Errors and uncertainties in Ge-detector based gamma spectrometry

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The IEEE specification of a Germanium-detector takes into account relative efficiency, resolution and peak/Compton-ratio but it should be more. In order to fully understand errors and uncertainties in such kind of measurements, there is a need to understand the fundamental basics of the instruments and the interaction processes. Based on this knowledge, it is possible to avoid errors and quantify uncertainties.

System for gamma spectrometry

A gamma spectrometry measurement device consists of a detector, electronics and personal computer with special software for operation and analysis. For an analysis, the system must be calibrated concerning energy and efficiency. For an energy calibration, lines from naturally occurring radionuclides can easily be used. The efficiency calibration can either be performed based on objects with same geometry, density and matrix or by Monte-Carlo-modelling

Uncertainties from the measurement

Any decay or nuclear reaction close to a detector can result in an interaction in the detector producing charges. These charges are collected and the deposited energy of this event is represented by the number of charges and will be stored as one count within a spectrum at that energy. As each detector has an individual volume, the charges that are produced closed to the primary interaction points need individual times to be collected. Thus one has to define a collection time for the electronics.

As a result the system has a dead time which depends on count rate and electronics setting.

Additionally there will be random summation of pulses (pile-up) and true coincidence summing from photons emitted in one decay and a very short life time of the intermediate state.

An easy way to correct for dead time is just to lengthen the counting time (real time) by the accumulated dead times resulting in a longer live time.

This correction fails for changing dead times during measurement. Here either a loss-free counting approach or a detailed analysis of time stamped list mode raw data is needed.

Besides the time relevant information, the two main sources of uncertainty can be found in the background both from environment and sample itself and in the full energy peak efficiency of the sample detector configuration.

Background reduction

For special samples, the reduction of background is the only possibility to reach the needed MDAs for quantification. Improvement by different steps can be seen in Figure 1.

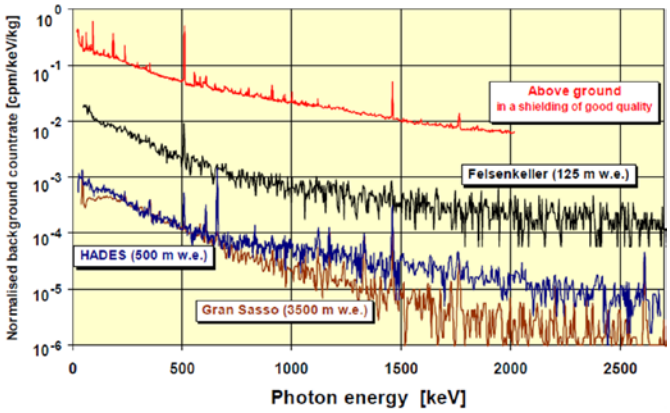

Figure 1: Improvement of background [1].

Efficiency calibration

Mathematical modelling of efficiency functions allows for detailed analysis of the influence of the overall uncertainty and therefore the need to improve results by keeping the most important parameters under control [2, 3]

[1] http://www.seibersdorf-laboratories.at/produkte-services/ionisierende-strahlung-radioaktivitaet/cellar/laboratories.html.

[2] Breismeister, J.F. (ed.) MCNP-A general Monte-Carlo N particle Transport Code Version 4B, Los Alamos National Laboratory Report LA-12625-M (March 1997).

[3] Bronson F. I. and Wang, I. Validation of the MCNP Monte Carlo Code for Germanium Detector Gamma Efficiency Calibrations, Presented at Waste Management 96, February 26, Tucson AZ.