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Lithium Isotope Separation using Cation Exchange Resin with High Cross-Linkage

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Abstract

The lithium isotope separation by the displacement chromatography using cation exchange resin has been studied. The cross-linkage effect of cation exchange resin on lithium isotope enrichment was confirmed by using the commercial cation exchange resin in our previous paper. In the present work, we synthesized the cation exchange resin with 50% cross-linkage, which is higher cross-linkage ratio than the commercial cation exchange resin, and the cation exchange isotope separation experiment using synthesized resin was carried out. As a result, we obtained the isotope separation coefficient of 6.6×10^{-3} . This isotope separation coefficient is the highest one among results obtained by the cation exchange isotope separation methods.

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Keywords: Lithium isotope separation; Ion exchange; Cation exchange resin; Cross-linkage effect

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1. Introduction

Tritium used as fusion fuel needs to be produced artificially by the ${}^6\text{Li}(n,\alpha)\text{T}$ reaction, because tritium natural abundance among hydrogen isotopes is too low. The enrichment of lithium-6 is effective for the tritium breeding. On the other hand, the enriched lithium-7 is required for the pH control chemical of the primary coolant in the PWR [1]. The enriched lithium isotopes are supplied by the amalgam lithium isotope separation method, which is one kind of chemical exchange isotope separation methods. This method is known to have the high isotope separation factor [2]. However, recently the new lithium isotope separation method with mercury free has been required from viewpoint of reducing the environmental load. One of promising lithium isotope separation methods is a cation exchange method. The fast lithium isotope separation was demonstrated by using the cation exchange reaction by Tayler and Urey [3,4]. It is not a novel isotope separation methods. Many studies on lithium isotope separation by using many types of cation exchanger have been performed, and the wide-range separation factors have been obtained [5-7]. Lithium isotope separation factors in many systems are summarized in Tables of Ref. [8]. The higher separation factors were generally obtained in the case of using inorganic cation exchangers than that in the case of using organic cation exchange resins. The difference of isotope separation factors among the various cation exchangers can be explained by the hydration number around the lithium ion [5,7]. The separation factors obtained by the isotope exchange reaction using the cation exchange resins are known to differ depending on the cross-linking degrees [5]. In our previous work [9], we clarified the relationship among the isotope separation factor, the hydration number, and the degree of cross-linkage of cation exchange resin by using the commercially prepared cation exchange resins with different crosslinking degrees; we found that the isotope separation factor is linearly related to the degree of cross-linkage. This fact indicates the possibility of our obtaining the higher separation factor by using the resin with higher cross-linkage. However, the commercial strongly acidic cation-exchange resin with the highest degree of cross-linkage is 24%. Thus, in the present work, we synthesized the sulfo-type strongly acidic cation exchange resin with 50% degree of cross-linkage, and the lithium isotope separation chromatography experiment using this synthesized resin was carried out.

2. Experimental method

2.1. Synthesis of cation exchange resin

The sulfo-type strongly acidic cation exchange resin was synthesized in two steps; the base resin synthesis and the adding the sulfo base. The base resin was synthesized using styrene and divinyl-benzene. The used divinyl-benzene is high purity type (93%) and mixture of isomers. The degree of cross-linkage can be controlled by changing the mixing ratio of styrene and divinyl-benzene; we adjusted the mixing ratio to 50%. The mixture of styrene and divinyl-benzene was solved into the mixture of 40 vol% of methyl benzoate and 60 vol% of bis(2-ethylhexyl)phthalate. By synthesizing in this mixture solvent, the high porous styrene-divinylbenzene resin was obtained. The suspended copolymerization method was used as the synthesis method. The monomer oil with polymeric initiator (2,2'-Azobis(isobutyronitrile) and 1,1'-Azobis(cyclohexane-1-carbonitrile)) was put into the suspending agent, and was stirred in 300rms. The synthesizing temperature was raised up as followings; 60 °C in 2h, 70 °C in 4h, and 90 °C in 10h. Once the reaction was stopped and still standing in one night, the suspended copolymerization was carried out again at a temperature of 353K in 10h. The synthesized base resin was washed by concentrated HCl, hot water and acetone to remove the attached suspending agent and solvent. The synthetic yield of base resin evaluated by weight was almost 100%. The synthesized base resin was warmed in tetrachloroethylene at 40 °C in 4h in order to swell the base resin. The chloro-sulfonic acid was added and reacted with the base resin at 40 °C in 6h. The swelling time and the sulfonation time was twice and three time longer than our general resin synthesis times, respectively. As a result, we obtained the sulfo-type strongly acidic cation exchange resin with 50% degree of cross-linkage. The synthesise cation exchange resin was washed by water, hot water, and acetone well. The synthetic yield evaluated by weight was almost 100%. From this result, the expected capacity of this synthesized resin is 3 meq./g.

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