Preparation of Carrier-free Yttrium-88 from Strontium Target by Solvent Extraction†

Nagao IKEDA, Kan KIMURA, Riki SEKI and Hideharu FUJIMOTO

Department of Chemistry, Tokyo Kyoiku University

Otsuka, Tokyo

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1. Introduction

Preparation of a radioactive yttrium tracer is of much interest in relation to rare earth chemistry. Usually, ^{90}Y (half-life: 64.0 h) separated from ^{90}Sr , or ^{91}Y (58.8 d) processed from fission products has been used for tracer studies. These nuclides are, however, almost pure β -emitters which need rather tedious β -counting. In this point of view, ^{88}Y seems quite favorable, because it decays mainly by electron capture with γ -transitions and it has a suitable half-life (108.1 d) for tracer works.

For the production of ^{88}Y , several ways are possible. Among them, $^{89}\text{Y}(n, 2n)^{88}\text{Y}$ or $^{89}\text{Y}(\gamma, n)^{88}\text{Y}$ reaction produces ^{88}Y with the isotopic carrier ^{89}Y . Physicochemical works sometimes demand that the tracer to be used should have as high a specific activity as possible. To fulfil the requirement, production of carrier-free ^{88}Y is desirable. It seems to be one of the most suitable ways to separate carrier-free ^{88}Y from deuteron- or proton-bombarded strontium target. As for the proton bombardment on strontium, Sachdev, Porile and Yaffe¹⁾ measured the cross section of the $^{88}\text{Sr}(p, n)^{88}\text{Y}$ reaction, showing the maximum value of 1000 mb at $E_p = 13$ MeV.

As to the mutual separation of yttrium and strontium, separation of carrier-free ^{90}Y from its parent ^{90}Sr has been well-studied²⁾. The methods are based on surface adsorption, coprecipitation, ion-exchange

chromatography, paper chromatography, solvent extraction, etc.

In the case of isolation of ^{88}Y from a strontium target, the situation is rather complicated because of the presence of macro-amounts of strontium in the target solution, and of hard γ -radiations emitted by ^{88}Y and some radioactive impurities. Solvent extraction seems the most convenient for isolation of ^{88}Y , because the salting-out effect of strontium salt is expected and the extraction procedure is generally rapid and simple. This paper deals with the preparation of carrier-free ^{88}Y from proton-bombarded strontium oxide by solvent extraction with bis (2-ethylhexyl) phosphoric acid (HDEHP) in toluene.

2. Experimental

2.1 Reagents

HDEHP (supplied from Tokyo Kasei Kogyo Co., Ltd.) and other reagents were of the reagent grade and used without any further purification.

2.2 Target and proton bombardment

As the available proton beam was of 50 MeV, a thick target arrangement was adopted. In the preliminary experiments, 1, 2, and 3 mm-thick strontium oxide (powder) and 3 mm-thick strontium borate (pellet)

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targets were bombarded. Both the amount of ^{88}Y induced and $^{88}\text{Y}/^{85}\text{Sr}$ ratio were found to increase with increasing total thickness of the target, corresponding to the excitation function reported by Sachdev, et al.¹⁾ There was no trouble with heat removal from thick targets during irradiation. The use of strontium oxide simplified the target preparation and post-irradiation chemical treatments as compared with the use of borate. Therefore strontium oxide was used as the target.

Strontium oxide was charged in a 25 mm (height) $\times$ 30 mm (width) $\times$ 5 mm (thickness) or a 25 $\times$ 30 $\times$ 12 mm cell made of 0.2 mm-thick aluminum foil and the mouth of each cell was closed at 20 mm height. The cells were set in a target holder of 70-inch synchrocyclotron at Institute for Nuclear Study, Tokyo University, and bombarded in 50 MeV proton beam (0.85 μA on the average) for 1.5 h.

The target was stored for sufficient time to diminish the activity of ^{87}Y (80 h) which decays to $^{87\text{m}}\text{Sr}$ (2.83 h), and then subjected to separation of ^{88}Y .

2.3 Chemical procedure

The procedure for separation of ^{88}Y from the irradiated target was developed being based on the solvent extraction data³⁾. The bombarded target was dissolved in a little excess of 6N HCl. The solution was evaporated to near dryness. The residue was dissolved in 100 ml of 0.1N HCl. The solution was shaken with 10 ml of 50% HDEHP (toluene solution) to extract ^{88}Y . The extraction was repeated twice. The organic phases were combined and washed twice with each 20 ml of 0.1N HCl. The organic phase was then shaken with 5 ml of 10N HCl to extract ^{88}Y in aqueous phase. The back-extraction was repeated 4 times. The combined aqueous phase was washed twice with each 20 ml of toluene.

3. Results and discussion

The γ rays from the irradiated target were measured by a Ge(Li) [detector-4096

channel pulse height analyzer counting system. A γ -ray spectrum of irradiated target together with aluminum backing, after cooling for 16 d, is shown in Fig. 1.

Fig. 1 The γ -ray spectrum of the irradiated strontium target.

The irradiated target was found to contain ^{87}Y (80 h), $^{87\text{m}}\text{Sr}$ (2.83 h), ^{85}Sr (64.0 d), ^{83}Rb (83 d), ^{84}Rb (33.0 d) and ^{86}Rb (18.66 d) in addition to ^{88}Y (108.1 d). The 1.275 MeV photopeak was assigned to ^{22}Na produced probably by $^{27}\text{Al}(p, 3p3n)^{22}\text{Na}$ reaction in the aluminum backing. At cooling time of 5d, photopeaks due to ^{86}Y (14.6 h), $^{87\text{m}}\text{Y}$ (14 h) and ^{83}Sr (32.4 h) were also observed.

To check the separation procedures written in 2.3, the activity of an aliquot of each aqueous and organic phase at each separation step was measured. It was revealed that the distribution ratios for yttrium and strontium differ by a factor of approximately 10^6 , and carrier-free ^{88}Y was obtained in very high radionuclidic purity. The γ -ray spectrum of the final ^{88}Y product is

Fig. 2 The γ -ray spectrum of the ^{88}Y product.

shown in Fig. 2. The radionuclidic purity of the product ^{88}Y was examined also radiochemically: An aliquot was taken from the final ^{88}Y product solution, and ^{88}Y in the aliquot was completely removed by extraction. Then ^{85}Sr retained in the aliquot was determined γ -ray spectrometrically by accumulating γ pulses for 5.5 h. This examination proved that ^{85}Sr activity in the final ^{88}Y product was one thousandth as low as ^{88}Y activity at about 2 months after the bombardment. It was also revealed that more than 99% of ^{88}Y was recovered in the final product solution.

By the procedures shown in 2.3, carrier-free ^{88}Y can be directly obtained in high radionuclidic purity, and it takes only 1 h or less for the separation process. It is thus concluded that a very simple extraction-washing cycle offers a method for a rapid preparation of carrier-free yttrium

from the irradiated strontium target.

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