Development of rapid solvent extraction technique with flow injection analysis for superheavy element chemistry

T. Koyama,[*1] N. Goto,[*1] M. Murakami,[*1,*2] K. Ooe,[*1] H. Haba,[*2] S. Goto,[*1] and H. Kudo[*3]

For the chemical investigation of superheavy elements with atomic numbers ≥ 104, rapid chemical separation is needed because they have relatively short half-lives. We developed a solvent extraction system applying flow injection analysis (FIA). This FIA system consists of solvent extraction and phase separation parts (Fig. 1). In the solvent extraction part, aqueous and organic phases are mixed in a tube with a very small inner diameter of 100–200 μm. Because of the large specific interfacial area and short diffusion length in the tube, extraction equilibrium is rapidly attained. In the phase separation part, on-line liquid-liquid phase separation is achieved with a hydrophobic poly(tetrafluoroethylene) (PTFE) membrane. In this work, solvent extraction of ^{95g}Nb ($T_{1/2}$ = 35 d) using this system was investigated as a model experiment for element 105, Db.

The ^{95g}Nb tracer was produced through the bombardment of a ^{nat}Zr metal target foil with a 14-MeV proton beam supplied by the RIKEN AVF cyclotron. The carrier-free ^{95g}Nb tracer was prepared by the chemical separation from the target using an anion-exchange technique.[1)]

In the solvent extraction experiment using the FIA system, 5 M HCl solution containing ^{95g}Nb tracer and 0.1 M Aliquat 336 in 1,2-dichloroethane solution were used as aqueous and organic solutions, respectively. The aqueous and organic solutions were pumped using double-plunger pumps and mixed in a T-connector. The mixture was fed into the extraction coil of the PTFE tube of inner diameter 0.17 mm, and on-line liquid-liquid phase separation was performed using the membrane phase separator of thickness 75 μm and a 0.8-μm pore size PTFE filter.

In order to evaluate the time needed for attaining extraction equilibrium, the flow rate and extraction coil length were varied. After extraction, both solutions eluting from the phase separator were collected in polypropylene tubes. Experiments without the phase separator were also performed. Batch extraction experiments of ^{95g}Nb using 0.6 mL of each phase were also performed for comparison with the results obtained using the FIA system. The two separated phases were then subjected to γ-ray spectrometry using a Ge detector in all experiments. The distribution ratio (D) was calculated as the radioactivity ratio of each phase by using the same flow rate (Eq.1).

$$D = A_{\mathrm{org}} / A_{\mathrm{aq}} \qquad (1)$$

The results of using the FIA system and the shaking time in the batch experiments are shown in Figs. 2 (a) and (b), respectively. In the experiment using the FIA system, the extraction equilibrium was attained within a contact time of approximately 2 s. On the other hand, a shaking time of 40 min was needed to attain extraction equilibrium in the batch experiment. This result shows that extraction equilibrium can be rapidly attained using the FIA system. On-line liquid-liquid phase separation was successfully performed using the membrane phase separator in the FIA system.

Thus, the developed FIA system is applicable for the solvent extraction experiments of superheavy elements with half-lives of several tens of seconds considering other time-consuming steps such as dissolution and sample preparation for α-particle measurement.

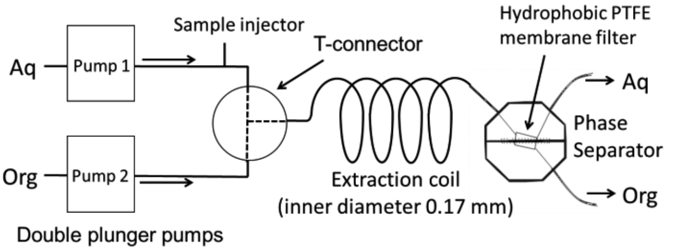

Fig. 1. Schematic view of the FIA system.

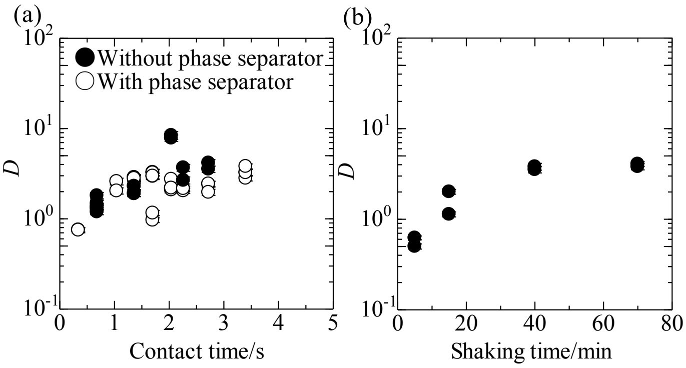

Fig. 2. The dependence of D value of ^{95g}Nb on the contact time in the FIA system (a) and the shaking time in the batch experiment (b).

References

1) Y. Kasamatsu et al : J. Nucl. Radiochem. Sci. **8**, 69 (2007).

[*1] Graduate School of Science and Technology, Niigata University

[*2] RIKEN Nishina Center

[*3] Department of Chemistry, Faculty of Science, Niigata University