Development of a production technology of ^{211}At at the RIKEN AVF cyclotron: (ii) Purification of ^{211}At by a dry distillation method

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Astatine-211 is one of the promising radioisotopes for targeted cancer therapy[1] because ^{211}At has a suitable half life of $T_{1/2}$ = 7.214 h for medical applications and a high α-particle emission probability of 100% in addition to its short-lived decay daughter ^{211g}Po ($T_{1/2}$ = 516 ms). We have started to develop a production technology of ^{211}At at the RIKEN RI Beam Factory to distribute this useful radioisotope to the general public. In a separate paper,[2] we have reported the production technology of ^{211}At from the ^{209}Bi(α,2n)^{211}At reaction using the AVF cyclotron. In this report, we describe a chemical purification procedure of ^{211}At from the irradiated ^{209}Bi target by a dry distillation method. A schematic of the dry distillation apparatus is shown in Fig. 1. After the irradiation,[2] the ^{209}Bi target was placed on a copper tray in a quartz tube (28-mm i.d. × 200-mm length) and heated up to 850°C using an electric furnace. ^{211}At sublimated from the target material was extracted from the quartz tube to a PFA tube (1-mm i.d. × 1-m length) through a quartz capillary (1.95-mm i.d. × 130-mm length) with O_2 gas flow at a flow rate of 20 mL min^{-1}. The PFA tube was cooled at –72°C in a mixture of dry ice and ethanol to collect the gaseous ^{211}At. After distillation for 30 min at 850°C, the quartz capillary was removed from the quartz tube, and the inside of the quartz capillary and the PFA trap tube were washed with 1 mL of water to recover ^{211}At. The chemical yield of ^{211}At was determined by γ-ray spectrometry using a Ge detector. The radionuclidic purity was determined by α-particle spectrometry and γ-ray spectrometry using Si and Ge detectors, respectively.

The chemical purity and the decontamination factor of ^{209}Bi from ^{211}At were evaluated based on a chemical analysis using ICP-MS. The α-particle and γ-ray spectra of the purified ^{211}At are shown in Figs. 2A and 2B, respectively. Only the peaks corresponding to ^{211}At are observed in the spectra. The chemical yield of ^{211}At was approximately 60%; the major loss of ^{211}At was due to the low trap yield of the PFA tube. The radionuclidic purity of the ^{211}At solution was >99.9%, and the atomic ratio of ^{210}At/^{211}At was < 1.0×10^{-5} at the end of irradiation. Among the elements having atomic number $Z \geq 13$ (Al), Cu (405 ppb), Al (23 ppb), Tl (20 ppb), Bi (9 ppb), and Zn (8 ppb) were detected with a concentration >5 ppb. The decontamination factor of ^{209}Bi from the purified ^{211}At was 3.0×10^{-7}. We are ready to distribute 1 GBq of ^{211}At for researches in nuclear medicine.

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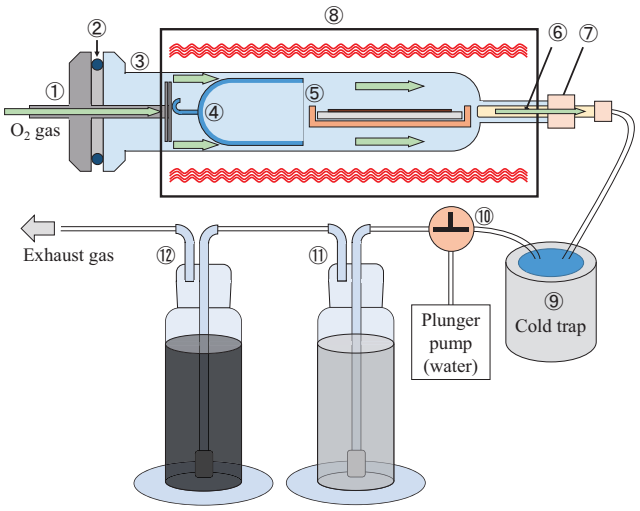

Fig. 1. Schematic of the dry distillation system of ^{211}At. ①: KF40 flange with a heat sink for preheating of the O_2 gas. ②: O-ring. ③: Quartz tube (28-mm i.d. × 200-mm length). ④: Quartz spacer. ⑤: Bi target on an Al plate in Cu tray. ⑥: Quartz capillary (2-mm i.d. × 130-mm length). ⑦: PFA connector. ⑧: Electric furnace. ⑨: PFA trap tube (1-mm i.d. × 1-m length) cooled in a mixture of ethanol and dry ice. ⑩: PFA three-way valve. ⑪: 1 M $Na_2S_2O_5$ gas wash bottle. ⑫: Charcoal gas wash bottle.

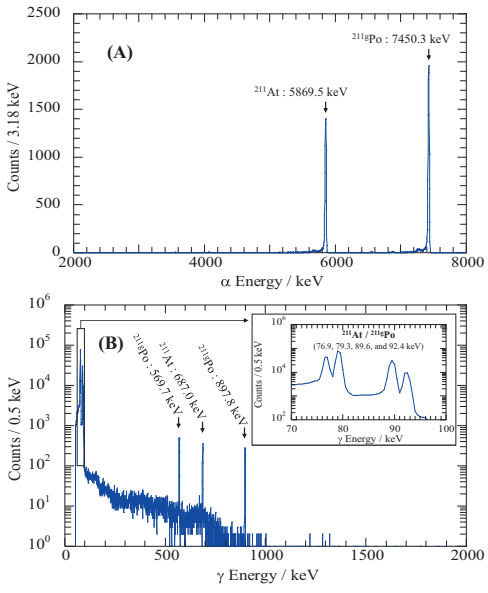

Fig. 2. Typical (A) α-particle and (B) γ-ray spectra of the purified ^{211}At obtained from a Bi target.

References

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