

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.¹⁾ This apparatus consists of a continuous dissolution apparatus called the Membrane DeGasser (MDG)²⁾, a Flow Solvent Extractor (FSE), and liquid scintillation detectors for the α /SF-spectrometry. The FSE consists of a Teflon capillary (i.d. = 0.5 mm) and a phase separator. In our previous study,¹⁾ 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}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 μA . 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 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 γ -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}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}Re in equilibrium obtained in the batch extraction. We found that the extraction equilibrium of $^{174,176}\text{Re}$ in 0.5 M 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 ≥ 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 $D = 0.3\text{--}20$ in TOA concentrations of 0.005–0.1 M. The average chemical yields are $71 \pm 15\%$ for ^{174}Re and $79 \pm 18\%$ for ^{176}Re . Very recently, we performed solvent extraction with the short-lived ^{170}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}Bh ($T_{1/2} = 10.3$ s).³⁾ The result of this experiment is under analysis.

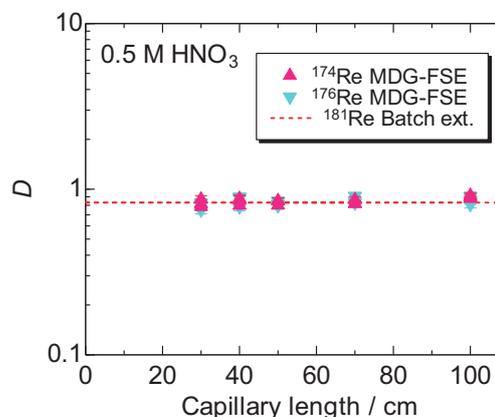


Fig. 1. Variation of the D values of $^{174,176}\text{Re}$ as a function of capillary length. The concentrations of HNO_3 and TOA are 0.5 M and 0.01 M, respectively. The dashed line indicates the D value of ^{181}Re in equilibrium obtained in the batch extraction.

References

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