# Production of Alpha Particle emitting $^{211}$At using MC-50 Cyclotron

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## 1. Introduction

The alpha emitter $^{211}$At (7.214 h) is considered to be a promising radionuclide for targeted cancer therapy due to its decay properties[1]. Among the factors that impede progress in this field, the availability of $^{211}$At in sufficient amounts and purity is perhaps one of the most important. The $^{211}$At isotope is produced via the $^{209}$Bi(a, 2n)$^{211}$At reaction on natural monoisotope $^{209}$Bi, which has a threshold around 20MeV and reaches the maximum cross section of ca. 900mb at 30MeV[2]. However, one cannot use the full range of the beam energies suitable for production of $^{211}$At—the following reaction, $^{209}$Bi(α, 3n), has its threshold at 28MeV and results in $^{210}$At (8.1h), which decays to the radiotoxic alpha emitter $^{210}$Po (138.38 d). The goal is then to maximize the $^{211}$At yield while keeping the content of $^{210}$At at an acceptable level. This work was mainly focused on these optimum conditions for production of $^{211}$At using 45 MeV alpha beam.

## 2. Methods and Results

The bismuth was melted onto a baking of alumina. Alumina-baked targets were prepared by heating the bismuth metal powder (-325 mesh; MORTON THIOKOL) on the alumina baking plate in a furnace. (After melting, the bismuth was distributed as evenly as possible with a porcelain spatula.) The thickness of the bismuth layer was measured with micrometer at 20 points on the target and total weight of the bismuth was estimated from the difference of weight of the target before and after plating. Because of surface tension, the bismuth tended to distribute quite evenly for thin layer (1000 μm), while thicker layers (1100 μm) were more difficult to prepare with an even thickness.

The $^{209}$Bi(α,2n)$^{211}$At reaction was used for production. For the yield measurements, 30-min irradiations at beam currents of 300 nA were used. Alpha beam currents were measured first with a faraday cup before irradiating the target with alpha beam.

After the irradiations and an appropriate cooling time, the irradiated targets were removed, and measured by using a γ-ray spectrometer. The γ-ray spectrometer was an coaxial ORTEC high-purity germanium (HPGe) detector (PopTop, GMX30P, relative efficiency 30% and FWHM 1.9 keV at 1332.50 keV peak of $^{60}$Co) with a crystal diameter of 60 mm and a height of 60 mm. The HPGe detector was coupled to a 16384 multi-channel analyzer with the associated electronics to determine the photo-peak area of the γ-ray spectrum by using the Gamma Vision (EG&G Ortec) program. The photopeak efficiency curve of the γ-ray spectrometer was determined using certified point sources of $^{60}$Co, $^{133}$Ba, $^{137}$Cs and $^{152}$Eu. The detection efficiency curves $\varepsilon(E_\gamma)$ as a function of the photon energy were determined at several short and relatively long distances from the end-cap of the detector to avoid coincidence losses, and to assure a low dead time (<10%) and a point like geometry. The gamma emission of At and Po radioisotopes with there are compiled in Table 1.

The activity measurements of the irradiated samples were started at about 60 minutes after the end of the bombardment (EOB). This cooling time was enough to separate the complex γ-lines from the decay of the undesired short-lived radionuclides.

Table 1. Gamma lines with intensities of $^{210}$At, $^{211}$At

| Radioisotopes | Gamma-ray energy (keV) | Intensity (%) |
|---|---|---|
| $^{210}$At | 116.2 | 0.65 |
| | 245.31 | 79.44 |
| | 402.0 | 0.77 |
| | 506.8 | 0.69 |
| | 527.60 | 1.14 |
| | 817.2 | 1.71 |
| | 852.7 | 1.38 |
| | 929.9 | 0.75 |
| | 955.8 | 1.80 |
| | 1181.4 | 99 |
| | 1436.70 | 29 |
| | 1483.3 | 46.5 |
| | 1599.5 | 13.4 |
| | 2254.0 | 1.52 |
| $^{211}$At | 669.78 | 0.0037 |
| | 687.0 | 0.261 |
| | 742.72 | 0.0010 |
| $^{210}$Po | 803.10 | 0.0012 |
| $^{211g}$Po | 328.2 | 0.0032 |
| | 569.65 | 0.535 |
| | 897.80 | 0.551 |

Fig. 1 and 2 show γ-spectra from Bi target irradiated with α-particles with energies of 33.96 and 29.16 MeV, respectively. As it expected, there were only minute amounts of $^{210}$At (i.e. γ- lines of 245, 1181, 1436, 1483 and 1600 keV), in the spectra from the 29.16 MeV

irradiation while there were much larger amounts resulting from the 33.96 MeV irradiation. The maximum activity in this work, using 30-min irradiations at beam currents of 300 nA, was 180 μCi (EOB). Fig. 3 show the ratio of the activities of $^{210}$At and $^{211}$At at EOB. The ratio of the activities of $^{210}$At and $^{211}$At at EOB was found to be 7.37 x $10^{-4}$ from a target irradiated with 29.16 MeV α-particles. This radionuclide purity is sufficient for the possible medical applications.

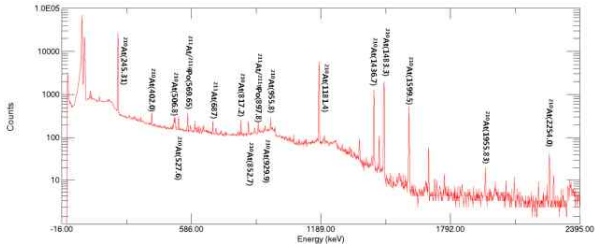


Fig. 1. γ-spectrum obtained with the HPGe detector from a Bi target irradiated with 33.96 MeV α particles.

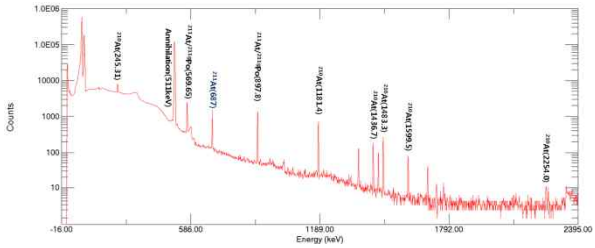


Fig. 2 γ-spectrum obtained with the HPGe detector from a Bi target irradiated with 29.16 MeV α particles.

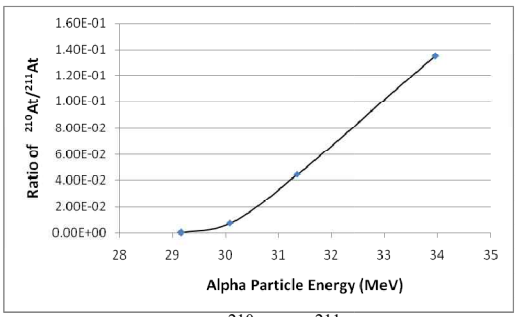


Fig. 3. Activity radio of $^{210}$At to $^{211}$At at the EOB

## 3. Conclusions

A optimum condition for production of $^{211}$At using 45 MeV alpha beam was found. It allows the irradiation of thick bismuth layers with a 45 MeV alpha particle beam. The ratio of $^{210}$At and 211 at EOB is $<10^{-3}$ . This can be used for the routine production of $^{211}$At for research and development of prospective labelled compounds for nuclear medicine.

## REFERENCES

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