ACTIVATION ANALYSIS OPPORTUNITIES USING A $5 \cdot 10^{12}$ TO $5 \cdot 10^{13}$ n/sec 14 MeV GENERATOR

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Capabilities of 14 MeV neutron activation analysis with a high output generator are evaluated and found to be comparable with conventional activation analysis regarding sensitivity and precision; additional elements are instrumentally accessible at trace levels. Nuclear reactions featuring higher selectivity are listed and their sensitivity is compared to the present state of 14 MeV activation. Quasi-prompt activation ($T < 1$ sec) expands the scope of the technique to rapid nondestructive assays of trace species in bulk samples.

Introduction

The interest of 14 MeV NAA with neutron fluxes above those currently available has been recognized for some time. Progress in this direction has been stifled by the lack of adequate high output neutron sources. Following numerous unsuccessful attempts in the past, new devices may soon be available producing steady state yields of $5 \cdot 10^{12}$ to $5 \cdot 10^{13}$ n/sec. Indeed a program has recently been initiated at Sandia Laboratories, Albuquerque, New Mexico, to develop the technology for such a neutron source. Although the primary application of this work is future radiotherapy devices, the technology is equally applicable to neutron activation sources. The combined interests of neutron cancer therapy and controlled fusion technology are pushing neutron source technology rapidly and high flux sources should be available in the next 2–4 years. This paper discusses opportunities for expanding 14 MeV activation analysis using such ultra-high output devices.

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Analytical applications

Improvement of sensitivity and precision

Clearly the well known sensitivities of 14 MeV NAA will in most cases be improved proportionately to the increase in neutron flux. Since trace determinations are possible for a considerable number of elements with presently available neutron fluxes, the gain in sensitivity for these cases will yield higher precision due to the improvement of the count rates and the peak-to-back-ground ratios. This is important for example in the trace determination of nitrogen. Moreover, the high-output neutron generator will make it possible to use Ge(Li) detectors; this will further enhance the selectivity of this activation mode.

In addition, novel capabilities can also be anticipated. A series of elements with too low specific activities under present activation conditions will be accessible at trace levels via nondestructive determinations; these include: B, S, As, Nb, Pd, Sn, Lu, Ta, Ir, Pt, Au, Hg, Pb.

Procedures featuring higher selectivity

In several cases the measurement sensitivity needed for trace analysis will be obtained with reactions of lower cross section but yielding reaction products of distinctive decay characteristics (half-life, γ-ray energy). For some elements high selectivity will be attainable through the use of short-lived nuclides. The following examples may be noted: determination of bromine via $^{79m}$Br ($T = 4.8$ s), of cadmium via $^{113}$Ag ($T = 1.2$ m), of erbium via $^{167m}$Er ($T = 2.3$ s) and of lead via $^{203m}$Pb ($T = 6.1$ s).

A common problem in 14 MeV neutron activation are the interfering reactions yielding the same nuclide from different target elements. Specific reactions are in many cases available but they have lower cross sections. The impact of a high output neutron generator in the cases outlined above is summarized in Table 1. A comprehensive compilation of suitable elements, their activation reactions and the possible interferences is presented in this table along with an estimate of the detection limits for those cases where an improvement over current capabilities can be anticipated. The data are derived from information given by NARGOWALLA et al. One may note that there are fewer interferences with low cross section reactions.

Quasi-prompt activation

A number of fast neutron reactions yielding nuclides with $T < 1$ sec appear feasible (Table 2). A significant feature of this approach is its applicability for rapid nondestructive assays of important trace species in bulk samples or in production line problems such as ore sorting. Detection limits are expected to range from 0.01 to 0.1 ppm.