

Production of ^{155}Tb via an α -particle induced reaction on ^{153}Eu

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^{155}Tb ($T_{1/2} = 5.32$ d) decays by electron capture, following the emission of low-energy γ rays (87 and 105 keV). This isotope is expected to be useful for single photon emission computed tomography¹⁾ and γ -ray perturbed angular correlation spectroscopy, which potentially leads to imaging that can probe local chemical environments in the human body.²⁾ We have been aiming to produce ^{155}Tb through the $^{153}\text{Eu}(\alpha, 2n)^{155}\text{Tb}$ reaction.³⁾ The advantage of this method over the proton irradiation of the $^{155,156}\text{Gd}$ target is that the chemical separation of ^{155}Tb from Eu is easier than that from Gd because Eu can be reduced from 3+ to 2+ in aqueous conditions.⁴⁾ Previously, we measured the production cross sections of ^{155}Tb via the α -particle induced reaction on ^{153}Eu and found that the maximum cross section is 900(120) mb at an α -beam energy of 28.5(5) MeV,³⁾ which is sufficiently high for the large-scale production of ^{155}Tb . In this study, we produced ^{155}Tb by the α -beam irradiation of an enriched ^{153}Eu target and performed chemical separation.

The ^{153}Eu target was prepared with ^{153}Eu oxide powder purchased from ISOFLEX (USA), which had a ^{153}Eu enrichment level of 99.8(1)%. The powder was first heated at 900°C for 20 hours and then pressed into a $^{153}\text{Eu}_2\text{O}_3$ pellet with a thickness of 73.4 mg/cm² and a diameter of 7 mm. The ^{153}Eu target was irradiated with an α -particle beam of 27.8 MeV at the RIKEN AVF cyclotron. The average beam current was 2.1 particle μA (μA), and the irradiation time was 77 min. After the irradiation, the target was subjected to γ -ray spectroscopy. Here, the γ -ray peaks of ^{155}Tb and ^{156}Tb ($T_{1/2} = 5.35$ d) were observed. The radioactivity of ^{155}Tb at the end of the bombardment (EOB) was determined to be 13.1(4) MBq, corresponding to a production yield of 4.9(2) MBq/($\mu\text{A}\cdot\text{h}$). This is consistent with 4.7(6) MBq/($\mu\text{A}\cdot\text{h}$) calculated from the experimental cross sections.³⁾ The ratio of ^{156}Tb to ^{155}Tb was evaluated to be 8.3(4)%.

Figure 1 shows the chemical separation scheme of ^{155}Tb . We first dissolved the $^{153}\text{Eu}_2\text{O}_3$ target (24.4 mg as ^{153}Eu) with concentrated HCl and then performed a three-step separation. In the first step, Eu^{3+} was reduced to Eu^{2+} by zinc powder in the presence of SO_4^{2-} , which formed the precipitate of EuSO_4 .⁴⁾ The precipitate was removed through a filter paper (Millipore RAWP02500) by suction. The yield of ^{155}Tb in the filtrate was 90(4)%. In our preparatory experiment, we measured the precipitation yield of Eu to be 92(1)% using a ^{148}Eu tracer. Therefore, in this study, the amount of ^{153}Eu in the filtrate was estimated to

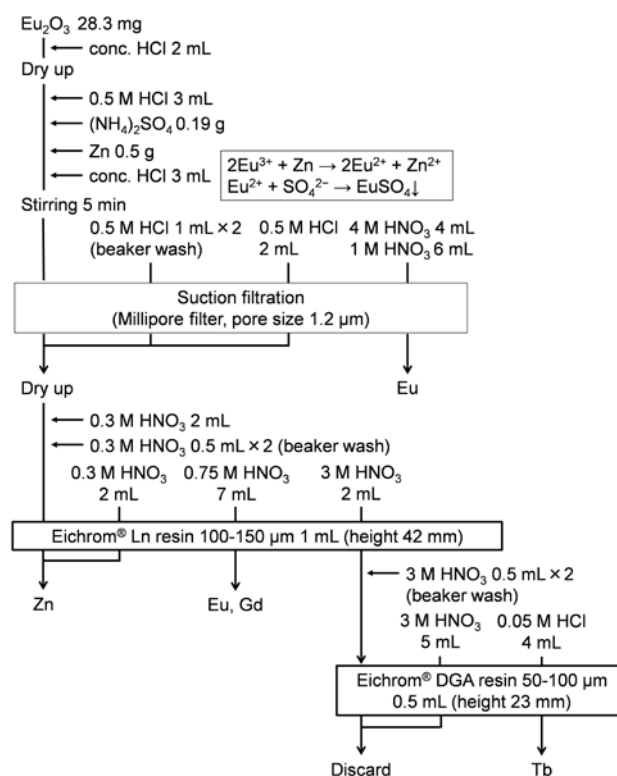


Fig. 1. Chemical separation scheme of ^{155}Tb .

be ~ 2 mg.

After we evaporated the filtrate and dissolved the residue in 0.3 M HNO_3 , we performed extraction chromatography using a column of Ln resin (Eichrom).⁵⁾ First, zinc was eluted from the column with 0.3 M HNO_3 , and then Eu and Gd (potentially contained in the target material) were eluted with 0.75 M HNO_3 . ^{155}Tb was finally eluted with 3 M HNO_3 . The chemical yield of ^{155}Tb was 82(4)%. Note that we optimized this separation between Gd and Tb in advance using a ^{153}Gd tracer, and the decontamination factor of Gd was evaluated to be higher than 910.

We performed further purification of ^{155}Tb with a DGA resin (Eichrom). The chemical yield of ^{155}Tb was $\sim 100\%$.

The radioactivity of the purified ^{155}Tb was 10.3 MBq at EOB and the overall chemical yield was 76(3)%. Hence, by a 27.8-MeV α -particle beam irradiation at 2 particle μA for 14 hours, 100 MBq of purified ^{155}Tb at EOB will be obtained, which is sufficiently high for imaging experiments. The purified sample was subjected to inductively coupled plasma mass spectrometry (ICP-MS). The amount of ^{159}Tb was measured to be 0.4 ng, yielding a ^{155}Tb specific

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radioactivity of 28.5(8) MBq/ng at EOB. The amount of ^{153}Eu in the purified sample was 110 ng; hence, the decontamination factor of ^{153}Eu was 1.7×10^5 . Other impurities (>100 ng) were Ga (320 ng), Ba (3300 ng), and Pb (180 ng).

References

- 1) C. Favaretto *et al.*, EJNMMI Radiopharm. Chem. **6**, 37 (2021).
- 2) K. Shimazoe *et al.*, Commun. Phys. **5**, 24 (2022).
- 3) Y. Shigekawa *et al.*, RIKEN Accel. Prog. Rep. **57**, 174 (2024).
- 4) A. G. Kazakov *et al.*, Radiochim. Acta **106**, 135 (2018).
- 5) B. Webster, Ph.D. thesis, Univ. Surrey, UK (2021).