Study of ^{252}Cf fission fragments with MRTOF-MS: reexamination of existing mass data's accuracy

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The problem with the accuracy and precision of nuclear mass data originates from the high expenses to produce them at ion-beam facilities, and the second or third mass measurement of the same nuclide by different groups is typically difficult to accept as a primary goal of a new experiment. This results in extended periods before inconsistencies or inaccuracies of mass data are pinned down. However, for isotopes produced by spontaneous fission of the long-lived actinide isotopes, the costs for isotope production are meager compared to other production methods using the accelerators. This study reported a case that indicates the necessity for re-examining prior measurements by studying the ^{252}Cf fission fragments with the multi-reflection time-of-flight mass spectrograph (MRTOF-MS).

In the measurements of the fission fragments, we observed atomic and molecular adduct ions with the same/different charge states, for example, $^{14}N_2$-attached 2+ ions and $^{40}Ar_2$-attached 3+ ions, and stable molecular ions. Thus, many ions with different mass numbers can be included in the same time-of-flight spectrum. This facilitated the confirmation of a mass correlation between not only two ion species but also all mass correlations with all other observed species simultaneously.

Figure 1 shows the difference between the mass excess (ME) values of the literature and the present measurement: $\Delta\mathrm{ME} \equiv \mathrm{ME_{Lit}} - \mathrm{ME_{ThisWork}}$. The ME was determined by the single reference method with the mass references listed in Table 1. For $A/q = 75.5$ and 76.0 ion series, all values were in the ± 1.0 range, implying that the measurements were consistent with the literature values within 1σ. In contrast, the $A/q = 77.0$ ion series results spread, and a discrepancy of larger than 3σ was observed in the case of ^{154}Nd^{2+}-^{154}Ce^{2+}. The accuracy of mass determination by the MRTOF-MS is at the 3.5×10^{-8} level when an accurate isobaric reference is used.[1] This MRTOF-MS's high linearity of time-of-flight regarding ion mass suggests a problem with the error evaluation of at least one of the prior measurements. However, which one is correct is unclear, thus reexamining the uncertainty in the existing mass data is necessary.

The wide-range and simultaneous mass measurement with the MRTOF-MS facilitates checking the consistency of the existing mass data and indicates the necessity of reexamining them.

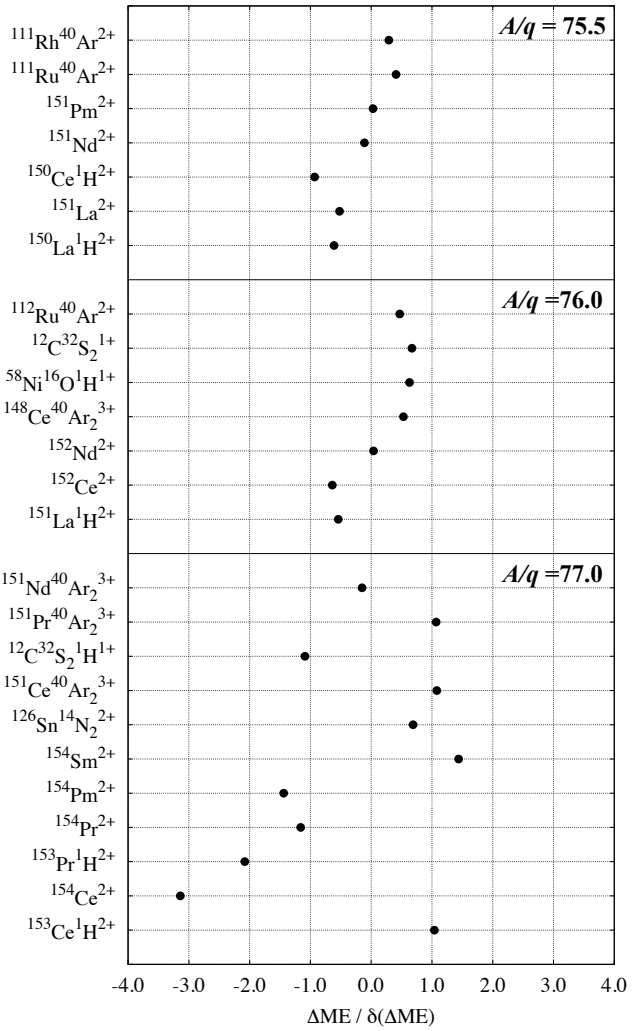

Fig. 1. Difference between the mass excesses of the literature and the present measurement. The values are normalized by their errors, $\delta(\Delta\mathrm{ME}) = \sqrt{\delta\mathrm{ME}^2_{\mathrm{Lit}} + \delta\mathrm{ME}^2_{\mathrm{ThisWork}}}$.

Table 1. Mass references.

Species	A/q	$\mathrm{ME_{Lit}}$ (keV)
^{151}Pr^{2+}	75.5	−66 780 ± 12
^{152}Pr^{2+}	76.0	−63 782.2 ± 9.8
^{154}Nd^{2+}	77.0	−65 579.6 ± 1.0

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Reference
1) S. Kimura *et al.*, Int. J. Mass Spectrom. **430**, 134 (2018).

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