Development of a large-scale production system of astatine-211 for targeted alpha-particle therapy

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Astatine-211 (^{211}At), with half-life of 7.214 h, is one of the promising radionuclides for targeted α-particle therapy.[1] Due to the proper ranges of the α particles in tissue, the ^{211}At-labeled medicine is effective in killing cancer cells. We have been developing production technologies of ^{211}At in the ^{209}Bi(^{4}He, $2n$)^{211}At reaction at the AVF cyclotron,[2–5] where ^{211}At is produced by irradiating a ^{4}He^{2+} beam with a maximum intensity of 25-particle μA (pμA) to a stational metal Bi target. To meet the rapidly growing demand of ^{211}At in Japan, further development to increase the production yield of ^{211}At by using more intense beams from the RIKEN Ring Cyclotron (RRC) and the recently upgraded RIKEN Linear Accelerator (SRILAC)[6] is an important issue. However, owing to the low melting point (271.5°C) and thermal conductivity (7.97 W/m · K at 300 K) of the metal Bi, the target melts when the intensity is increased to >25 pμA in the conventional system,[4] making it impossible to quantitatively produce ^{211}At. Thus, we devised a novel ^{211}At production system with a rotating Bi target and a dry distiller for chemical separation of ^{211}At.[7]

Figure 1 shows a layout of the developed ^{211}At production system. The metal ^{209}Bi target is placed in the target vessel. By rotating the vessel, a centrifugal force maintains the target shape even if the target melts due to the irradiation. Because it can be irradiated from any direction, there is no need to construct a costly vertical beam line. The target vessel is heated with a high-frequency induction heater (HFIH) and ^{211}At sublimated from the target is transported to a hot laboratory (HL) by a He gas stream. Thus, chemical separation of ^{211}At can be realized immediately after or during irradiation to reduce its radioactive decay loss.

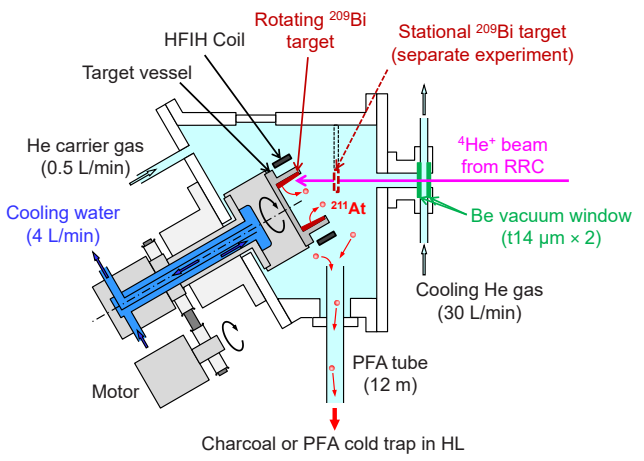

Fig. 1. Layout of the large-scale ^{211}At production system.

The ^{209}Bi target in the vessel made of carbon (60-mm inner diameter (*i.d.*) × 27-mm height) was irradiated in He gas (100 kPa) with a 28-MeV ^{4}He^{+} beam from the RRC through Be foils (14-μm thickness × 2) (Exp. 1). The ^{209}Bi target was sufficiently thick to completely stop the beam (>200 mg/cm^2). The beam intensity was 0.25 pμA. During irradiation, the target vessel was rotated at 800 rpm and cooled in He gas. After the irradiation, the rotation was stopped, the target vessel was heated to 650°C with HFIH, and ^{211}At was sublimated and transported with He carrier gas at a flow rate of 0.5 L/min to the HL through a perfluoroalkoxy alkane (PFA) tube (1.5-mm *i.d.* × 12-m long) heated to 110°C. In the HL, ^{211}At was collected with an activated charcoal trap (4-mm *i.d.* × 50-mm long). In a separate experiment (Exp. 2), the ^{209}Bi target in the vessel rotated at 2000 rpm was irradiated with a 25-pμA ^{4}He^{+} beam for 85.5 min. ^{211}At was sublimated at 750°C and transported through the PFA tube (1.6-mm *i.d.*) at the He flow rate of 0.25 L/min to the PFA tube trap (1-mm *i.d.* × 1-m long) cooled with liquid nitrogen at the HL. Finally, the PFA trap was washed with 300 μL of chloroform ($CHCl_3$) to collect ^{211}At in a glass vial. The radioactivities of ^{211}At in the activated charcoal, PFA trap, and vial were determined by γ-ray spectrometry with a Ge detector. The chemical yields of ^{211}At were estimated by comparing the radioactivities to that produced in the stational ^{209}Bi target (1-mm thickness) placed just before the target vessel in a separate irradiation (Fig. 1).

The chemical yield of ^{211}At with the activated charcoal in Exp. 1 was 77 ± 3% which was sufficiently high to compare it with those obtained in the conventional method.[3–5] In Exp. 2, 206 ± 10 MBq of ^{211}At at EOB was trapped in the PFA tube, and 186 ± 8 MBq, which is useful for general medical research, was recovered in the vial with $CHCl_3$. We plan to continue the development of this system using more intense beams, such as that of 100 pμA from the RRC and SRILAC.

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References

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