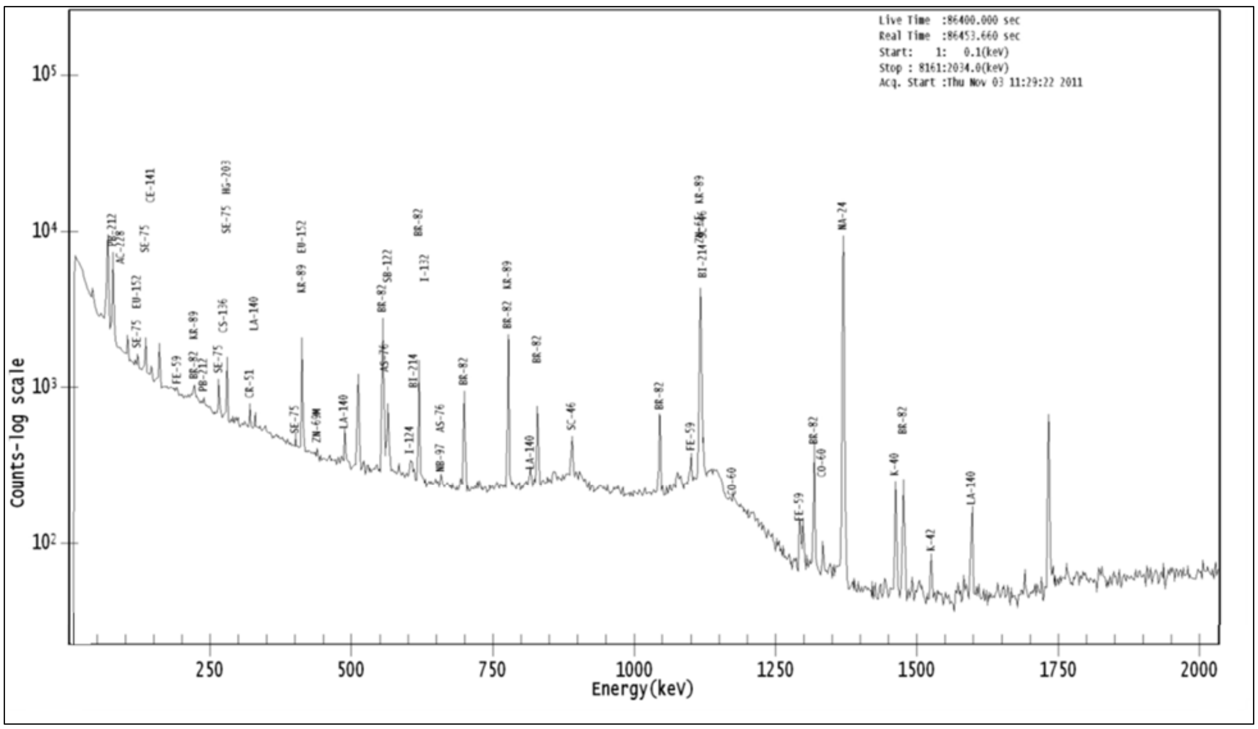
Details about NAA at NRL

The MIT-NRL has extensive capabilities for performing element analysis on a wide range of materials using Neutron Activation Analysis (NAA). These capabilities also enable the reactor's research staff to produce small amounts of radioactive tracers, and to detect, identify, and measure the radioactivity of natural or man-made materials.

