OBSERVATIONS RELATIVE TO EPITHERMAL AND FAST NEUTRONS IN INAA

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Various theoretical and practical aspects of epithermal neutron activation analysis (ENAA) and fast-neutron-induced reaction interferences in conventional instrumental thermal neutron activation analysis (TNAA) have been considered. A new generalized advantage factor which reflects a practical improvement of detection limits in ENAA is proposed. In the determination of practical advantage factors, consideration is also given to the different irradiation channels available for the experiment in a given reactor, or even in several accessible reactors. Fast neutron reaction interference factors are tabulated for both ENAA and TNAA and examples are given of specific interferences in TNAA for some biological and geological matrices.

Introduction

Following irradiations by reactor spectrum neutrons, many common types of geological samples emit intense levels of $^{24}\text{Na}$, $^{28}\text{Al}$, $^{42}\text{K}$, $^{46}\text{Sc}$, $^{51}\text{Cr}$, $^{56}\text{Mn}$, $^{59}\text{Fe}$ and $^{146}\text{La}$ activities. Irradiations of biological matrices similarly produce high levels of $^{24}\text{Na}$, $^{32}\text{P}$, $^{38}\text{Cl}$, $^{43}\text{K}$ and $^{65}\text{Zn}$ activities that can be interferences to the determination of other trace elements of interest. All the radionuclides listed above are produced by $(n, \gamma)$ reactions which have a low $1/\sigma_{\text{th}}$ (resonance integral to thermal neutron cross section ratio). The relative yield of these activation products may be greatly reduced by employing the technique of epithermal neutron activation analysis (ENAA). Specifically, the analytical sensitivity for radionuclides with relatively high $1/\sigma_{\text{th}}$ ratios such as Ag, As, Au, Ba, Br, Cd, Cs, Ga, Gd, In, Mo, Pd, Pt, Rb, Sb, Se, Sm, Sr, Ta, Tb, Th, Tm, U and W may be often enhanced by use of ENAA in the analyses of geological, biological and various other types of matrices. The relative yield of these activation products may be greatly reduced by employing the technique of epithermal neutron activation analysis (ENAA). Specifically, the analytical sensitivity for radionuclides with relatively high $1/\sigma_{\text{th}}$ ratios such as Ag, As, Au, Ba, Br, Cd, Cs, Ga, Gd, In, Mo, Pd, Pt, Rb, Sb, Se, Sm, Sr, Ta, Tb, Th, Tm, U and W may be often enhanced by use of ENAA.

In this work we briefly review some of the theoretical and especially the practical considerations in the application of ENAA. A new generalized advantage factor is proposed and the optimization of irradiation channels is considered. In addition, interference multiplication caused by ENAA, and threshold reaction interferences in both ENAA and TNAA (thermal neutron activation analysis) are further evaluated.
Advantage factors in ENAA

BRUNE’s definition, \( F_a \)

One of the most widely used methods of calculating advantage factors was first proposed by BRUNE et al.\(^{16}\) in 1964. For a specific analytical determination the advantage of ENAA as compared to conventional reactor spectrum irradiations is estimated by an advantage factor, \( F_a \), defined by the expression:

\[
F_a = \frac{R_i}{R}
\]  

where, \( R \) and \( R_i \) are the Cd (or B) ratios for the radionuclide to be determined and the interference radionuclide, respectively. The \( R \) values are determined from the expression:

\[
R = \frac{N}{N_e}
\]

where \( N_e \) and \( N \) are specific counting rates produced by activation of a target nuclide, with and without Cd (or B) shielding.

BEM’s definition, \( F_a' \)

In 1981, BEM et al.\(^{17}\) pointed out that following ENAA, the activity of the radionuclide to be determined is also reduced by a factor of \( R \), so statistical counting errors may increase. This fact is not reflected in BRUNE’s\(^{16}\) advantage factor, \( F_a \). According to BEM et al., the advantage factor should be defined by the improvement in counting statistics for the radionuclide to be determined by ENAA relative to TNAA. BEM’s advantage factor, \( F_a' \), is defined by the expression:

\[
F_a' = \frac{\delta_e}{\delta_e}
\]

where, \( \delta \) and \( \delta_e \) are the relative errors in the counting statistics by TNAA and ENAA, respectively. The working equation was shown by BEM et al. to be:

\[
F_a' = \left\{ \frac{1}{N} + \frac{2N_p}{N^2} \right\}^{1/2} / \left\{ \frac{R}{N} + \frac{2R^2 N_{be}}{N^2} \right\}^{1/2}
\]