Advanced development of GARIS-II using He-H_2 mixture as a filled gas toward the study of superheavy element

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Performance of a gas-filled recoil ion separator (GARIS-II) has been investigated using various asymmetric fusion reactions[1–5]. The studies have indicated that the separator has a large transmission under a low-background condition in comparison with GARIS and that the separation of unwanted particles is improved using He-H_2 mixture as a filled gas. The low-background condition is very important for identifying superheavy elements (SHE) produced with a low cross section of pb-order. Therefore, the usefulness of He-H_2 mixture as a filled gas toward the study of SHE was investigated further in this work. As a typical example, results for ^{214}Th, which was produced via the reaction of ^{197}Au(^{23}Na,6n), are given here.

The reaction products of ^{214}Th were separated in-flight from projectiles and other by-products using GARIS-II, and then they were guided into a double sided silicon detector after passing through a time-of-flight detector[1–3]. The separator was filled with He-H_2 mixture gases with various H_2 mixing ratios (0, 10, 20, and 36%). The gas pressure was maintained 47 Pa.

The yields of ^{214}Th, which was assigned from an α-transition of 7.678 MeV, were measured by varying the fraction of H_2 composition from 0 to 36% as shown in Fig. 1. Each yield is plotted against the magnetic rigidity $B\rho$. The optimum $B\rho$ value was determined by fitting to the data points using a Gaussian function. The optimum $B\rho$ value was shifted from 1.711 to 1.821 Tm by increasing the mixing ratio of H_2 from 0 to 36%, and the yields of ^{214}Th were enhanced 1.43 times.

The shift of the optimum $B\rho$ value implies that the equilibrium charge state $\bar{q}$ of recoil ions moving in a filled gas becomes small. The $\bar{q}$, which was deduced from the optimum $B\rho$ values, are plotted against the mixing ratio of H_2 in Fig. 2. The $\bar{q}$ was decreased with increasing H_2 composition. The $\bar{q}$ in pure H_2 can be estimated to be 3.58 using empirical systematics, which was obtained using a Dubna gas-filled recoil separator DGFRS[6]. Interpolated values of $\bar{q}$ between 4.28 and 3.58 in the case of pure He and H_2 are indicated as a broken line in Fig. 2. The interpolation well agrees with the obtained $\bar{q}$ values using various mixing ratios within an error bar. On the other hand, the transmission is improved with increasing the mixing ratio of H_2, although the width parameter $\Delta B\rho/B\rho$ becomes slightly worse from 8.4% to 9.4%. To establish a suitable condition to study SHE using the He-H_2 mixture, further investigation is in-progress.

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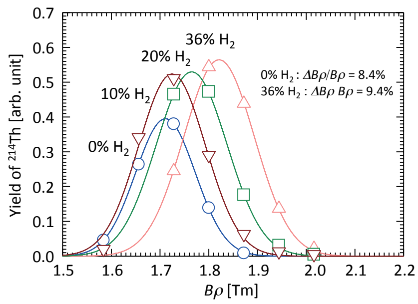

Fig. 1. Yield curve of ^{214}Th as a function of magnetic rigidity for various He-H_2 mixture gases (○:pure He, ▽:10% H_2, □:20% H_2, △:36% H_2). Each solid curve is a Gaussian function fitted to data points.

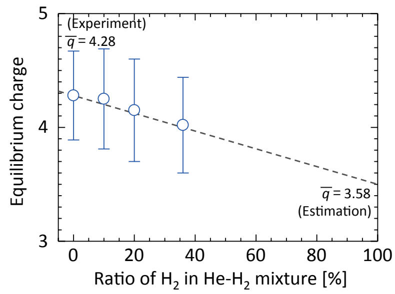

Fig. 2. Equilibrium charge state of ^{214}Th ions moving in a He-H_2 mixture. Interpolation between experimentally obtained $\bar{q}$ of 4.28 and estimated $\bar{q}$ of 3.58 from DGFRS's work[6] is indicated as a broken line.

References

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