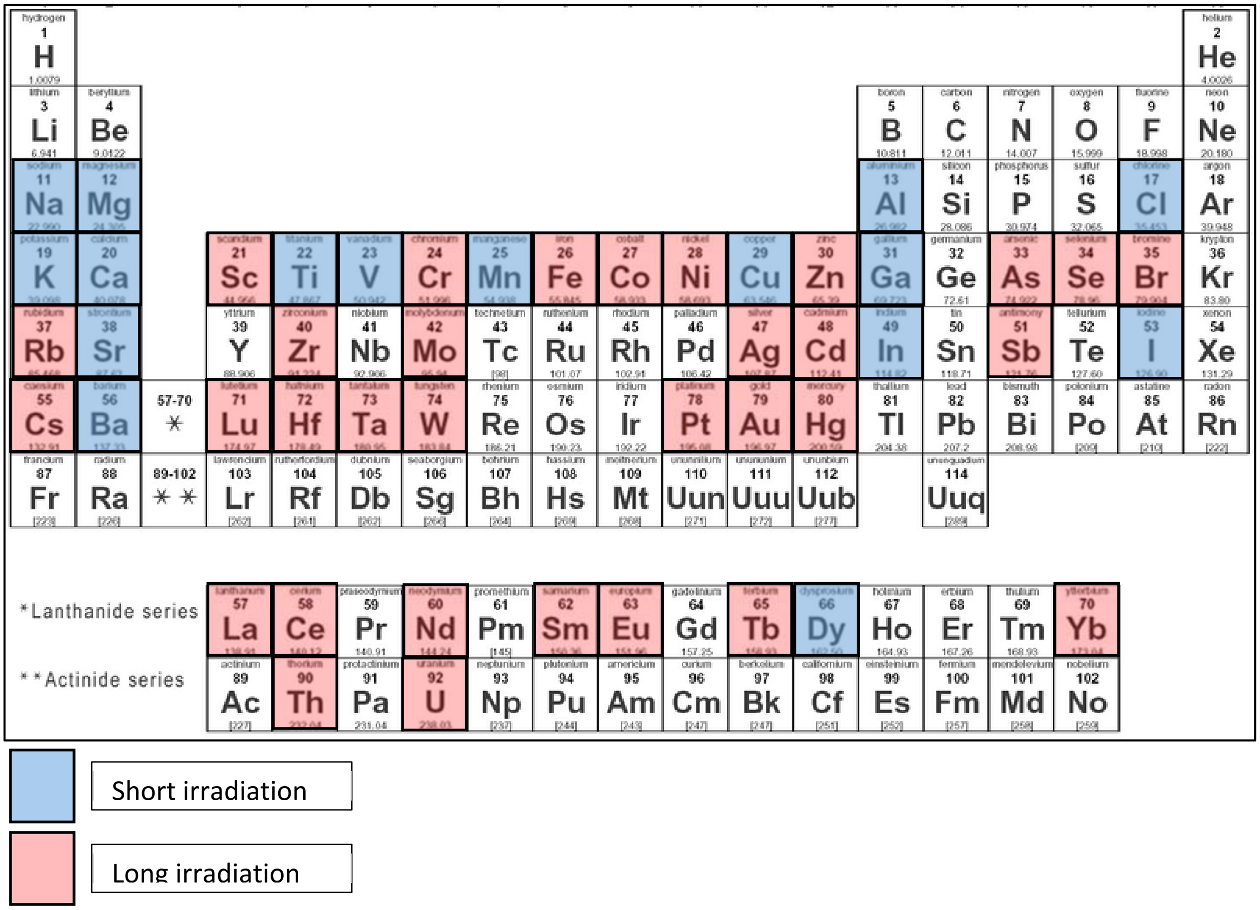
NAA Basics

Neutron Activation Analysis is based on two simple physical procedures. The first entails the neutron irradiation of the sample material which causes a small fraction of some stable isotopes to be transformed into radioactive isotopes. The second is the measurement of the gamma rays emitted during the radioactive decay of these newly created radioisotopes.



NAA gamma ray spectrum of biological sample for nutrition study.

A typical full analysis involves two irradiations of different durations and the collection of three or four gamma spectra of the activated materials so that elements with activation products with half-lives from a few minutes to a few years can be accurately measured. Up to 48 elements from sodium through uranium can be measured by standard NAA. Elements that have activation products with half-lives that are too short or too long, or that do not emit gamma rays as part of their decay, cannot be measured using NAA.



Elements that can be measured using NAA.

