PC10: การศึกษาสภาวะที่เหมาะสมในการสกัดแยกอิตเทรียมปริมาณน้อยให้มีความบริสุทธิ์สูง

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บทคัดย่อ

ได้ทำการทดลองหาสภาวะที่เหมาะสมในการสกัดแยกอิตเทรียม (Y) ปริมาณน้อยออกจากสตรอนเชียม (Sr) ปริมาณสูง เพื่อนำไปประยุกต์ใช้ในการสกัดแยกไอโซโทปรังสีอิตเทรียม-90 ออกจากไอโซโทปรังสีสตรอนเชียม-90 ตั้งต้น เพื่อให้ได้ Y ความบริสุทธิ์สูง โดยใช้ปริมาณสารเทียบเท่าความแรงรังสีของสตรอนเชียมตั้งต้น 1 คูรี ประกอบด้วย Sr 30 มิลลิกรัม Y 1.8 ไมโครกรัม ซึ่งใช้กรดไดเอททิลเฮกซิล ฟอสฟอริก เอซิด (HDEHP) ในสารละลายโดเดกเคนเป็นสารละลายสกัดแยกสารทั้งสองชนิด ผลการทดลอง แสดงให้เห็นว่า ประสิทธิภาพการสกัดแยกระหว่าง Sr และY ขึ้นกับความเข้มข้น ปริมาตรของสารละลายสกัด และความเข้มข้นของกรดที่ใช้สทริปอิตเทรียมออกจากสารละลายสกัด สารละลายไดเอททิลเฮกซิล ฟอสฟอริก เอซิด ปริมาตร 3 มิลลิลิตร ที่ความเข้มข้น 0.3 โมลาร์ สามารถสกัดแยกอิตเทรียม ได้ 97.33 เปอร์เซนต์ ปริมาณคงเหลือของสตรอนเชียมในชั้นราฟฟิเนตเกือบ 100 เปอร์เซ็นต์ สอดคล้องกับการตรวจสอบในชั้นสารละลายของอิตเทรียมที่พบว่ามีการเจือปนของสตรอนเชียมเพียง 0.08 ส่วนในล้านส่วน (0.3 ไมโครกรัม) ซึ่งเป็นปริมาณที่ใกล้เคียงกับปริมาณสตรอนเชียม-90 ที่เจือปนอยู่ในไอโซโทปรังสีอิตเทรียม-90 ที่ใช้ทางการแพทย์

คำสำคัญ: สตรอนเชียม-90 อิตเทรียม-90 ไอโซโทปรังสี การสกัดแยก

The extraction of high purity yttrium from concentrated strontium

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Abstract

A highly purified radioisotope yttrium (Y-90) used in radiotherapy can be extracted from radioisotope strontium (Sr-90). Process for extracting trace amount of yttrium from high concentration of strontium to obtain high purity yttrium was studied. Optimized conditions are applied for preparation of Y-90 radioisotope. In the study, 1.8 µg Y-carrier was extracted from feed solution of 30 mg Sr-carrier which is equivalent to the Sr-90

content with radioactivity of 1 Ci. Diethyl hexyl phosphoric acid (HDEHP) 0.3 molar in dodecane was used as extracting solution. Extraction efficiency of yttrium was 97.33% in the first 3-ml volume of HDEHP. Almost 100% of Sr remained in raffinate solution, while only 0.08 ppm (0.3 μg) was carried over in yttrium fraction. This value of contamination is within the range of Sr-90 found in Y-90 solution that is routinely used in clinical application.

Keywords: Sr-90, Y-90, radioisotope, extraction

1. Introduction

Yttium-90 has a half-life of 64.2 hours and beta energy of 2.23 Mev, which is suitable for treatment of various cancers. Therefore, the application of this radionuclide as therapeutic radiopharmaceuticals has been widely used in Europe and America[1-3]. However, in Asia especially Thailand, the treatment of cancer with this radionuclide is rarely used due to its high cost. The price per millicurie of imported Y-90 is 2,500 bahts on average. The typical therapeutic dose of Y-90 labeled peptide ranges between 50 – 200 mCi of Y-90 per patient. In total, the treatment expense per patient is between 125,000 – 500,000 bahts (exclusive biomolecule). For this reason the in-house productions of Y-90 based on ion exchange $^{90}Sr/^{90}Y$ generator have been studied for more than 10 years. However, the disadvantage of this method is that the exchange resin adsorbed Sr-90 and then loses its capacity due to damage caused by radiation. This leads to the contamination of Sr in Y solution[4-5]. In addition, the Y-product is eluted with chelating agent such as EDTA, which strongly attached to Y-90 and became unsuitable for labeling with peptide. In order to provide the increased levels of ^{90}Y required for this purpose, a new method to produce a carrier-free Y-90 from Sr-90 with a curie quantity must be developed.

