Measurement of multiple isobar chains as a first step toward SHE identification via mass spectrometry†

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The SHE-mass project is a joint effort between KEK and RIKEN with a long-term goal of identifying new superheavy element (SHE) isotopes produced via hot fusion. It makes use of cryogenic-capable, high-purity helium gas cell to convert the energetic (5–50 MeV) evaporation products of fusion reactions into thermal ions. The evaporation products are separated from projectile-like fragments by use of the GARIS-II gas-filled recoil ion separator. The thermalized ions are transferred to a multi-reflection time-of-flight mass spectograph (MRTOF) which can analyze the ions with a mass resolving power of $R_m > 100000$. The SHE-mass system is described in some detail in Ref. 3.

We previously reported initial results of the SHE-mass project, where MRTOF mass measurements were performed on $^{205,206}$Fr, $^{205,206}$Rn, $^{205,206}$At, and $^{205}$Po produced via $^{169}$Tm($^{40}$Ar, X) reactions at a bombarding energy of 193 MeV. In the interim, numerous upgrades were made to the apparatus, increasing the system efficiency and improving stability of operation.

In July, 2016, the $^{169}$Tm($^{40}$Ar, X) reaction was revisited at a bombarding energy of 207 MeV. At this higher energy, it was possible to simultaneously observe $4n$ and $5n$ evaporation channels ($^{204,205}$Fr$^+$), $5p3n$ and $5p4n$ evaporation channels ($^{204,205}$Rn$^+$) as well as higher-order evaporation channels ($^{204,205}$At$^+$, $^{204,205}$Po$^+$, $^{205}$Bi$^+$). The very small $\beta$-decay branching ratios of $^{204,205}$Fr$^+$ (4(2)% and <1%, respectively) and the long half-lives of the lower-Z isotopes indicate that these are dominantly directly produced and not decay products.

Of particular interest for the long-term goals of the SHE-mass project, the very low-yield isotopes $^{205}$Bi, $^{204,205}$Po, and $^{206}$Rn could be identified with very few detected ions, as shown in Figs. 1 & 2. The 3-$\sigma$ deviation in the case of $^{205}$Po is attributed to the admixture of a high-lying isomeric state. Based on this we can confidently claim that this technique can be applied to low-yield SHE for confirmation of their identity.

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References