

Chemical Exchange Isotope Separation of Calcium and Lithium via Organic Phase Macrocyclic Crown-Ether.

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The optimal conditions for calcium-48 (⁴⁸Ca) isotope separation and enrichment mass production were investigated using crown-ether liquid-liquid extraction. The advantages of this technique are that it is quick and allows for a high concentration of solution. The results of the liquid-liquid extraction system revealed a significant dependence on the acidity solvent distribution coefficient. The presence of HCl acid enhanced and maintained the formation of the ion-crown complex. The distribution coefficient (D) for calcium in HCl and aqueous solvent was found to be 0.1707 ± 0.0010 and 0.0202 ± 0.0003 , respectively.

Keywords: Isotope Separation, Calcium, Lithium, Crown-ether, Enrichment

1. Introduction

Neutrinoless double-beta decay ($0\nu\beta\beta$) has been extensively studied to demonstrate lepton number non-conservation. [1]. The CANDLES (Calcium Fluoride for Neutrino and Dark Matter Studies by Low Energy Spectrometer) project employs calcium-48 (⁴⁸Ca), one of the natural double beta decay nuclides with the highest Q-value (4.27 MeV). Nevertheless, this isotope's natural abundance is only 0.187 percent. The goal of this research is to improve the calcium isotope separation by crown-ether through liquid-liquid system for cost-effective enrichment and mass production. Lithium experiments, which are easier to handle and measure the isotopic ratio, were carried out under the same conditions as calcium experiments to study the isotope effect by ICP-MS.

2. Methodology

0.07M of DC18C6 crown-ether dissolved in 200 mL chloroform prepared as an organic phase solution. The aqueous phase feed solutions are CaCl₂ and LiCl dissolves in pure water and 12 M HCl. Both organic and aqueous solutions with the volume ratio of 10/1 were mixed in Erlenmeyer flask using a magnetic stirrer for 1 minute and allowed for 10 minutes before the separation. The loaded solvent in the organic phase was back extracted with the same volume ratio by using pure water. All extraction processes performed at room temperature. The aqueous sample was measured the concentration by AAS (Shimadzu AA-6800) and isotopic analysis by ICP-MS (Agilent 7900).

3. Results

The results were compared to Khoroshilov and Ivanov's [2] work on boron isotope separation by chemical exchange in liquid-liquid systems using boric acid and an organic phase in the form of tributyl phosphate (TBP) or a trioctylamine in o-xylene (TOA) (Table 1). The results show that the calcium values obtained in the HCl acid solvent are comparable to the boric acid extraction using TBP. And the lithium separation factor is in the same order. However, Khoroshilov and Ivanov stated that under their experimental conditions, there is a lack of formation of a sufficiently stable boric acid – TBP complex in the TBP system.

Table 1. Comparison between liquid-liquid extraction system of calcium, lithium, and boron

Method	Element	Organic	Solvent	Distribution coefficient (D) or extraction coefficient (K _D)	Single stage separation factor (α)
LLE +DC18C6 crown-ether (this work)	Calcium	DC18C6 crown-ether	CaCl ₂ (HCl)	0.1707±0.0010	In progress
			CaCl ₂ (aq)	0.0202±0.0003	In progress
	Lithium		LiCl (HCl)	0.0089±0.0001	1.009±0.003
			LiCl (aq)	0.0258±0.0002	1.010±0.004
Extraction in the liquid – liquid system [2]	Boron	TBP	H ₃ BO ₃ (aq)	0.215±0.0010	1.0067±0.0035
		TOA		120±25	1.0250±0.0050

4. Conclusion

Liquid-liquid extraction of calcium and lithium using organic phase contains crown-ether was investigated. The finding shows the solvent effect between aqueous and HCl solvent. The boron extraction by TBP corresponds to the values obtained for the distribution coefficient and separation factor. However, TOA provided significantly more value, resulting in a better environment for enrichment. The volume ratio and the formation of ion-crown complexes will be considered in future calcium extraction experiments.

References

- [1] S. Umehara *et al* 2020 *J. Phys.: Conf. Ser.* **1342** 012049
 [2] A V Khoroshilov and P I Ivanov 2018 *J. Phys.: Conf. Ser.* **1099** 012006