Modification of ^{211}At production apparatus to increase its production efficiency

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^{211}At is one of the most promising radionuclides for targeted α-particle therapy. We have been developing the production technology of ^{211}At based on the ^{209}Bi$(\alpha, 2n)^{211}$At reaction at the RIKEN azimuthally varying field (AVF) cyclotron[1–4] and distributing ^{211}At to approximate 20 research groups in Japan. The poor thermal conductivity (7.97 W/(m · K) at 300 K) and low melting point (272°C) of metallic Bi necessitate an effective target cooling system for the production of ^{211}At. In the proposed method,[4] an elliptical ^{209}Bi metal target with an area of 4.3 cm^2 and typical thickness of 20 mg/cm^2 on a 1-mm Al backing is irradiated with a 28.0-MeV α (^{4}He^{2+}) beam at an angle of 15° to the beam axis. A beam wobbler system is used to rotate the beam spot position on the target to prevent heat concentration. During the irradiation, the target is cooled with circulating water (4 L/min; 5°C) and He gas (30 L/min). Using this method, ^{211}At can be quantitatively produced with α beam intensities up to 10 particle μA (pμA).[4] To meet the growing demand for ^{211}At, in this study, we modified the production apparatus to realize its production with a larger intensity of 25 particle μA.

Figure 1 illustrates the schematic of the modified apparatus. The incident angle of the beam to the ^{209}Bi target is reduced from 15° to 10° to accept beams with a larger target area (6.5 cm^2) and thinner target thickness (13 mg/cm^2), whereas the effective thickness is unchanged. During the irradiation, the Bi surface is cooled with He gas (30 L/min), and the Al backing is cooled with water (4.0 L/min; 5°C) as same as the previous setup.[4]

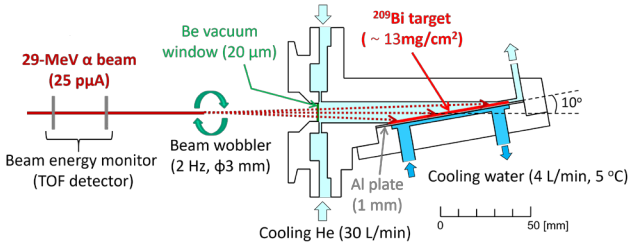

Fig. 1. Schematic of the modified chamber.

With the modified apparatus, two metallic ^{209}Bi targets with thicknesses of 12.94 and 12.88 mg/cm^2 were irradiated with a 27.9-MeV α beam for 0.5 hours. The average beam intensities were 2.1 and 25.0 particle μA, respectively. Following the irradiation, the targets were subjected to γ-ray spectrometry with a Ge detector to determine the production yields of ^{211}At. The produced ^{211}At was separated from the ^{209}Bi target using a dry distillation method.[2,3] The ^{209}Bi target irradiated with the 25.0-particle μA α beam was transferred to a quartz tube and heated up to 850°C under O_2 gas flowing at 15 mL/min. ^{211}At sublimated from the target was transported to a cold perfluoroalkoxy (PFA) tube (−96°C) by the O_2 flow. The PFA tube was washed with 300 μL $CHCl_3$ to collect ^{211}At in a glass v-vial. Finally, the $CHCl_3$ solution was dried with N_2 flow (3 L/min) at ∼25°C and 100 kPa. The chemical yield of the dry ^{211}At was determined through γ-ray spectrometry. The chemical purity of the dry ^{211}At and decontamination factor of ^{209}Bi for ^{211}At were evaluated based on a chemical analysis using the Agilent 7900 ICP-MS.

No evidence of melting was found for both the targets (Fig. 2). The experimental thick target yields (TTYs) of ^{211}At were 23.2 ± 0.9 and 23.1 ± 0.9 MBq/μAh with beam intensities of 2.1 and 25.0 particle μA, respectively, suggesting that ^{211}At can be produced quantitatively with an intensity of 25 particle μA. Figure 3 depicts the experimental and theoretical TTYs of ^{211}At in the ^{209}Bi$(\alpha, 2n)^{211}$At reaction. The experimental TTY at 27.9 MeV is 94 ± 4% of the theoretical value,[5] which agrees with that obtained in our previous work (91 ± 6% at 28.4 MeV).[1]

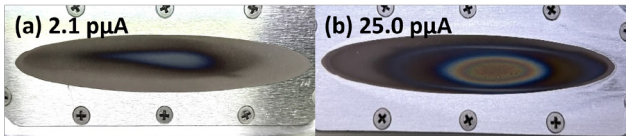

Fig. 2. Photos of the irradiated ^{209}Bi targets with (a) 2.1- and (b) 25.0-particle μA α beams at 27.9 MeV.

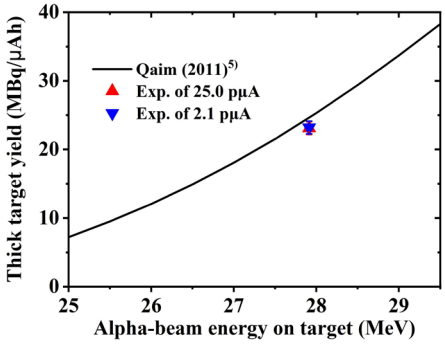

Fig. 3. Experimental and theoretical thick target yields of ^{211}At in the ^{209}Bi$(\alpha, 2n)^{211}$At reaction.

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The chemical yield of ^{211}At was $77 \pm 4\%$. The chemical impurities over 1 ng in dry ^{211}At were Cu (13.4 ng), Al (59.0 ng), Zn (21.8 ng), Pb (8.9 ng), Fe (12.0 ng), Mg (13.1), and Bi (1.5 ng). The decontamination factor of ^{209}Bi for the purified ^{211}At was $> 10^7$.

References

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