Production of ^{174}Re in the ^{nat}Gd(^{23}Na,*xn*) reactions for future studies on Bh chemistry using GARIS

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We have been developing a gas-jet transport system coupled to GARIS as a novel technique for superheavy element (SHE) chemistry.[1)] So far, isotopes of ^{261}Rf (atomic number $Z = 104$), ^{262}Db ($Z = 105$), and ^{265}Sg ($Z = 106$) have been produced in the ^{248}Cm(^{18}O,5*n*), ^{248}Cm(^{19}F,5*n*), and ^{248}Cm(^{22}Ne,5*n*) reactions, respectively, and the production and decay properties of these isotopes have been investigated for chemical studies.[1–3)] Recently, the chemical synthesis and gas-chromatographic analysis of $Sg(CO)_6$ were successfully conducted with ^{265}Sg.[4)] We plan to obtain a heavier element, Bh ($Z = 107$), by investigating production conditions of ^{266,267}Bh in the ^{248}Cm(^{23}Na,*xn*) reactions. In this work, as the first step, we optimized setting parameters of the GARIS gas-jet system using ^{174}Re produced in the ^{nat}Gd(^{23}Na,*xn*) reactions. Since Re is a homologous element of Bh in the periodic table, the Re isotopes would be useful in fundamental experiments on Bh chemistry in the future.

The $^{nat}Gd_2O_3$ target with a thickness of 340 μg cm^{-2} was prepared by electrodeposition onto a 2-μm Ti foil. The $^{23}Na^{7+}$ ion beam was extracted from RILAC. The beam energy was 130.6 MeV at the middle of the target, and the typical beam intensity was 1.4 particle μA. The evaporation residues (ERs) were separated by GARIS. Several magnetic rigidities were investigated ($B\rho$ = 1.58–1.94 Tm) at a He pressure of 33 Pa. Then, the ERs were guided into a gas-jet chamber of 100-mm depth through a 0.7-μm Mylar window. The ERs were transported by a He/KCl gas-jet to a chemistry laboratory. The He flow rate was 5 L min^{-1}, and the chamber pressure was 78 kPa. The KCl aerosols were then collected on a glass filter for 60 s and subjected to γ-ray spectrometry with a Ge detector after a cooling time of 60 s. A 20-μm Al foil was placed at the entrance of the gas-jet chamber to evaluate the gas-jet transport efficiency.

Figure 1 shows a typical γ-ray spectrum observed in the ^{nat}Gd(^{23}Na,*xn*) reactions. In this work, the γ-rays of $^{172–177}$Re and ^{172,173}W were identified in the spectra. The decay curve of the 243.4-keV γ-ray of ^{174}Re is shown in the inset of Fig. 1. The half-life of ^{174}Re was determined to be $T_{1/2} = 2.40 \pm 0.04$ min, which agreed with that in the literature.[5)] Figure 2 shows the variation in the yield of ^{174}Re as a function of magnetic rigidity. The dashed curve represents the result of the least-squares fitting with the Gaussian curve with a maximum yield at $B\rho = 1.74 \pm 0.01$ Tm and a resolution of $\Delta B\rho/B\rho = 10.0 \pm 0.4\%$. This optimum $B\rho$ agrees well with that ($B\rho = 1.78 \pm 0.05$ Tm) deduced from our systematic trend for the low-energy recoil ions.[6)] The gas-jet transport efficiency was about 80%. The radioactivity of ^{174}Re available at the chemistry laboratory is 55 ± 2 kBq pμA^{-1} after the 60-s aerosol collection. This yield is high enough to allow development of chemistry apparatuses and investigation of chemical systems for the study of Bh chemistry in the future.

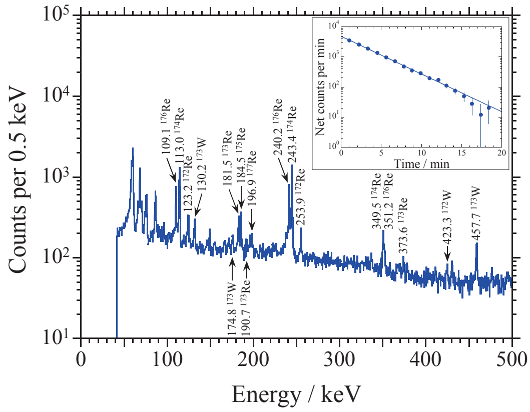

Fig. 1. Typical γ-ray spectrum observed in the ^{nat}Gd(^{23}Na,*xn*) reactions at $B\rho$ = 1.74 Tm.

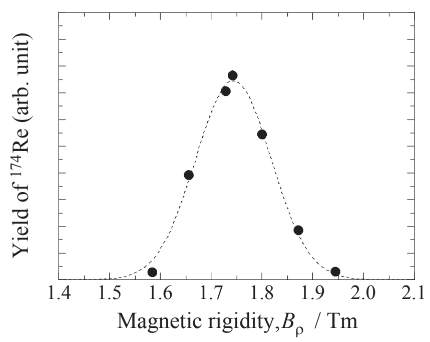

Fig. 2. The yield of ^{174}Re as a function of magnetic rigidity.

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