In the present paper, the principle of using some $\kappa$-matrix elements $\kappa_{ij}$, such as $^{175}\text{Yb} \ (i \ \text{or} \ j)$-$^{169}\text{Yb} \ (j \ \text{or} \ i)$, $^{153}\text{Gd} \ (i \ \text{or} \ j)$-$^{159}\text{Gd} \ (j \ \text{or} \ i)$, $^{103}\text{Ru} \ (i \ \text{or} \ j)$-$^{97}\text{Ru} \ (j \ \text{or} \ i)$ and $^{97}\text{Zr} \ (i \ \text{or} \ j)$-$^{95}\text{Zr} \ (j \ \text{or} \ i)$, as neutron energy spectra monitors or indicators is discussed in detail. Some experimental results showed the tendency of change of $\kappa_{kj}$ with $\kappa_{ij}$ of $^{169}\text{Yb} \ (i)$-$^{175}\text{Yb} \ (j)$ and the ratios of infinitely dilute resonance integrals $S_i$, $S_j$ and $S_k$ to the respective thermal neutron capture cross-sections, where $k$ represents nuclides other than $i$ and $j$.

**Introduction**

The neutron activation $R$-matrix elements $R_{ij}$ and $\kappa$-matrix elements $\kappa_{ij}$ may be the simplest and useful new form in expressing the correlations among various elements in neutron activation analysis. $R_{ij}$ is the ratio of the production rates of nuclides $i$ and $j$ by neutron capture reactions under same irradiation condition, $B_i^O/B_j^O$, where $B_i^O$ (or $B_j^O$) is the number of atoms of $i$ (or $j$) produced per gram parent element per second. $\kappa_{ij}$ is the ratio of the apparent neutron fluxes at the position of irradiation, $I_i/I_j$, where the apparent neutron flux $I_i$ (or $I_j$) is calculated from $B_i^O$ (or $B_j^O$) and the thermal neutron (or 2200 m s$^{-1}$ neutron) capture cross-section $\sigma_i$ (or $\sigma_j$) in producing $i$ (or $j$) /$I$.

By definition, if the neutron energy spectra do not change, $\kappa_{ij}$ and $R_{ij}$ will remain constant, i.e., they depend only on neutron energy spectra. In fact, some $\kappa_{ij}$ and $R_{ij}$ change appreciably as the neutron energy spectra vary, and therefore they may be used as neutron energy spectra monitors or indicators. The most suitable monitors are: $^{169}\text{Yb}/i$-$^{175}\text{Yb}/j$, $^{159}\text{Gd}/i$-$^{153}\text{Gd}/j$, $^{97}\text{Ru}/i$-$^{103}\text{Ru}/j$ and $^{97}\text{Zr}/i$-$^{95}\text{Zr}/j$. The reasons are: (1) the parent nuclides of each pair, such as $^{168}\text{Yb}/i$-$^{174}\text{Yb}/j$, belong to the same element, so that...
\( \kappa_{ij} \) and \( R_{ij} \) can be determined accurately; and (2) the ratios of infinitely dilute resonance integrals to the respective thermal neutron capture cross-sections, i.e., \( S_i/\sigma_i = Q_{oi} \) and \( S_j/\sigma_j = Q_{oj} \), are appreciably different. Apparently, all \( \kappa_{ij} \) and \( R_{ij} \) with property (2) may be used as neutron energy spectra monitors and thus will be offered for fine selection, but those which do not possess property (1) cannot be determined very accurately because of the errors introduced through weighings and radioactivity measurements. Obviously, if the neutron energy spectrum is pure thermal, all \( \kappa_{ij} \) should be equal to unity, and therefore, \( \alpha = \beta \left( \kappa_{ij} - 1 \right) \) may be used as a parameter expressing the deviation of neutron energy spectrum from pure thermal, where \( \beta \) is any constant. Besides, \( \kappa_{ij} \) can be used to examine the accuracy of nuclear data; this is a valuable application.

**Theory**

The \( \kappa_{ij} \) or \( \alpha \) are good parameters for expressing neutron energy spectra. In comparison with the form used in Refs \[2\] and \[3\], \( \kappa_{ij} \) are equivalent to \( (f+Q_{oi})/(f+Q_{oj}) \), where \( f = \phi_s/\phi_e \), \( \phi_s \) is the subcadmium neutron flux, and \( \phi_e \) is the epithermal or intermediate neutron flux per unit in\( E \) neutron energy interval. However, due to the variation of temperature at the irradiation positions (different from 20 °C), deviation from \( (1/E) \) shape of epithermal neutron energy distribution, the inaccuracy of \( Q_{oi} \) and \( Q_{oj} \) etc., the error of the obtained \( f \) value in each irradiation may be large. In fact, the \( f \) values obtained from Ru monitors and Zr monitors, are appreciably different \[3\].

Besides the \( Q_{ok} = S_k/\sigma_k \) of nuclides \( k \) (other than \( i \) and \( j \)) of various elements in the literature have shown large fluctuations. Therefore, \( f \) may not be the most satisfactory parameter for expressing neutron energy spectra.

But, if we use nuclide \( j \) (175Yb or 169Yb or 153Gd or 159Gd or 103Ru or 97Ru or 95Zr or 97Zr or ...) as standard and \( \kappa_{ij} \) of isotopes \( i \) and \( j \) as neutron energy spectra indicator, and make a transformation,

\[
(f+Q_{oi})/(f+Q_{oj}) = 1 + (Q_{oi} - Q_{oj})/(f+Q_{oj})
\]