_{n,i}$ is a normalized spectrum ($\int_{i=0}^{m} S_n = 1$). For a complete spectrum consisting of m channels, m equations result.

Spectrum deconvolution uses the shape of the measured spectrum to calculate its components by fitting the pure (reference) spectrum of each component to the measured composite spectrum (mixture). Mathematically, this can be done by least-square fitting. The true count rates c_n are calculated by minimizing the sum of squared differences between the measured (y_i) and predicted ($y_i^{'}$) for all channels of the spectrum using the following equation:

$$\sum_i^m (y_i - y_i^{'})^2 = \sum_i^m (y_i - \sum_n c_n S_{n,i})^2 \tag{2}$$

This is therefore an optimization problem.

The following equation is used to determine the activity in an energy window:

$$A_n = \frac{cts}{T} K_{n,j} \tag{3}$$

where:

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cts = total counts in window j
T = measuring time
$K_{n,j}$ = Calbibration factor of nuclide n in energy window j

3 METHOD

The Python programming language was used for the implementation.

In the following, the idea of the program will be briefly presented:

1. Load the necessary .csv-files (pure Lu-spectrum, pure Iodine-spectrum and the mixed-spectrum to be investigated)
2. Calculation of $S_{Lu,i}$ and $S_{I,i}$
3. Application of the Savitzky-Golay filter for smoothing all spectra
4. Creation of the obj. function (see Eq. 2)
5. Minimization of the obj. function → returns c_{Lu} and c_{Iod} (see Eq. 2)
6. Determination of the pure Lu and iodine spectra: $y_i = c_{Lu}S_{Lu,i}$ and $y_i = c_{Iod}S_{I,i}$
7. Calculation of the respective activity (A_{Lu} and A_{Iod}) by determining the total counts in the respective window (Eq. 3):
   a Lu-window
   b Iod-window
8. Determination of R^2 between y_i and $y_i^{'}$

The corresponding spectra are displayed graphically (see Figure 1). For the normalized Lu-spectrum ($S_{Lu,i}$ Figure 1a), a 300 s measurement of 10 kBq Lu served as the basis, analog, a 300 s measurement of 1 kBq I131 served as the basis for $S_{I,i}$ (Figure 1b).
The evaluation does not take into account that Lu177m decays to Lu177 with a shorter half-life (parent-daughter relationship, transient equilibrium). Furthermore, Lu177m was contaminated with Lu177.

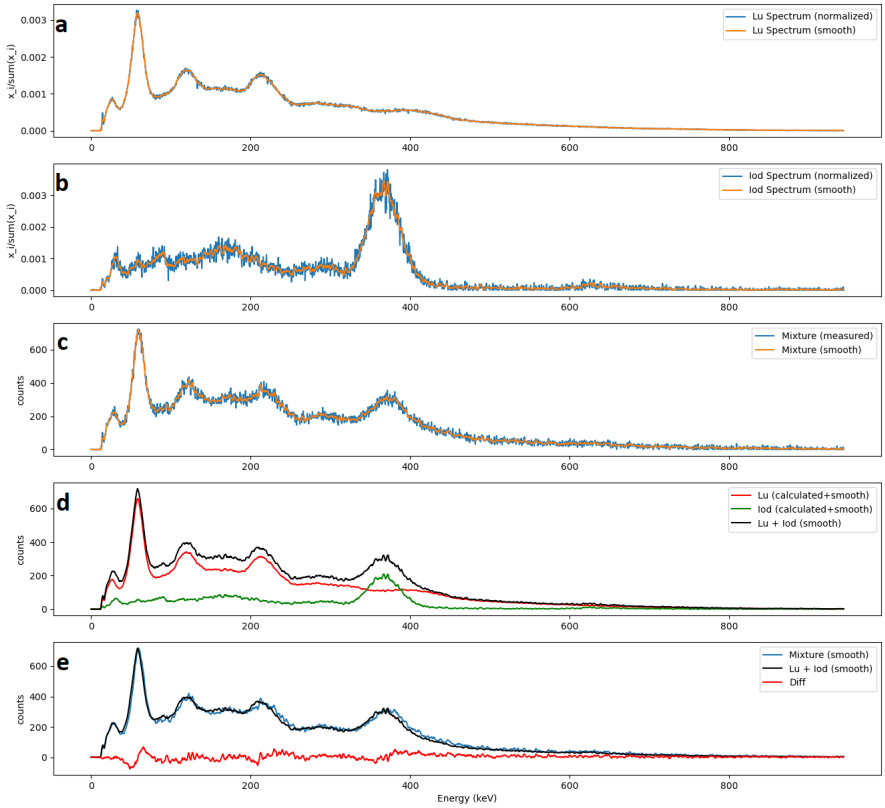

Fig. 1. Plot of the different spectra for a sample consisting of 100 Bq Lu177m and 100 Bq I131: (a) normalized reference spectrum for Lu177m ($S_{Lu,i}$); (b) normalized reference spectrum for I131 ($S_{I,i}$); (c) measured mixed spectrum; (d) calculated spectra according to Eq. 1; (e) $\sum_i^m (y_i - y_i')^2$, $R^2 = 0.986$.