Study on Separation Efficiency of Yb/Lu according to the Types of Ammonium Ion

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1. Introduction

Lutetium-177 (^{177}Lu, $t_{1/2}$ = 6.7 d) is increasing in demand as an important therapeutic radionuclide for targeted radiotherapy in nuclear medicine because of its high theranostic potential [1]. ^{177}Lu emits β^- particles ($E_{\beta,max}$ = 498 keV) with a soft tissue penetration range of less than 3 mm and γ-rays (E_γ = 208 keV (11.0%) and 113 keV (6.4%)) suitable for imaging with a detector [2].

^{177}Lu can be produced in high yield by the $^{176}Lu(n,\gamma)^{177}Lu$ reaction. However, this production method has a limitation in that carrier ^{176}Lu are mixed and by-products ^{177m}Lu with a long half-life ($t_{1/2}$ = 160 d) are produced. In this respect, no-carrier added (nca) ^{177}Lu has high specific activity and high radionuclide purity without long-lived radionuclide impurity, making them particularly useful for radioimmunotherpy. The nca ^{177}Lu can be produced by the $^{176}Yb(n,\gamma)^{177}Yb \rightarrow {}^{177}Lu$ reaction by irradiating neutrons to an enriched $^{176}Yb_2O_3$ target [3,4]. The critical process is the radiochemical separation of nca ^{177}Lu from macroscopic amount of Yb target with adjacent atomic number.

As the demand of lanthanide nuclides (including ^{177}Lu) increases, numerous researchers have devoted themselves to developing faster and more efficient separation techniques. In particular, the separation technology based on ion exchange to improve selectivity have been developed. In ion exchange technology, generally, α-HIBA (α-hydroxyisobutyric acid) and NH_4^+ (ammonium hydroxide) is used as a complexing agent and a separating ion, respectively. However, P.S. Balasubramanian [5] reported that ^{177}Lu was separated from neutron-irradiated ytterbium using a cation exchange resin (Dowex-50X8, 200-400 mesh) with α-HIBA and Zn^{2+} ion as a separating ion. The reason that Zn^{2+} ion showed better separation efficiency than general NH_4^+ ion was due to the large particle size of the resin (37-74 μm) used. There are few papers evaluating the separation efficiency using cations other than general NH_4^+ ion. Therefore, in this present work, the separation of nca ^{177}Lu from Yb target is investigated using primary, secondary and tertiary ammonium ions in addition to NH_4^+ ion.

This study is to evaluate the separation efficiency according to the types of ammonium ion through separation experiments using stable isotope Yb and Lu. Separation experiments were performed using α-HIBA adjusted to pH with ammonium hydroxide, methylamine, ethylamine, diethylamine, pyridine, ethanolamine and ethylenediamine, respectively. The separation of stable isotopes was detected on-line by a post-column reaction system using PAR (4-(2-pyridylazo) resorcinol). The on-line system makes it easier and faster to perform many experiments in a variety of conditions.

2. Experiments

2.1. LC instrument with an on-line post-column system

A schematic diagram of the LC instrument with an on-line column system is shown in Fig. 1. The LC instrument was composed of a high-pressure pump and a six-port Rheodyne valve equipped with sample loop of 500 μl. The LC column was prepared by packing the cation exchange resin BP-OA into Eco Plus glass column. The lanthanide sample was injected into the mobile phase α-HIBA. The eluted metal ions were mixed in a mixing-tee with the post-column reagent added using a peristatic pump. Then, the mixed solution was monitored using a UV-vis spectrophotometer (Agilent 8453) through the flow cell.

