# Study on background suppression of charged particles using GARIS-II filled with He-$H_2$ mixture

D. Kaji,[*1] K. Morimoto,[*1] S. Yamaki,[*1,*2] H. Haba,[*1] Y. Komori,[*1] S. Yano,[*1] R. Aono,[*1,*3] Y. Namba,[*1,*3] and S. Goto[*1,*3]

The performance of a gas-filled recoil ion separator (GARIS-II) has been evaluated using various asymmetric fusion reactions[1–3]. The feasibility of a high transmission under a low-background condition is a key issue for superheavy elements (SHEs) produced with a low cross section of pb-order. In previous work[1], it was found that GARIS-II filled with a He-$H_2$ mixture as a filled gas is promising to suppress background particles. To aid future study of SHEs, the usefulness of a He-$H_2$ mixture was investigated further in this work. As a typical example, the results for $^{218,217}$Pa, which were produced via the reaction of $^{197}$Au($^{24}$Mg,xn) [x=3,4], are given here.

The products of $^{218,217}$Pa were separated in-flight from projectiles and other by-products using the GARIS-II, and then they were guided into a double sided silicon detector after passing through a time-of-flight detector. The separator was filled with a He-$H_2$ mixture with various $H_2$ mixing ratios (0, 10, 20, and 30%). The gas pressure was maintained at 53 Pa. Recently, a new gas-mixing system, shown in Fig. 1, was developed as the previous system used a commercial gas with fixed mixing ratio. This system enables the mixing ratio to be tuned under constant pressure. The system was well calibrated by a gas analyzer.

The reaction products of $^{218,217}$Pa, which were assigned to $\alpha$-transitions of 9.616 and 8.337 MeV with half-lives of 113 $\mu$s and 3.8 ms respectively as shown in Fig. 2, were measured by varying the fraction of $H_2$ composition from 0 to 30%. The reaction products of $^{217,218}$Pa including long-lived isotopes of $^{215,214}$Ac are clearly identifiable with an increasing mixing ratio. The values of the equilibrium charge state $\overline{q}$, which are deduced from the optimum magnetic rigidity $B\rho$ values, are plotted against the $H_2$ composition in Fig. 3. The $\overline{q}$ in pure $H_2$ is estimated to be 3.80 using empirical systematics, obtained using a Dubna gas-filled recoil separator DGFRS[4]. Interpolated values of $\overline{q}$ between 4.47 and 3.80 in the case of pure He and $H_2$ are indicated as a broken line in Fig. 3. It seems that the measured $\overline{q}$ values agree well with the linear interpolation of the DGFRS.

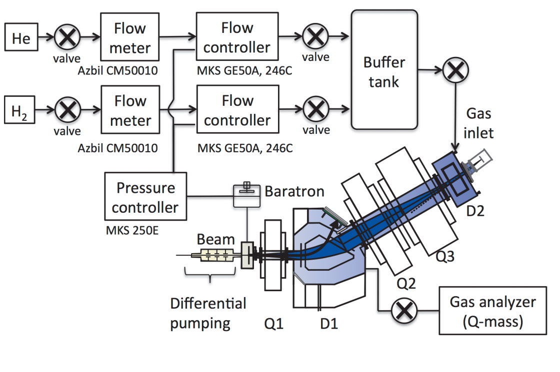


Fig. 1. New gas control system for GARIS-II filled with He-$H_2$ mixture.

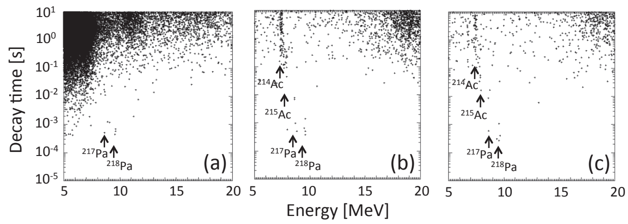


Fig. 2. Two-dimensional scatter plots, obtained by a time-position correlation analysis, of decay time against decay energy. Fractions of $H_2$ composition are (a) 0%, (b) 10%, and (c) 30%.

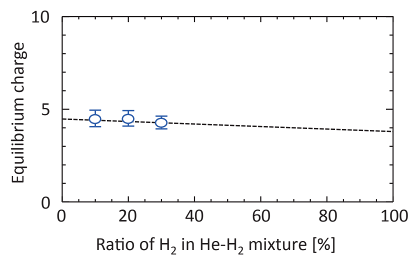


Fig. 3. Equilibrium charge state of $^{217}$Pa ions moving in a He-$H_2$ mixture. The broken line is the linear interpolation between the experimentally obtained $\overline{q}$ of 4.47 and the estimated $\overline{q}$ of 3.80 from the DGFRS's work[4].

References

1) D. Kaji et al., RIKEN Accel. Prog. Rep 48, 214 (2015).
2) D. Kaji et al., RIKEN Accel. Prog. Rep 47, 213 (2014).
3) D. Kaji et al., RIKEN Accel. Prog. Rep 46, 189 (2013).
4) Y.T. Ogganessian et al., Phys. Rev. C64, 064309 (2001).

*1 RIKEN Nishina Center
*2 Department of Physics, Saitama University
*3 Graduate school of Science and Technology, Niigata University