Progress of ^{211}At production at the RIKEN AVF cyclotron

X. Yin,*1 N. Sato,*1 A. Nambu,*1 Y. Shigekawa,*1 and H. Haba*1

^{211}At is one of the most promising radionuclides for targeted α-particle therapy. The most common method for ^{211}At production is to irradiate natural Bi with α particles via the ^{209}Bi$(\alpha, 2n)^{211}$At reaction. We have been developing production technologies of ^{211}At at the RIKEN AVF cyclotron.[1–3] In our current method,[3] a metallic ^{209}Bi target with a typical thickness of 20 mg/cm^2 on a 1-mm Al backing is irradiated with a 28.0-MeV α beam at an angle of 15° to the beam axis. During the irradiation, the target is cooled with circulating water (1.5 L/min, 10°C) and He gas (30 L/min). The maximum beam intensity of 10 particle μA (pμA) can produce ^{211}At with a thick target yield of 48 MBq/pμA h. After the irradiation, the target was placed in a quartz tube, was heated up to 850°C, and kept for 10 min with O_2-gas flowing at 10 mL/min. ^{211}At sublimated from the target was trapped by a PFA tube cooled at −96°C. 200–400 μL $CHCl_3$ was used to wash the PFA tube to collect ^{211}At in a glass v-vial. Finally, the $CHCl_3$ solution was dried to obtain a dry ^{211}At in the v-vial with N_2-gas flowing at 100 mL/min.

The demand for RIKEN ^{211}At is increasing every year. It is desirable to increase the production yield of ^{211}At by irradiating the ^{209}Bi target with a more intense beam. Due to the poor thermal conductivity (9.79 W/(m·K)) and a low melting point (272°C) of Bi, an effective cooling system is essential. In this work, we modified the channel of the cooling water to increase its flow rate from 1.5 to 4.0 L/min. We also lowered the temperature of the water from 10 to 5°C. However, we could prepare only one dry ^{211}At in a single drying and it took approximately 15 min to dry 200 μL of $CHCl_3$. To increase the productivity of the dry ^{211}At, we developed a rapid drying apparatus that makes it possible to simultaneously produce 4 v-vials of dry ^{211}At within less time.

The ^{209}Bi targets with thicknesses of 17.7 mg/cm^2 and 18.6 mg/cm^2 were irradiated for 40 mins with a 28-MeV α beam using the previous and new irradiation systems, respectively. The beam intensity was 25 particle μA. After the irradiations, the targets were subjected to γ-ray spectrometry to determine the activity of ^{211}At.

In a separate experiment, 642 MBq of ^{211}At in 300 μL of $CHCl_3$ was divided into 3 v-vials of 100 μL each and dried simultaneously in the rapid drying apparatus with N_2-gas flowing at 3 L/min at room temperature and 100 kPa. The N_2 gas was aspirated by a chemical pump and exhausted through 1 M $Na_2S_2O_5$ solution and a charcoal trap (Fig. 1(b)). The v-vials were subjected to γ-ray spectrometry before and after drying.

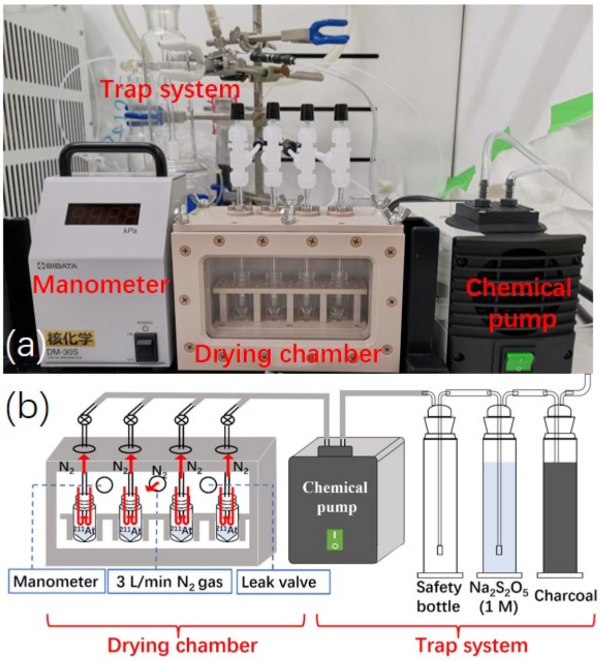

Fig. 1. (a) Photo and (b) schematic of rapid drying apparatus for ^{211}At.

Figures 2(a) and 1(b) show photos of the irradiated ^{209}Bi targets with the previous and new irradiation systems, respectively. The target cooled with 1.5-L/min water at 10°C was damaged severely. The produced ^{211}At activity of 503 ± 16 MBq is only 61% compared with the theoretical yield.[4] The damage of the target cooled with the 4.0-L/min water at 5°C with the new system seems smaller, and the produced ^{211}At activity of 667 ± 23 MBq is 82% of the theoretical yield.[4] As expected, a higher flow rate and lower temperature of cooling water help to produce ^{211}At more quantitatively. Our current production yield of ^{211}At (1.0 GBq/h at 28.0 MeV with a 25-particle μA α beam) was increased by a factor of 2.1 compared to our previous one by a 10-particle μA α beam irradiation.[1]

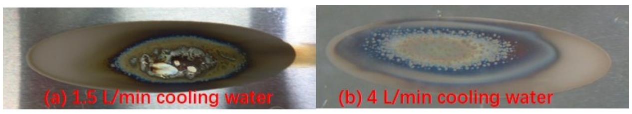

Fig. 2. Photos of the ^{209}Bi targets irradiated with the previous (a) and new (b) irradiation system at the 1.5 and 4.0 L/min flow rate of cooling water, respectively.

*1 RIKEN Nishina Center

Each 100 μL of the ^{211}At $CHCl_3$ solution in the 3 v-vials was dried within 5 min. The activities of ^{211}At before and after drying were consistent with each other after the decay corrections. With the rapid drying apparatus, the time required to dry ^{211}At was significantly reduced.

References

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