Alpha Beam Energy Determination Using a Range Measuring Device for Radioisotope Production

Junyong Choi[a], Byeongil Kim[a], Seungpyo Hong[a], Ranyoung Kim[a], Kwon Soo Chun[a]*
[a]Radiopharmaceuticals Production Center, Korea Institute of Radiological & Medical Sciences, 75 Nowon-ro, Nowon-gu, Seoul, Korea, 139-706
**Corresponding author: kimbi@kirams.re.kr*

1. Introduction

The incident energy of the beam is one of the important factors in the production of radioisotopes using a cyclotron. The beam energy has a significant effect on the production yield. The threshold for the $^{209}Bi(\alpha,2n)^{211}At$ reaction occurs at about 20 MeV and peaks at about 31 MeV; however, one cannot take advantage of the full breadth of the cross section for this nuclear reaction because of concerns about generating ^{210}At through $^{209}Bi(\alpha,3n)^{210}At$ nuclear reaction. This radionuclide is problematic because greater than 99% of its decays results in the production of ^{210}Po, a 138.4-day half life α-particle emitter that can be extremely toxic to bone marrow due to the proclivity of polonium for the bone [1]. The threshold energy of the $^{209}Bi(\alpha,3n)^{210}At$ reaction is at about 30MeV. Our laboratory suggested an energy measurement method to confirm the proton-beam's energy by using a range measurement device [2][3]. The experiment was performed energy measurement of alpha beam. The alpha beam of energy 29 MeV has been extracted from the cyclotron for the production of ^{211}At.

2. Methods and Results

The range measurement for accelerated charged particles was performed with developed range measurement device using an absorber at the KIRAMS where the MC-50 cyclotron is utilized [3]. In this paper, we present a more accurate, rapid method to determine the energy of accelerated alpha particles by using a developed range measurement device.

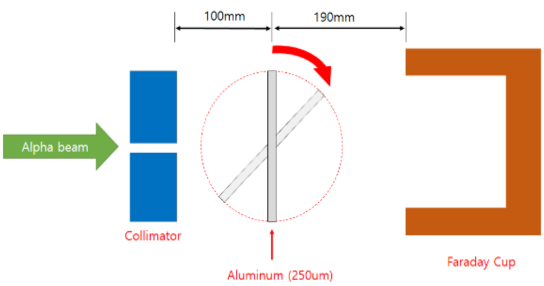

Fig. 1. Schematic diagram of the range measuring device.

2.1 Methods

Fig.1. shows the schematic diagram of the range measuring device. This device was composed of four parts: an absorber, a drive shaft, and a servo motor and a Faraday cup. The drive shaft was mounted on the absorber and connects with the axis of the servo motor and rotates linearly and circularly by this servo motor. A Faraday cup is for measuring the beam flux. As this drive shaft rotates, the thickness of the absorber varies depending on the rotation angle of the absorber. The specification of an absorber used in this experiment is as follows:

Aluminum : 0.25mm (0.01in) thick, annealed, Puratronic® , 99.9999% (metals basis), 2.7 g/cm^3 density,

If the rotation angle of a specific stopping material with 250 ㎛ thickness is Θ, then the actual path length (ℓ) of the alpha beam is $\ell = 250$ ㎛ / $cos\Theta$. The measured range of alpha particles in aluminum was compared with ASTAR [4], SRIM 2008 [5] and MCNPX simulation [6] .

2.2 Results

I is the incident particle flux per second and is related to the beam current. I_0 is initial value of the *I*. The relative count rate is I / I_0. In this experiment, relative count rate is increased while the absorber is rotating at Fig 2.

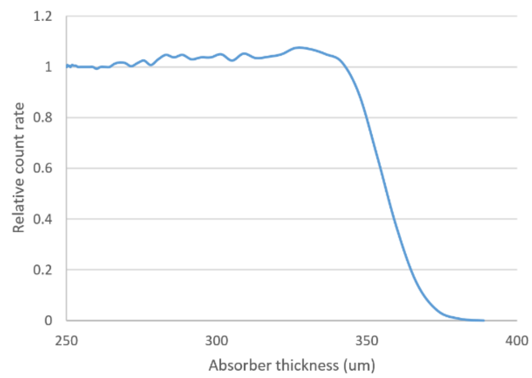

Fig. 2. Alpha-particle absorption curve (an alpha beam energy: 29MeV, a stopping material: aluminum, a bias voltage: 0V)

For this reason, the secondary electron emission from the Faraday cup can cause a loss of negative charge, and the secondary electron emission from the surface of the Faraday cup may cause an unwanted gain in positive charge by the Faraday cup. As the bias voltage is supplied, the secondary electron emission from a Faraday cup is suppressed. The bias voltages typically used go up to a few hundred volts, and sometimes to more than 1000 volts. Therefore, a suppressor electrode is added on the Faraday cup to supply the bias voltage for this experiment. Fig.3. shows one of the results from the experiment that supplied -1kV of the bias voltage. The average range of the 29MeV of alpha particle extracted from MC-50 was measured as 351.5um ±0.5 .

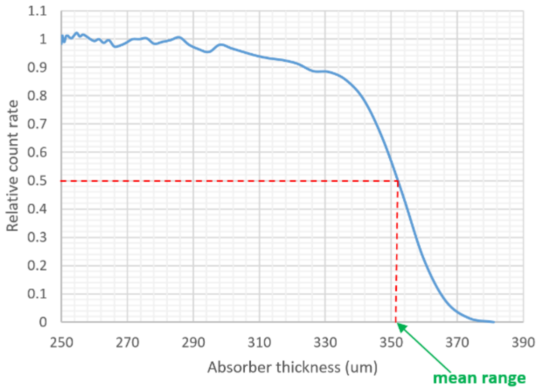

Fig. 3. Alpha-particle absorption curve (an alpha beam energy: 29MeV, a stopping material: aluminum, a bias voltage: -1kV)

Table I: Comparison of four different ranges, R_ASTAR, R_SRIM, R_MCNPX, and R_MEASURE, in aluminum.

29MeV	R_ASTAR	R_SRIM	R_MCNPX	R_MEASURE
range(um)	363.74	357.86	349.39	351.5 ±0.5

Table II: Alpha beam energy were calculated with the ASTAR, SRIM and MCNPX, respectively, based on R_MEASURE (351.5um)

R_MEASURE 351.5um	ASTAR	SRIM	MCNPX
energy(MeV)	28.45	28.69	29.10

The measured range (R_MEASURE) of alpha particles from aluminum was compared with ASTAR (R_ASTAR), SRIM 2008 (R_SRIM) and MCNPX (R_MCNPX) simulation. The compared result was shown on the Table I. The alpha particle energy were calculated with the ASTAR, SRIM and MCNPX, respectively, based on the particle range (351.5um) in Al foil. The determined result is shown on the Table II. The values of result are Min. 28.45MeV, max. 29.1MeV and avg. 28.75MeV from this experiment with 29.0MeV of the alpha beam energy via the MC-50 cyclotron. And the range between minimum and maximum values of the result shows 0.65 MeV.

3. Conclusions

The energy of the alpha particle accelerated and extracted from MC-50 cyclotron was calculated with the measurement of the particle range in Al foil and using ASTAR, SRIM, MCNPX software. There were a little discrepancy between the expected energy and the calculated energy within the 0.5MeV error range. We have a plan to make an experiment with various alpha particle energies and another methodology, for example, the cross section measurement of the nuclear reaction.

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