

## On-line solvent extraction of Re with a rapid solvent extraction apparatus coupled to the GARIS gas-jet system

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To enable aqueous chemistry studies of Sg (atomic number  $Z = 106$ ) and Bh ( $Z = 107$ ), we have been developing a continuous rapid solvent extraction apparatus coupled to the GARIS gas-jet transport system.<sup>1)</sup> This apparatus consists of a continuous dissolution apparatus called the Membrane DeGasser (MDG)<sup>2)</sup>, a Flow Solvent Extractor (FSE), and liquid scintillation detectors for the  $\alpha$ /SF-spectrometry. The FSE consists of a Teflon capillary (i.d. = 0.5 mm) and a phase separator. In our previous study,<sup>1)</sup> we investigated the performances of the MDG and FSE using lighter homologs of Bh,  $^{92,94m}\text{Tc}$  ( $T_{1/2} = 4.25, 293$  min) and  $^{181}\text{Re}$  ( $T_{1/2} = 19.9$  h), produced in the  $^{nat}\text{Mo}(d,xn)$  and  $^{nat}\text{W}(d,xn)$  reactions, respectively, at the AVF cyclotron. In this work, we coupled the MDG and FSE to the GARIS gas-jet system and performed on-line solvent extraction of the  $^{174,176}\text{Re}$  ( $T_{1/2} = 2.4, 5.3$  min) produced in the  $^{nat}\text{Gd}(^{23}\text{Na},xn)$  reactions.

The  $^{nat}\text{Gd}_2\text{O}_3$  target with a thickness of  $349 \mu\text{g}/\text{cm}^2$  was prepared by electrodeposition onto a  $3\text{-}\mu\text{m}$  Ti foil. The  $^{23}\text{Na}^{7+}$  ion beam was extracted from RILAC. The beam energy was 124.3 MeV at the middle of the target, and the typical beam intensity was 1.6 particle  $\mu\text{A}$ . The nuclear reaction products after pre-separation with GARIS were guided into a gas-jet chamber (100-mm i.d.  $\times$  20-mm depth) through a  $2.5\text{-}\mu\text{m}$  Mylar window. The products were then transported to the MDG, which was placed in a chemistry laboratory through a Teflon capillary (2.0-mm i.d.  $\times$  10-m length) by He carrier gas at a flow rate of 1.5 L/min with KCl aerosols. In the MDG, they were continuously dissolved in 0.5 M  $\text{HNO}_3$  at 1 mL/min. The effluents from the MDG were mixed with 1 mL/min of tri-*n*-octylamine (TOA) in toluene in the Teflon capillary of the FSE. After the phase separation, both aqueous and organic phases from the FSE were subjected to  $\gamma$ -ray spectrometry with a Ge detector to determine the distribution ratios ( $D$ ) in the solvent extraction. We measured the  $D$  values of  $^{174,176}\text{Re}$  by varying the capillary length of the FSE from 30 cm to 100 cm to change the extraction time. We also varied the concentration of TOA from 0.005 M to 0.1 M to determine the applicable  $D$  range using the 40-cm capillary of the FSE. These  $D$  values were compared with those in equilibrium obtained in the off-line batch extractions with  $^{181}\text{Re}$ . The chemical yields (C.Y.) of  $^{174,176}\text{Re}$  were determined as  $\text{C.Y.} = ([A]_{\text{org.}} +$

$[A]_{\text{aq.}}) \times 100 / [A]_{\text{fil.}}$ , where  $[A]_{\text{org.}}$  and  $[A]_{\text{aq.}}$  indicate the radioactivities in the organic and aqueous phases, respectively, and  $[A]_{\text{fil.}}$  is the radioactivity in the aerosols collected on the glass fiber filter in the chemistry laboratory.

Figure 1 shows the variation of the  $D$  values of  $^{174,176}\text{Re}$  as a function of the capillary length. The dashed line indicates the  $D$  value of  $^{181}\text{Re}$  in equilibrium obtained in the batch extraction. We found that the extraction equilibrium of  $^{174,176}\text{Re}$  in 0.5 M  $\text{HNO}_3$  - 0.01 M TOA in toluene can be attained with a 0.5-mm i.d.  $\times$  30-cm capillary at 1 mL/min for both aqueous and organic solutions. However, for TOA concentrations  $\geq 0.05$  M, it was found that the 40-cm capillary was too short to reach the extraction equilibrium. When using the 100-cm capillary of the FSE, the  $D$  values of  $^{174,176}\text{Re}$  were consistent with those in equilibrium in the wide range of  $D = 0.3$ – $20$  in TOA concentrations of 0.005–0.1 M. The average chemical yields are  $71 \pm 15\%$  for  $^{174}\text{Re}$  and  $79 \pm 18\%$  for  $^{176}\text{Re}$ . Very recently, we performed solvent extraction with the short-lived  $^{170}\text{Re}$  ( $T_{1/2} = 9.2$  s) produced in the  $^{152}\text{Gd}(^{23}\text{Na},5n)$  reaction with the GARIS gas-jet + MDG and FSE system as a model experiment for  $^{266}\text{Bh}$  ( $T_{1/2} = 10.3$  s).<sup>3)</sup> The result of this experiment is under analysis.

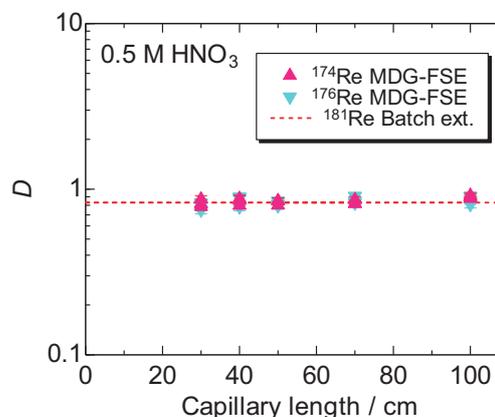


Fig. 1. Variation of the  $D$  values of  $^{174,176}\text{Re}$  as a function of capillary length. The concentrations of  $\text{HNO}_3$  and TOA are 0.5 M and 0.01 M, respectively. The dashed line indicates the  $D$  value of  $^{181}\text{Re}$  in equilibrium obtained in the batch extraction.

### References

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