Investigation of alpha-electron coincidences in data from liquid scintillation detection

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Introduction

SISAK[a] is a fast, chemical-separation system for liquid-liquid extraction. The system is described in another contribution to TAN'03 and in e.g. references [1, 2].

During recent years, work has been undertaken to deploy SISAK in studies of the chemical properties of the transactinide elements (Z ≥ 104) [1, 3-6]. The only suitable detection method found was liquid-scintillation (LS) detection [7], mainly because of the rather high flow rates (0.5-2.0 mL/s) encountered in the SISAK system. Other detection methods usually require either thin, dry samples or very thin liquid films. No suitable method was found to prepare such samples without an unacceptable time delay between separation and detection.

In December 2000 the first successful transactinide experiment [3] with SISAK was performed at the Lawrence Berkeley National Laboratory (LBNL) in Berkeley, USA. This experiment proved that it was possible to extract and detect the transactinide ^{257}Rf with SISAK. ^{257}Rf has a half-life of about 4 s , and the cross section is about 12 nb [8]. The activity is delivered to the chemistry apparatus with a gas-jet transport system. With the SISAK system the gas-jet activity is continuously dissolved in an aqueous phase, then mixed with an organic phase containing a suitable extraction agent, separated and added to a liquid scintillation cocktail for α detection. The whole operation is on-line and continuous and SISAK is probably the fastest system for transactinide studies in the *liquid* phase available today. The on-line LS detection system used for SISAK experiments was developed in Mainz by Wierczinski [7] and co-workers and has continuously been improved [1,3,9]. The search for improvements continue and as a part of this a study of conversion electrons in coincidence with α particles was initiated and is reported here.

The effect of conversion electrons on α-liquid scintillation spectra

If an α decay is populating an exited level in the daughter nucleus and this level deexcites by emission of a conversion electron, the resulting α spectrum can become seriously distorted. This is because the light emitted from the scintillator due to an electron is about 8-12 times as high as from an α particle (due to the differences in the LET (Linear Energy Transfer) between the respective particles and the medium they interact with) [10]. Thus, a 50 keV electron will cause emission of light pulses equivalent to about 0.5 MeV of α energy. The result is that α spectra obtained from sources with coincident or near coincident conversion electrons will have distorted α peaks.

In measurement of transactinides the production rate is rarely high enough to obtain α spectra with prominent α peaks. Instead one usually relies on observing correlated chains of α particles with the correct energy and time sequence. However, when LS detection is used, α - electron coincidences might change the observed α energy so much that it falls outside the energy window. This together with the fact that many transitions in the transactinides are highly converted, can lead to a serious loss of observed events. E.g. in the ^{257}Rf SISAK experiments the correlated daughter to ^{257}Rf is ^{253}No. The decay of ^{253}No feeds a level at 300 keV in ^{249}Fm. From systematics one expects a conversion coefficient of about 0.05,

which means that about 1 out of 20 ^{253}No α decays will be correlated with an electron of around 150 keV (the K electrons are bound by 150 keV for Fm atoms), see Fig. 1. Thus, about 5% of the α particles from ^{253}No will be observed with more than 1 MeV of extra energy, which is outside the energy window used.

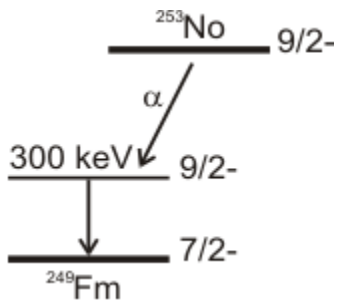

Figure 1. Simplified decay scheme of ^{253}No, showing the converted transition in ^{249}Fm (α_{Total}=0.05).

