An attempt to modify the membrane degasser (MDG)

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We have been developing a rapid solvent extraction apparatus coupled to the GARIS gas-jet system for aqueous chemistry studies of element 106, Sg, and element 107, Bh.[1,2] This apparatus consists of a continuous dissolution apparatus called a membrane degasser (MDG), a flow solvent extractor (FSE), and liquid scintillation detectors. In the MDG, nuclear reaction products transported by the gas-jet method are continuously mixed and dissolved with an aqueous solution. The gas is removed through a hydrophobic membrane, and the solution is injected to the FSE. In our previous studies, we fabricated the MDG and studied the dissolution efficiencies of ^{90m}Nb ($T_{1/2}$ = 18.8 s), ^{90g}Nb (14.6 h), and ^{178a}Ta (2.36 h) produced in the ^{nat}Zr$(d,x)^{90m,g}$Nb and ^{nat}Hf$(d,x)^{178a}$Ta reactions.[1] We found that the dissolution efficiency of the short-lived ^{90m}Nb isotope is as low as approximately 50%, though those for the long-lived ^{90g}Nb and ^{178a}Ta isotopes are greater than 80%. We considered that the reason for the difference in dissolution efficiencies between the short-lived and long-lived isotopes is as follows: (i) the gas-jet-transported products are not mixed well with the aqueous solution and (ii) the long-lived isotopes accumulate in the MDG. In this work, we fabricated a miniaturized MDG to reduce the accumulation of the reaction products in the MDG. A major modification is the reduction of the inner volume of the MDG from 23 μL to 1.8 μL. We measured the dissolution efficiencies of ^{90m}Nb, ^{90g}Nb, and ^{178a}Ta using the miniaturized MDG and compared the results with those obtained with the conventional MDG. We also studied the dissolution efficiencies of ^{144}Eu ($T_{1/2}$ = 10.2 s), ^{143}Sm (68 s), and ^{143}Eu (2.59 min) using the conventional MDG. The ^{144}Eu with a half-life of 10 s is favorable because its dissolution efficiency is less influenced by the accumulation in the MDG than that of the long-lived isotopes.

^{90m,g}Nb and ^{178a}Ta were produced in the same reactions as mentioned above. Two ^{nat}Zr foils with a thickness of 2.4 μm and four ^{nat}Hf foils with a thickness of 4.4 μm were irradiated with a 24 MeV deuteron beam supplied by the RIKEN AVF cyclotron. The beam currents were 4.6 and 1.5 μA. The reaction products were transported by the He/KCl gas-jet system to the miniaturized or conventional MDG in the chemistry laboratory. The flow rate of the He carrier gas was 1.5 L/min. Before entering the MDG, nuclear reaction products were continuously mixed with 1 M HCl at a flow rate of 1 mL/min inside a PTFE capillary of 0.75 mm inner diameter (*i.d.*) and 5 cm length. Effluents from the MDG were collected for 30 or 60 s with polypropylene tubes and were subjected to γ-ray spectrometry with a Ge detector. The dissolution efficiencies were determined by comparing the radioactivity in the effluents with that directly collected on a glass fiber filter. We also produced ^{144}Eu, ^{143}Sm, and ^{143}Eu through the ^{nat}Sm(d,x) reaction. Six $^{144}SmF_3$ targets deposited on Ti foils, each with a thickness of 495 μg/cm^2 were irradiated with a 24 MeV deuteron beam of 3.9 μA. The dissolution efficiencies of these nuclides were determined with the conventional MDG using almost the same procedures as for ^{90m,g}Nb and ^{78a}Ta.

Table 1. Summary of the dissolution efficiencies obtained with the miniaturized and conventional MDGs.

Nuclide (Half-life)	Dissolution efficiency [%]	
	Miniaturized MDG	Conventional MDG
^{90m}Nb (18.81 s)	35 ± 2	36 ± 5
^{178a}Ta (2.36 h)	53 ± 3	71 ± 7
^{90g}Nb (14.6 h)	60 ± 20	81 ± 10
^{144}Eu (10.2 s)	—	43 ± 5
^{143}Sm (68 s)	—	74 ± 8
^{143}Eu (2.59 min)	—	78 ± 12

The dissolution efficiencies of ^{90m,g}Nb and ^{178a}Ta obtained with the miniaturized and conventional MDGs are summarized in Table 1. Those of ^{144}Eu, ^{143}Sm, and ^{143}Eu with the conventional MDG are also listed in Table 1. The dissolution efficiency of the short-lived ^{90m}Nb obtained with the miniaturized MDG is the same as that obtained with the conventional MDG. The efficiencies of the long-lived ^{178a}Ta and ^{90g}Nb with the miniaturized MDG are almost 20% lower than those with the conventional MDG. This might be the result of a decrease in the accumulation of the long-lived isotopes due to the smaller inner volume in the miniaturized MDG. The lower dissolution efficiency of the short-lived nuclides such as ^{90m}Nb and ^{144}Eu might be due to the insufficient mixing of the gas-jet-transported products with the aqueous solution. At this moment, we expect that a dissolution efficiency of ∼40% is attainable for $^{265}Sg^{a,b}$ ($T_{1/2}$ = 8.5 s, 14.4 s)[3] and ^{266}Bh ($T_{1/2}$ = 10.7 s) using this MDG.[4] To increase the dissolution efficiency of these short-lived nuclides, more rapid and efficient mixing of the gas with the aqueous solution is necessary. We will improve the mixing unit of the MDG in the future.

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References
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