Precision mass measurements of proton-rich nuclei in \( A \sim 60-80 \) region with the multireflection time-of-flight mass spectrograph

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Nuclear masses of nuclei near the proton drip line up to \(^{100}\)Sn are crucial in determining the rp-process pathway which drives explosive astronomical phenomena called type I X-ray bursts (XRB). In order to compare different XRB models meaningfully, the relative mass uncertainties must be improved. Precisions of the order of \( \delta m/m \lesssim 10^{-7} \) are necessary for current rp-process calculations. Half lives of the key nuclei in the rp-process are of the order of several tens to several hundreds of milliseconds. The multireflection time-of-flight mass spectrograph (MRTOF) satisfies the experimental requirements for these conditions.

We performed mass measurements of the proton-rich nuclei in the \( A \sim 60-80 \) region by utilizing the MRTOF combined with a gas-filled recoil ion separator GARIS-II via a gas-cell and an ion transport system. To produce the proton-rich nuclei the fusion-evaporation reaction \( \text{n} + \text{Ar} \rightarrow \text{X} \) was used. In this reaction, it was expected that the inadequate separation in GARIS-II between the evaporation residues and the primary beam would lead to breakage of the gas cell and the GARIS-II bulkhead thin mylar windows due to irradiation damage. Therefore, we installed two independent beam stoppers. We also installed a double-layered plastic scintillator combined with copper energy degraders to suppress the low energy \( \beta \)-rays (\( E_\beta \lesssim 4 \) MeV) at the GARIS-II focal plane for the \( \beta \)-activity search. The energy and maximum intensity of the \(^{36}\text{Ar}^{10+}\) beam were \( 3.30 \) MeV/nucleon and 3 particle \( \mu \)A, respectively. The average target thickness of \(^{56}\text{Ni}\) on Ti backing was \( 1.9 \) mg/cm\(^2\).

Figure 1 shows the intensity distribution of \( \beta \)-activities as a function of magnetic rigidity. Mass measurements were performed with two different GARIS-II settings, \( B_\rho = 0.86 \) Tm and \( B_\rho = 1.01 \) Tm. The settings corresponded, respectively, to the sulfur reaction products and unexpected reaction products on the titanium backing. We found two dozen isotopes in the time-of-flight spectra of the MRTOF with clear peaks. The nuclear masses were determined by the single-reference method; thus, in each isobaric series, we utilized an isotope as a mass reference. The summary of the preliminary results is shown in Fig. 2.

We successfully measured nuclear masses with the required precision under the worse separation condition in GARIS-II. We must now proceed to the more proton-rich side to improve the understanding of the rp-process in XRBs.

References
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