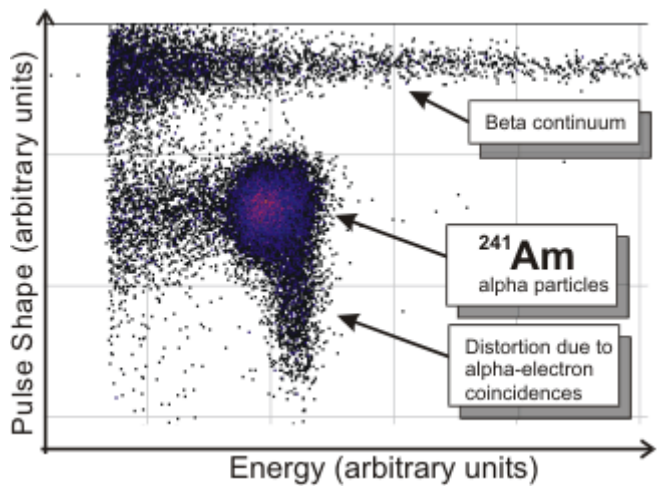

Figure 2. Measured pulse shape vs. energy plot of ^{241}Am α particles.
The half life for the intermediate level in ^{241}Np is 67 ns.

The aim of this work is to find a method to spot such α-electron coincidences and correct the observed energy to coincide with the energy observed for a pure α. Since the SISAK system already employs pulse-shape analysis to discriminate between α's and β's [10], it was natural to investigate if α-electron coincidences would change the pulse shape signal (basically a measurement of the length of the falling edge of the light pulses from the scintillator). As can be seen from Fig. 2, this seems to be the case: Energy vs. pulse shape is plotted in a contour plot for data obtained from ^{241}Am. The long tail of the α peak can be attributed to α-electron coincidences. The shape of the tail can be understood by taking into account the half life of the intermediate level. For ^{241}Am this half life is equal to 67 ns [11], as shown in Fig. 3. For another americium isotope with a similar type of decay, but with a shorter half life of only 1.4 ns [12] (Fig. 3) we can see that the pulse shape is much less effected, see Fig. 4.

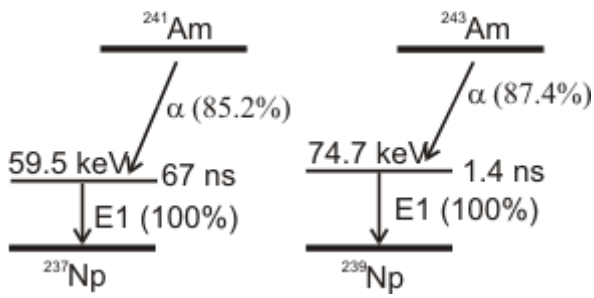

Figure 3. Simplified decay scheme of ^{241}Am and ^{243}Am.

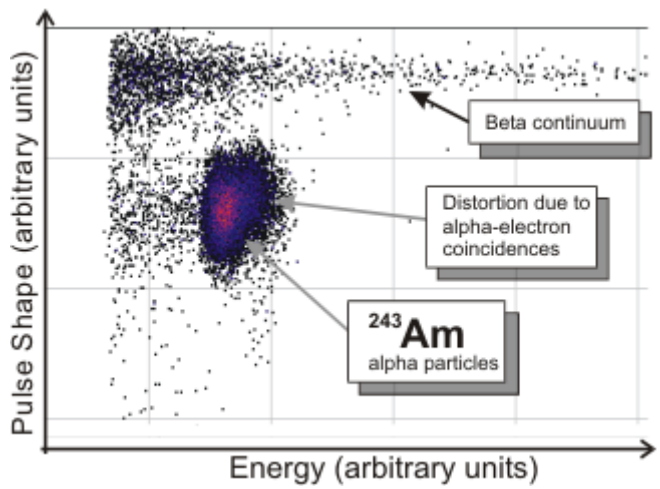

Figure 4. Measured pulse shape vs. energy plot of ^{243}Am α particles.
The half life for the intermediate level in ^{239}Np is 1.4 ns.

Digital Acquisition

From this data it can clearly be seen that the α-electron coincidences will change the LS data, both with respect to energy and pulse shape. It is also clear that the analog electronics used to obtain the data in Fig. 2 and 4 is not precise enough to distinguish between pure α events and α-electron coincidences. Therefore, experiments are under way in which a digital-acquisition system is used to sample each pulse from the scintillator and not only measure its width as the analog electronics do. With the pulses available a much more sophisticated analysis of the pulse shape can be performed, and hopefully this will enable both a better determination of the type of signal (β, α, or α-electron), but also correction for the additional energy added by the extra excitation of the scintillator causes by the electron.

Work with the digital acquisition system is under way and results will be presented at the TAN'03 conference.

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References and Notes

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