

Dynamic range of neutron activation analyses

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We consider neutron activation analysis (INAA) and prompt gamma activation analysis (PGAA) matrix-independent analytical techniques in the sense that the signal intensity depends only on the amount of the emitter nuclide, and not on the other components. However, the minimum detectable peak area (and thus the detection limit) depends on the baseline around a given characteristic peak, and that is affected by other components of the sample. The count rate from a given element also has a reasonable upper limit due to the throughput of the spectrometer. It turns out that the nuclides (chemical elements) can be detected only in a range of about 6 orders of magnitude when analysed from one single spectrum, as it happens in the case of PGAA. [1]

In NAA, on the other hand, we typically acquire several gamma-ray spectra. The spectra collected later allow for the detection of much lower activities which are still masked (i.e. are below the detection limit) in the first spectra, thus the dynamic range can be extended by two-three orders of magnitude on the low end.

There have been many definitions for the limits of detection and quantification used in nuclear spectrometry. The most famous one is by Lloyd Currie [2], whose expression's "distorted" versions can be found all over the literature: $DL = A + C \times \sqrt{B}$, where B is the background intensity, A and C are two constants sometimes given to four digits! It is important to mention that this expression can be adapted to multi-channel analyser spectra only with constraints. The evaluation of gamma spectra always starts with a peak search whose routines are based on digital filters (e.g. finding outliers from the running average), and the sensitivity is of course dependant on the algorithm. Thus the detection limit is always determined by the method built in the actual spectrum evaluation program. The DL values observed during spectrum evaluation can vary significantly from those according to Currie criterion, which is why it is recommended to use a DL value based on the peak-search filter in practical cases.

The detection limit can also be modified with changing the counting efficiency. The most obvious solution is to use different sample-to-detector distances. Results received using short counting distances may, however, need corrections e.g. for true coincidence summing, which can be the source of further uncertainties. Using a given distance, it might still be a problem that most of the spectrum counts are accumulated in the low-energy peaks, or in the Compton plateau from higher-energy peaks, while the peaks of interest may remain hidden. For this problem, the combination of low-energy germanium detectors (whose counting efficiency drops rapidly above 1 MeV) with regular HPGe detectors attenuated by 1–2 cm of lead in front (thus suppressing the low-energy peaks) may offer a solution.

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- [1] Zs. Révay, T. Belgya in: *Handbook of Prompt Gamma Activation Analysis in Neutron Beams* (Ed. G.L. Molnár), Springer, Dordrecht, **2004**, pp. 1–37.
- [2] L. Currie, *Anal. Chem.* **1968**, *40*, 586.