Production of no-carrier-added barium tracer of ^{135m}Ba

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The long-lived ^{133}Ba isotope (half-life $T_{1/2}$ = 10.51 y) is the only Ba isotope commercially available from Japan Radioisotope Association. Since ^{133}Ba is produced at a nuclear reactor, its specific radioactivity is low with a typical value of approximately 0.5 MBqμg^{-1}. Barium-135m with $T_{1/2}$ = 28.7 h can be produced from the ^{133}Cs$(\alpha, x)^{135m}$Ba reaction by using a cyclotron. Barium-135m emits a single 268.2-keV γ-ray, which would be useful for radiotracer studies of Ba, especially for single- photon-emission computed tomography (SPECT).[1] In this work, we investigated a procedure to produce ^{135m}Ba of high specific radioactivity by using the ^{133}Cs$(\alpha, x)^{135m}$Ba reaction and no-carrier-added chemical separation.

CsCl powder (Sigma-Aldrich; chemical purity > 99.999%) was pressed into a disk of 10-mm diameter and 240-mg cm^{-2} thickness at a pressure of 2×10^3 kg cm^{-2} for 3 min. The CsCl pellet covered with a 10-μm Al foil (chemical purity > 99.99%) was placed on a target holder. The target was irradiated for 30 min with a 50-MeV alpha beam having an intensity of 3.0 μA at the RIKEN AVF cyclotron. During the beam irradiation, the target was cooled with circulating helium gas (30 L min^{-1}) and water (1.5 L min^{-1}). The beam axis was continuously rotated in a circle of diameter approximately equal to 2 mm at 2 Hz to avoid local heating of the target by using electromagnets on the beam line of the RIKEN AVF cyclotron. After the irradiation, ^{135m}Ba was chemically separated from the target material and by-products such as ^{135}La and ^{132}Cs by using a chromatography column filled with the Eichrom Sr resin[2] (Fig. 1). The radioactivity and radionuclidic purity of the purified ^{135m}Ba were determined by γ-ray spectrometry using a Ge detector. The chemical purity and specific radioactivity were evaluated by chemical analysis using an inductively coupled plasma mass spectrometer (ICP-MS). The γ-ray spectrum of the purified ^{135m}Ba is shown in Fig. 2. Only Ba isotopes of ^{131}Ba, ^{133}Ba, ^{133}mBa, and ^{135m}Ba were identified. The radioactivity of ^{135m}Ba was determined to be 2.25 MBq at the end of bombardment (EOB). The chemical yield of ^{135m}Ba was greater than 96%. Decontamination factors of ^{135}La and ^{132}Cs from ^{135m}Ba were evaluated to be 103 and 105, respectively. The radionuclidic purity of ^{135m}Ba was approximately 68% at the EOB. The major radionuclidic impurity was ^{133}mBa ($T_{1/2}$ = 38.9 h) which was produced in the ^{133}Cs$(\alpha, x)^{133}$mBa reaction. Referring to the excitation functions for the ^{133}Cs$(\alpha, x)^{135m}$Ba and ^{133}Cs$(\alpha, x)^{133}$mBa reactions in the TENDL-2015 library,[3] it is expected that the radionuclidic purity of ^{135m}Ba can be increased at lower beam energies. In the ICP-MS analysis, only Cu (1280 ng), U (160 ng), Zn (140 ng), and Ba (100 ng) were detected among the elements having atomic number $Z \geq 20$ in the purified ^{135m}Ba with a contamination level > 100 ng. The specific radioactivity of ^{135m}Ba was then 23 MBq μg^{-1} at the EOB. This specific radioactivity is two orders of magnitude larger than that of the commercial ^{133}Ba.

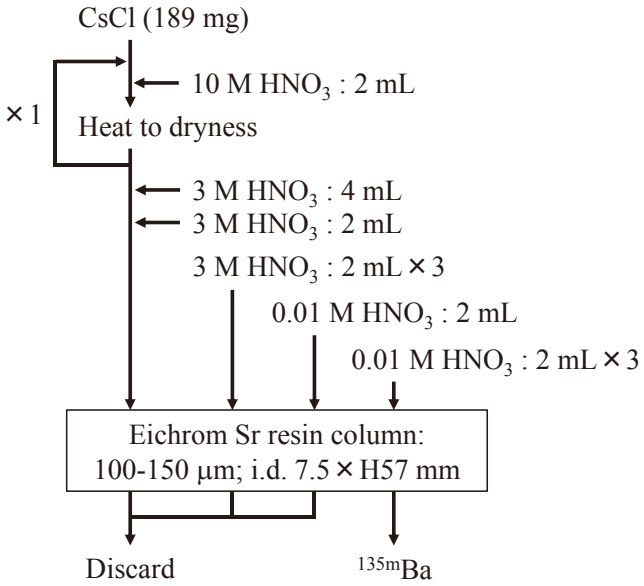

Fig. 1. Chemical separation procedure of ^{135m}Ba from the CsCl target.

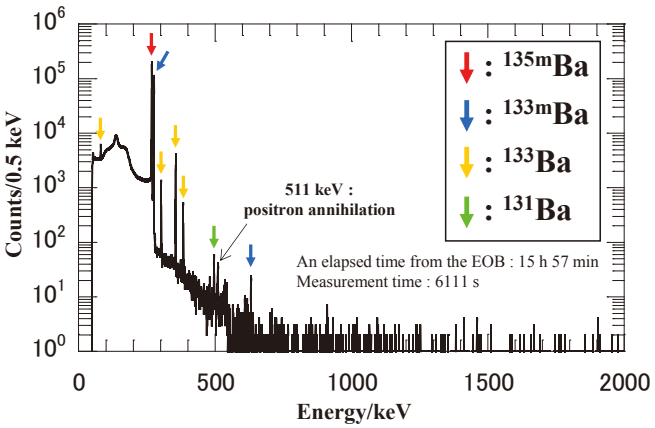

Fig. 2. γ-ray spectrum of purified ^{135m}Ba.

Based on the present results, we estimate that approximately 80 MBq of the no-carrier-added ^{135m}Ba could be produced after 24-h irradiation of the 240-mg cm^{-2} CsCl target with the 50-MeV and 3-μA alpha beam. The expected specific radioactivity is approximately 830 MBq μg^{-1}.

References

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