On Neutron Activation Analysis with γγ Coincidence Spectrometry

Rolf Zeisler [a,], Iberê Souza Ribeiro Junior [a,b], Martin G. Shetty [a,c], Danyal Turkoglu [a]*

*[a] National Institute of Standards and Technology, 100 Bureau Dr. MS8395, Gaithersburg, MD 20899-8395, USA; [b] University of São Paulo, Instituto de Pesquisas Energéticas e Nucleares, São Paulo, Brazil; [c] Current address: European Spallation Source DMSC, Copenhagen, Denmark; * E-mail: rolf.zeisler@nist.gov*

Instrumental neutron activation analysis (INAA) may be limited in its specificity as well as sensitivity by interference to the characteristic gamma rays and/or high background from other trace elements or matrix elements. For elements with radionuclides that have characteristic coincident gamma transitions an improvement of selectivity and sensitivity is envisioned with the use of coincidence spectrometry.

To achieve high efficiency, an array of four, and alternately of two, high volume HPGe detectors was assembled. Several different biological sample matrices were subjected to conventional INAA and subsequently analyzed with the coincidence system for comparison.

Instrumentation

Figure 1 shows the detector array of 3 LN_2 cooled and one electrically cooled high volume (68 % to 86 % efficient) HPGe detectors surrounding a 1000 cm^3 cube "sample chamber" with a sample position in the center. The alternate two detector array brings the two vertically oriented detectors to a 1 cm distance with a sample position in the center. The detectors are currently operated without shielding since background coincidence events are unlikely.

The detectors are supplied with conventional analog bias and pre-amplifier power. The spectral data acquisition is accomplished with a "digital data finder" (DGF) Pixie-4 instrument which communicates via optical fiber with the host computer. Novel software "qpx-gamma" [1] for the multi-detector system has been developed [2] and is evaluated in this study for the INAA application.

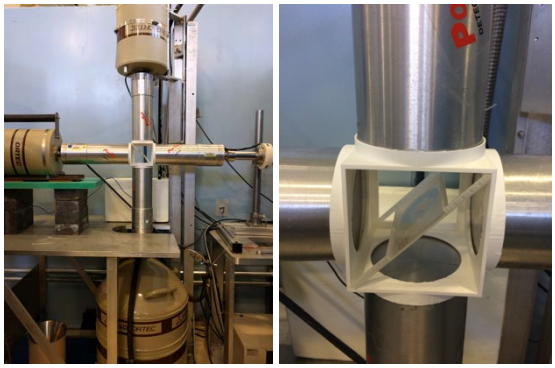

Figure 1: Four detector array and sample position.

Results and Discussion

The qpx-gamma software enables user selection of simultaneous display and output of single detector, multi-detector coincidence, as well as sum spectra. The critical gain matching of the detectors is supported by the software, however in the current experiments the gain was manually matched for all detectors. The gain stability was excellent over the duration of the experiments.

The applicability of γγ–coincidence spectrometry to activation analysis requires sufficient counting efficiency. Figures 2a and 2b show the detector efficiencies measured with a ^{152}Eu source for the single detectors versus the summation and the coincidence efficiencies. Due to the large germanium volume, only about a factor 10 is lost in the coincidence counting below 1 MeV with efficiency depending on the number and energies of cascade gammas.

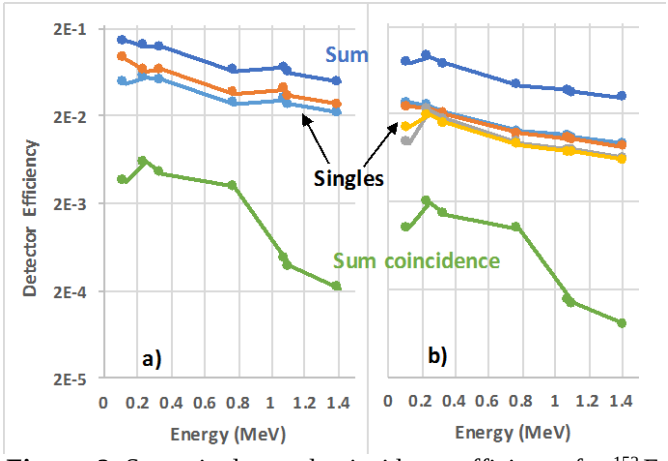

Figure 2: Sum, singles, and coincidence efficiency for ^{152}Eu source; a) two-detector array; b) four-detecor array.

Quantitative results are obtained for the coincident lines of Ag, Co, and Sc in several biological Standard Reference Materials (SRMs) and candidate reference materials with improvements of a factor 10 in the counting uncertainties. In particular, the determination of Ag in SRMs 1577b and 1577c agreed with the previously obtained results using coincidence counting in INAA [3]. An expected improvement for Se by reduction of the Bremsstrahlung background in the coincidence spectra was, however, not observed.

Overall, the experiments have demonstrated the capability of a high-efficiency counting array combined with advanced gamma spectrometry instrumentation and software to deliver quantitative results with improved signal-to-background ratios. Further exploitation through higher specificity, i.e., discrimination of coincidence events from single events, will be demonstrated in the future.

References

[1] https://github.com/usnistgov/qpx-gamma (December 2016).

[2] M. Shetty, D. Sahin (2016). *Data acquisition and analysis software for gamma coincidence spectrometry*. J Radioanal Nucl Chem 309: 243-247.

[3] B.E. Tomlin, R.M. Lindstrom, R. Zeisler (2008). *γγ coincidence spectrometer for instrumental neutron –activation analysis*. Nucl Instr Meth Phys Res A 589:243-249.