Neutron Activation Analysis (NAA)

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Abstract

A description of the general principles of Neutron Activation Analysis (NAA) is followed by a discussion of advantages, limitations, and applications. Landmine detection and radioisotope power generation were identified as the two promising future applications.

Keywords: *Landmine detection, radioisotope power generation, multi-element analysis, prompt gamma radiation, delayed gamma radiation.*

Introduction

Neutron Activation Analysis (NAA), discovered in 1936, is an important technique for quantitative multi-element analysis of major, minor, trace, and rare elements. The initial step in neutron activation analysis is irradiating a sample with neutrons in a nuclear reactor or sometimes in other neutron sources (Siddappa *et al*., 1996). The stable nucleus absorbs one neutron and becomes a radioactive nucleus. The concentration of the stable element of interest in the sample can be measured by detecting the decay of these nuclei (Nuclear Science Division and Contemporary Physics Education Project 2000).

The radioactive nuclei emit characteristic gamma rays. Detection of the specific gamma rays (of specific energy) indicates presence of a particular element. Suitable semiconductor radiation detectors may be used for quantitative measurement. The concentrations of various component elements in given samples are found by computer data reduction of gamma ray spectra. Sequential instrumental neutron activation analysis allows quantitative measurement of up to about 35 elements in small samples of 5 to 100 mg. The lower detection limit is in parts per million or parts per billion, depending on the element (Radiation Center 2003).

An example of a nuclear reactor used for irradiating samples is the Oregon State University TRIGA Reactor (OSTR), which is a water-cooled, swimming pool type of research reactor that uses uranium/zirconium hydride fuel elements in a circular grid array (Radiation Center 2003). The reactor core is surrounded by a ring of graphite that serves to reflect neutrons back into the core. The core is situated near the bottom of a 22 feet deep, water-filled tank, and the tank is surrounded by a concrete monolith that acts as a radiation shield and structural support. The reactor is licensed by the U.S. Nuclear Regulatory Commission to operate at maximum steady state power of 1.1 MW, and can also be pulsed up to a peak power of 3,000 MW.

General Principles

In typical NAA, stable nuclides (^{A}Z, the target nucleus) sample undergo neutron capture reactions in a flux of (incident) neutrons (Missouri University homepage 2003). The radioactive nuclides (^{A+1}Z, the compound nucleus) produced in this activation process usually decay by emission of a beta particle (β^-) and gamma ray(s) with a unique half-life. A high-resolution gamma-ray spectrometer is used to detect these 'delayed' gamma rays in the presence of the artificially induced radioactivity in the sample for both qualitative and quantitative analysis.

The sequence of events that occur during the most common type of nuclear reaction used