Extraction of transition metal with organophosphorus extractant is shown to be the most efficient procedure to separate Y-90 from Sr-90[5-7] with the separation factor as high as 10^6. In this present study, we aim to optimize a separation condition to purify 1.8 μg of Y-carrier by liquid extraction from feed solution containing 30 mg of Sr carrier, which is equivalent to 1 curie of Sr-90 activity. The optimized condition will be applied to extract Y-90 from Sr-90 parent nuclide.

2. Materials and Methods

Organic extractant of di(2-ethylhexyl)-phosphoric acid (HDEHP) with 97% purity, n-dodecane and nitric acid were purchased from Merck and used without purification. $YCl_3.6H_2O$ and $SrCl_2.6H_2O$ were obtained from Fluka.

2.1 Characteristic of HDEHP extractant

Feed solution containing 30 mg of Sr and 1.8 μg of Y equivalent to 1Ci of carrier added Sr-90 and 1 Ci carrier free Y-90 was prepared in a 10-ml 0.3 M nitric. The feed solution was extracted three times with 3-ml HDEHP in n-dodecane at a 3:1 constant volume ratio of feed: extractant. After each extraction, the 2-ml of feed layer aliquot was used to determine the amount of Sr carrier. The oily, HDEHP layer was stripped twice with 7M nitric acid. The two immiscible phases were mixed on a shaker (Gerhardt) at 200 rpm for 10 minutes. All strips and raffinate solutions were evaluated for the amount of Sr and Y using ICP-OES spectrometer (Perkin Elmer, Optima 5300 DV).

3.2 Scrubbing of Sr in HDEHP layer

The HDEHP extracted solution was scrubbed three times with different concentrations of nitric acid at 10 ml constant volume. The solution was then stripped twice with 7M nitric. The trace of Sr and Y in all strip solutions and washing solutions were measured with ICP-OES spectrometry.

3.3 Extraction efficiency of Y-carrier

Y carrier in feed solution was extracted with 5-ml HDEHP in n-dodecane for 10 minutes. After Sr in feed solution was separated, the residual of Sr carrier in HDEHP layer was scrubbed 5 minutes with 10 ml 0.5 M nitric acid for three times. The Y carrier was then stripped twice with 5-ml of 7 M nitric acid.

3.4 Recovery of Sr carrier by Sr-85 tracer

After the preparation of feed solution containing Sr and Y carrier, approximately 60-70 μCi (80 μl) radionuclide tracer of Sr-85 was added to the feed solution. This feed solution was then

extracted with 5 ml of 0.1 M HDEHP using the same procedure as feed without Sr-85. Then the strip solution, raffinate and washing solution were counted in an auto gamma counter (Packard cobra II) instrument and compared to the counts obtained from aliquot of Sr-85 in total feed.

3. Results and Discussion

4.1 Extraction characteristic

The trace amount of Y-carrier (1.8 µg) was completely extracted with 3-ml volume of 0.2 and 0.3 M HDEHP but not with 0.1 M HDEHP. The trace of Y remained in feed 2. Sr was also extracted with HDEHP and the extraction was shown to increase with increasing volume of HDEHP as shown in Figure1. In order to avoid accumulated Sr in the HDEHP layer, a 3-5 ml volume of HDEHP should be used to extract only Y carrier.

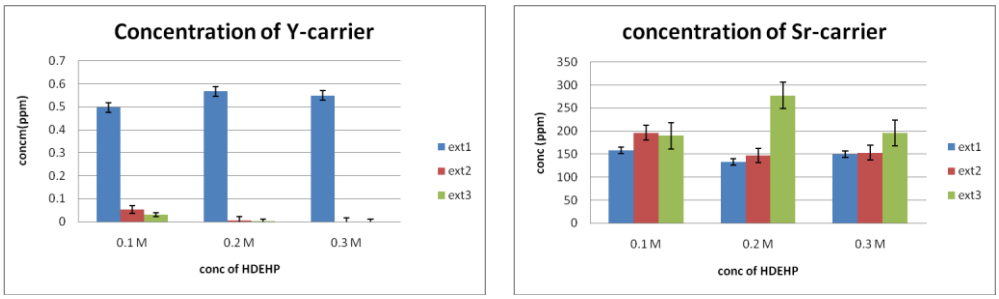

Fig.1 Extraction efficiency of Y carrier (left) and Sr breakthrough (right) on extraction with 9 ml of 0.1, 0.2 and 0.3 M HDEHP at 3 ml successive.