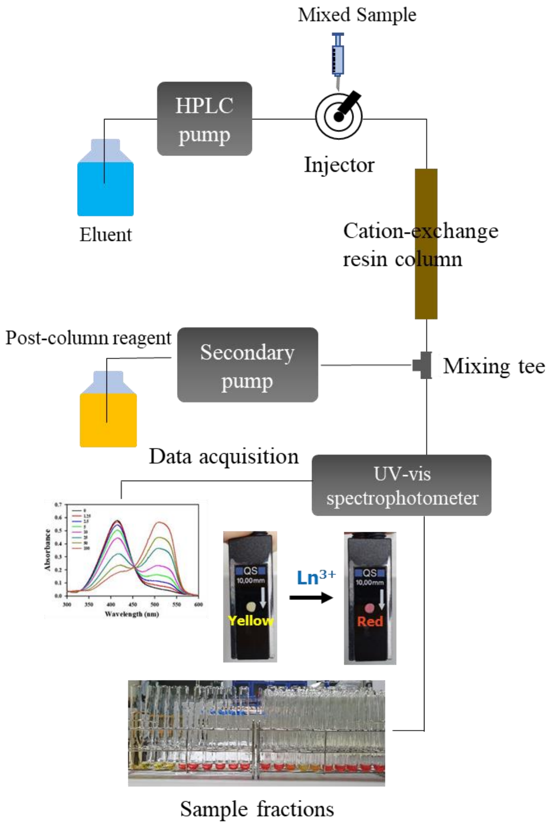

Fig. 1. Schematic diagram of the LC instrument with an on-line post-column system.

2.2. Separation of stable isotopes Yb and Lu

0.5 ml of sample, including 3 mg of Yb and 1 mg of Lu, was injected into the prepared column under isocratic condition in which the eluent α-HIBA is flowing at 1.5 ml/min. Herein, the pH of α-HIBA is adjusted by each ammonium hydroxide, methylamine, ethylamine, diethylamine, pyridine, ethanolamine and ethylenediamine. At the same time, post column reagent was eluted to the mixing-tees by a peristatic pump at the rate of 0.5 ml/min. Then, the mixed solution was measured using a UV-vis spectrophotometer at an interval of 30 s or 1 min.

3. Results and Discussion

This study evaluated the separation efficiency of Yb and Lu according to the types of ammonium ions such as primary, secondary and tertiary ammonium ions. It was found that the higher the amine order, the longer the column retention time and elution time. For example, when the ions contained in the eluent are methylamine (primary amine), the retention time is longer than that of NH_4^+ ion, and separation efficiency is improved (Fig. 2 and 3). The eluent containing amines of the second or higher order could not elute Yb and Lu. In order to effectively and selectively separate the Yb and Lu, it is important to select an appropriate type of ammonium ion. The more detail process will be discussed in this presentation.

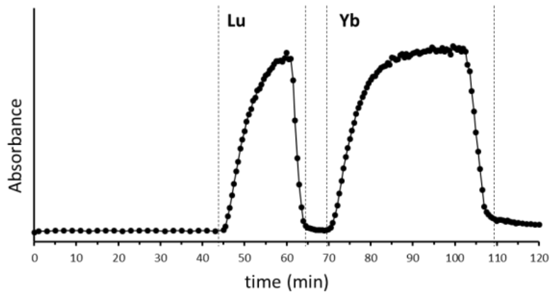

Fig. 2. Chromatogram of separation of stable isotopes Yb and Lu by α-HIBA (pH adjusted with NH_4OH).

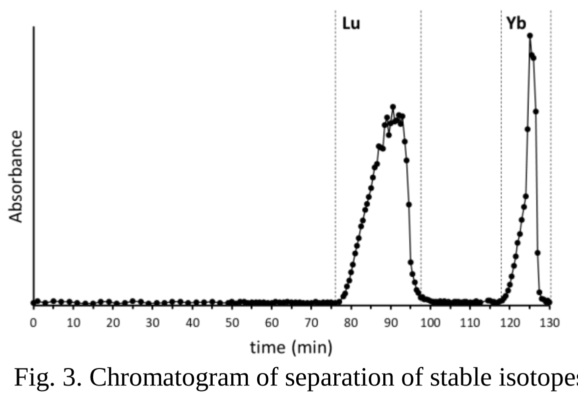

Fig. 3. Chromatogram of separation of stable isotopes Yb and Lu by α-HIBA (pH adjusted with CH_3NH_2).

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