Ionic liquid extraction of astatine for a nuclear medical utilization

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Astatine-211 is a nuclide with potential applications in α-ray internal therapy. Solvent extraction with an organic solvent has been used as a conventional method for separating ^{211}At from the ^{209}Bi target irradiated with an α beam from an accelerator. Although organic solvents are inexpensive and readily available, they are volatile and flammable, and therefore, they raise concerns about environmental pollution and handling of dangerous substances.

In recent years, ionic liquids have attracted attention as an alternative to organic solvents from the viewpoint of green chemistry. Ionic liquids are in the liquid phase at room temperature, have low volatility, and are flame-retardant: therefore, there is little environmental load or risk of accidents. Further, the amount of radioactive waste can be reduced compared to that using organic solvents because they can be used repeatedly. In addition, ionic liquids are considered promising solvents for extracting ^{211}At given the reports on radiation resistance.[1] However, few studies on the extraction of ^{211}At with ionic liquids have been reported in the literature.[2] Therefore, in this study, we investigated the suitability of the HCl system, which has been reported to show excellent performance for ^{211}At solvent extraction,[2] depending on the type of ionic liquid.

The nuclide of ^{211}At was produced via the ^{209}Bi$(\alpha, 2n)$ reaction at the RIKEN AVF cyclotron and delivered to Kanazawa University. The irradiated Bi target was dissolved in 3 mL of 6 M HNO_3 and mixed with an appropriate amount of H_2O to prepare a 1 M HNO_3 solution, 7 mL of which was used to extract the ^{211}At nuclide into 7 mL of dodecane solvent. After extracting ^{211}At to dodecane from HNO_3 solution, it was further extracted to 0.1 M, 1 M, and 3 M HCl solutions. Then, ^{211}At was extracted into five kinds of ionic liquids: $[C_8\ \mathrm{mim}]^+$ $[PF_6]^-$, $[C_8\ \mathrm{mim}]^+$ $[BF_4]^-$, and $[C_{4,6,8}\ \mathrm{mim}]^+$ $[Tf_2N]^-$, where $[C_n\ \mathrm{mim}]^+$ and $[Tf_2N]^-$ stand for alkylimidazolium ion and bis(trifluoromethanesulfonyl)imide ion, respectively. Finally, it was back extracted into 0.1, 1, and 3 M NaOH solutions. The radioactivity of ^{211}At was measured with a liquid scintillation counter for the HCl solution samples before and after extraction and the NaOH solution samples after back extraction. The extraction rate of ^{211}At from the HCl solution to the ionic liquid and the back extraction rate from the ionic liquid to the NaOH solution were determined. Further, the At chemical species in the HCl solution were inferred by the TLC analysis of dodecane before and after extraction.

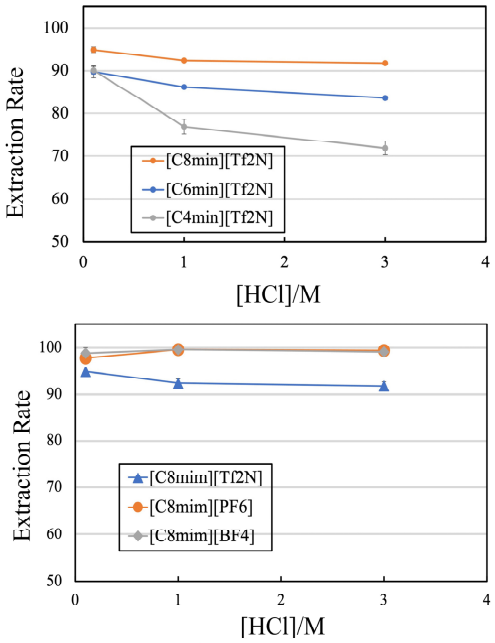

Fig. 1. At extraction rates of ionic liquids from HCl solutions.

Figure 1 shows the extraction rates of ^{211}At from the HCl solutions for five ionic liquids of ion pairs from three cations and three anions. When comparing cations, the larger the carbon chain, the higher is the extraction rate. When comparing anions, the larger the hydrophobicity, the smaller is the extraction rate. The hydrophobicity of cations and anions in the ionic liquid affects the ion exchange with At ions in the aqueous phase. In addition, the rates for $[C_8\ \mathrm{mim}]$ $[Tf_2N]$ have values exceeding 90% for both extraction and back extraction while $[C_8\ \mathrm{mim}]$ $[PF_6]$ and $[C_8\ \mathrm{mim}]$ $[BF_4]$ exhibit back extraction rates of less than 20%. Therefore, one of the ion liquids studied is considered promising for ^{211}At solvent extraction in practical applications.

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