4.2 Scrubbing of Sr-carrier in HDEHP layer

The purity of Y fraction scrubbed with 0.3 M and 0.5 M was shown to be equal. However, the scrubbed waiting time in 0.3 M nitric to completely separate the two layers was longer than the 0.5 M scrubbed fraction. Meanwhile the scrubbed fraction with 1.0 M nitric could remove a little of Y carrier from the HDEHP layer. Therefore, the wash with 10 ml of 0.5 M nitric is optimized to remove residual Sr carrier from the HDEHP layer without a loss of Y carrier.

Table1. Concentration of Sr-carrier in 10-ml washing solution of 0.3, 0.5 and 1.0 M nitric

Washing solution	Concentration of Sr carrier (ppm)		
	0.3M HNO_3	0.5M HNO_3	1.0M HNO_3
1st scrubbed	5.485 ± 3.12	4.165 ± 3.259	50.74 ± 32.85
2nd scrubbed	1.876 ± 0.053	0.435 ± 0.246	3.244 ± 1.789
3rd scrubbed	1.799 ± 0.337	0.152 ± 0.048	0.522 ± 0.225
1st stripped	0.123 ± 0.074 (0.369 μg)	0.088 ± 0.063 (0.264 μg)	0.240 ± 0.212 (0.720 μg)
2nd stripped	0.027 ± 0.016 (0.081 μg)	0.043 ± 0.008 (0.131 μg)	0.244 ± 0.242 (0.741 μg)

4.3 Extraction efficiency of Y-carrier

The extraction efficiency of Y-carrier with 5 ml of HDEHP at concentration 0.1, 0.2 and 0.3 M was shown in table 3. Y was mostly extracted in 0.3 M HDEHP with an efficiency of 96.25% and the lowest Sr-breakthrough (0.34 μg).

Table 2. Extraction efficiency of Y carrier and Sr breakthrough

Concentration	0.1 MHDEHP		0.2 MHDEHP		0.3 MHDEHP	
	Sr (ppm)	Y(ppm)	Sr(ppm)	Y(ppm)	Sr (ppm)	Y(ppm)
1st stripped	0.213	0.247	0.126	0.269	0.066	0.283
2nd stripped	0.647	0.005	0.016	0.014	0.022	0.025
Ext efficiency	-	78.75%	-	88.43%	-	96.25%
Sr breakthrough	4.3 μg	-	0.71 μg	-	0.34 μg	

4.4 Recovery of Sr-85

Recovery of Sr in feed solution is verified by Sr-85 tracer. From the washing step, Sr-85 loss in the first scrubbed was approximately 0.3%. In order to prevent the loss of valuable Sr-90 parent nuclide (as source for generate Y-90 for next extraction), this solution must be recovered and combined with feed solution. Although some Sr was loss with oily solution of HDEHP in waste stream (0.03%), Sr in the feed solution remained nearly 100% and used for radioactivity source next time.

Table 3: Recovery and breakthrough of strontium by Sr-85 tracer

solution	Sr-85 counts	% Sr-85 recovery (%breakthrough)
1st wash	37574	0.32
2nd wash	752	0.0065
3rd wash	735	0.0063
1st strip	451	0.0039
2nd strip	935	0.0081
HDEHP layer	3789	0.033
Raffinate	11552280	99.63

4. Summary

Optimized condition for extracting Y-carrier from the mixture of Sr and Y was accomplished with a small volume of 0.3 M HDEHP extractant. The residual of Sr in HDEHP layer was scrubbed with 0.5 M nitric acid. Finally, the Y-carrier in HDEHP layer was striped with 7M nitric. The extraction efficiency of Y-product was approximately 96-98% with low strontium breakthrough (approximately 1 μg mass). The contamination of Sr in Y fraction was confirmed by Sr-85 tracer with results as low as 0.01%. Sr-85 in raffinate solution remained nearly 100% and kept for the next extraction. Hence this extraction process can be applied for production of Y-90 radioisotope for medical purpose.

5. References

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