Elemental concentrations the unknown samples can be calculated either based on the parameters of the irradiation and counting and the physical properties of the elements of interest; or, more usually, by comparing the decay rates in the unknowns to decay rates in a set reference materials of known compositions.

Advantages of NAA

NAA has several distinct advantages over most other elemental analytical methods which makes it uniquely useful for a variety applications:

- Because the method detects or ‘counts’ gamma rays emitted by the decay of individual atoms, it is extremely sensitive.
- It can be applied to solids, liquids, suspensions, slurries, or even gases with little or no physical or chemical processing or the samples.
- It is largely non-destructive.
- It is an intrinsically multi-element analysis which is highly selective for many elements that are difficult to analyze for by other methods (*e.g.*, lanthanides).

Practical Aspects of NAA at the MIT-NRL

Neutron irradiations are performed in the reactor's reflector region which is accessed using either of two pneumatic systems or at a manual insertion location. For irradiations in the pneumatic systems, materials are placed in polyethylene sample holders or 'rabbits'. The rabbits have internal dimensions of either 1" diameter by 3-1/4" length (1-inch rabbits) or 1-3/8" diameter by 6-1/4" length (2-inch rabbits). For irradiations in the manually inserted locations, the total available sample space is 3" diameter by 24" length.

The pneumatic facility for 1-inch rabbits can be used to transfer samples between the irradiation location and a laboratory in the building adjacent to the reactor, which is near where the gamma spectroscopy is performed. This allows for elements which produce activation products with half-lives to be analyzed.

The pneumatic irradiation facilities have thermal neutron fluxes of up to $7.7\text{x}10^{12}$ n/cm^2 s and $5.6\text{x}10^{13}$ n/cm^2 s for the 1-inch and 2-inch rabbit irradiation locations respectively. The mechanically inserted irradiation facilities have a thermal neutron flux of up to $1.2\text{x}10^{13}$ n/cm^2 s. Lower fluxes can be achieved by running the reactor at lower overall power. The 1" pneumatic and 3" manual irradiation locations have highly thermalized neutron spectra (cadmium ratios of approximately 200). The 2" pneumatic irradiation location has a fast neutron flux of up to 3.5 $\text{x}10^{12}$ n/cm^2 s, which makes it possible to perform NAA based on fast reactions such as the ^{58}Ni (n,p) ^{58}Co.



Polyethylene 1-inch rabbit. Polyethylene 2-inch rabbit. Titanium 2-inch rabbit.

The laboratory in which irradiated samples are analyzed is currently equipped with three High Purity Germanium (HPGe) detectors. One of these s is a well-type detector which provides for very high efficiencies in the collection of the emitted gamma spectrum. Output from the detectors is processed using multichannel analyzers and gamma spectrum analysis software.

In addition to the standard NAA facilities, the reactor also has the ability to perform Prompt Gamma Neutron Activation Analysis (PGNAA). PGNAA is primarily used for the quantification of trace amounts of boron, but can also useful for the analysis of Cd, Sm, and Gd. The PGNAA facility is installed at a horizontal beam ports within the reactor containment building where the thermal neutron flux is approximately $2x10^7$ n/cm^2 s.

Previous NAA-related Reasearch Programs at the MIT-NRL

Studies which have either originated in, or been supported by the NAA lab include work on:

- Fine and coarse atmospheric particulate matter ($PM_{2.5}$ and PM_{10});
- Atmospheric mercury in vapor and size-segregated particulate phases;
- Biological uptake and partitioning of minerals;
- Deep, dated ice-core samples;
- Historic human hair samples for forensic toxic exposure assessment;
- Raw and processed coal samples, and size-segregated coal-combustion particulate emissions;
- Tree-ring samples for historical toxic contamination estimations.

For more information or to inquire about analyses, please contact:

Michael Ames, ScD
138 Albany Street
Cambridge, MA 02139
NW13-280
Tel: (617)258-5938
Email: mrames@mit.edu