Production cross sections of ^{177g}Lu in α-induced reactions on ^{nat}Yb

M. Saito,[*1,*2] M. Aikawa,[*1,*2] T. Murata,[*2,*3] N. Ukon,[*2,*4] Y. Komori,[*2] H. Haba,[*2] and S. Takács[*5]

Radioisotopes (RI) are used for therapy and diagnosis in nuclear medicine. The combination of both therapy and diagnosis (Theranostics) is one of the hot topics in the field. One of the candidate isotopes suitable for theranostics is ^{177g}Lu ($T_{1/2} = 6.6$ d).[1] It emits β particles ($E_{mean} = 134.2$ keV) and γ rays ($E_\gamma = 112.95$ keV ($I_\gamma = 6.17\%$) and 208.37 keV (10.36%)), which are suitable for therapy and diagnosis, respectively.

There are many possible reactions to produce ^{177g}Lu, e.g., neutron-induced reaction on ^{176}Lu and charged-particle-induced reactions on ^{174,176}Yb. Cross section data of such reactions are required to find the best production route of ^{177g}Lu. Among them, we focused on the cross sections of ^{177g}Lu in α-induced reactions on ^{nat}Yb, because we could find only one data set for this reaction up to 40 MeV[2] in a literature survey. Therefore, we performed an experiment to measure the excitation function of the reaction up to 50 MeV.

The experiment was performed at the AVF cyclotron of the RIKEN RI Beam Factory by using a stacked-foil activation method and high-resolution γ-ray spectrometry. Thin metallic foils of ^{nat}Yb (purity: 99%, Goodfellow Co., Ltd., UK) and ^{nat}Ti (purity: 99.6 %, Goodfellow Co., Ltd., UK) for the monitor ^{nat}Ti(α,x)^{51}Cr reaction were stacked together as a target. The average thicknesses of the Yb and Ti foils were determined by measuring the surface area and weight of the larger pieces, three Yb foils (25×25 mm^2) and one Ti foil (50×100 mm^2). Their average thicknesses were found to be 16.43, 16.15, 16.93, and 2.40 mg/cm^2, respectively. The target foils (8×8 mm^2) were cut from the measured foils. The stacked target was irradiated by a 50-MeV α beam with an average intensity of 207 particle nA for 2 hours. The initial beam energy was determined by using time of flight measurement,[3] and the energy degradation in the target was calculated by using the SRIM code available online.[4] The initial uncertainty of the α-beam energy was estimated to be $\pm$0.1 MeV, and it increased to $\pm$1.1 MeV at the last Yb foil. Nuclear decay data of ^{177g}Lu and ^{51}Cr were taken from the online NuDat 2.7 database.[5]

Cross sections of the monitor ^{nat}Ti(α,x)^{51}Cr reaction were derived from the γ line of $E_\gamma = 320.08$ keV ($I_\gamma = 9.91\%$) and compared with the IAEA recommended values[6] to assess the beam parameters. Our result shows a good agreement with the recommended values, and suggests that no adjustment is necessary for the beam parameters. Cross sections of the ^{nat}Yb(α,x)^{177g}Lu reaction were also derived from the γ line at $E_\gamma = 208.37$ keV ($I_\gamma = 10.36\%$). The preliminary result is shown in Fig. 1, together with the previous data[2] and the TENDL-2015 data.[7] Our result shows a smooth and monotonical increase, indicating disagreements with the other data.

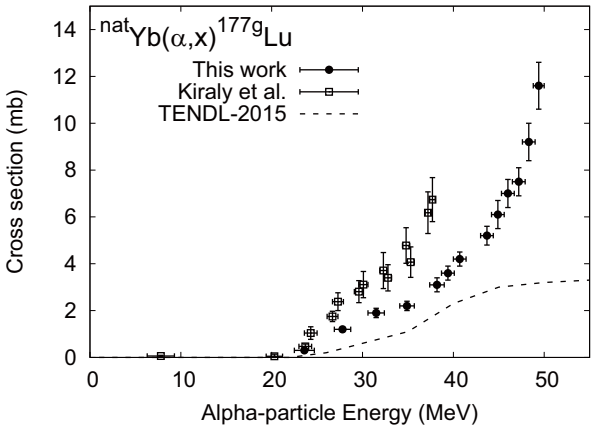

Fig. 1. Cross sections of the ^{nat}Yb(α,x)^{177g}Lu reaction in comparison with the previous data[2] and TENDL-2015 data.[7]

In summary, we performed an experiment on the α-induced reactions on ^{nat}Yb to produce ^{177g}Lu by using a stacked-foil activation method. Thin metallic ^{nat}Yb foils were irradiated by a 50-MeV α beam. Cross section values were determined from the activity of the produced radioisotopes by using high-resolution γ-ray spectrometry. The result was compared with the previous data and the TENDL-2015 data. We found that there are disagreements with the other data. A more detailed analysis is required to finalize the cross sections and confirm this deviation.

*1 Graduate School of Biomedical Science and Engineering, Hokkaido University
*2 RIKEN Nishina Center
*3 School of Science, Hokkaido University
*4 Advanced Clinical Research Center, Fukushima Medical University
*5 MTA ATOMKI, Hangarian Academy of Sciences

References
1) K. Rahbar *et al.*, J. Nucl. Med. **58**, 85 (2017).
2) B. Király *et al.*, Nucl. Instrum. Methods Phys. Res. B. **266**, 3919 (2008).
3) T. Watanabe *et al.*, Proc. 5th Int. Part. Accel. Conf. (IPAC2014), (2014), p.3566.
4) J. F. Ziegler *et al.*, SRIM: the Stopping and Range of Ions in Matter, http://www.srim.org/.
5) National Nuclear Data Center: the NuDat 2 database, http://www.nndc.bnl.gov/nudat2/.
6) Tárkányi *et al.*, IAEA-TECDOC-1211 (2007).
7) A. J. Koning *et al.*, Nucl. Data Sheets **113**, 2841 (2012).