Production cross sections of medical radioisotope ^{153}Sm in alpha-particle-induced reaction on natural neodymium

M. Sakaguchi,[*1,*2] M. Aikawa,[*3,*2] N. Ukon,[*4,*2] Y. Komori,[*2] H. Haba,[*2] N. Otuka,[*5,*2] and S. Takács[*6]

Samarium-153 ($T_{1/2}$ = 46.3 h) is a beta and gamma emitter that can be applied in radiology. This radionuclide is used for the palliation of metastatic bone cancer as the ethylenediamino-tetrakis-methylenediphosphonic acid (EDTMP) chelate.[1)]

^{153}Sm is typically obtained via the neutron capture reaction on enriched ^{152}Sm in nuclear reactors, but its specific activity is rather low.[2)] For the practical use of ^{153}Sm in radiotherapy, other production routes of ^{153}Sm with relatively high specific activities are required.

This radionuclide can be generated in an alpha-particle-induced reaction on natural neodymium. Only one excitation-function measurement has been reported in the literature for the ^{nat}Nd(α, x)^{153}Sm reaction up to 26.2 MeV.[2)] To confirm the available data and to obtain new data of this reaction, we decided to perform an experiment on the ^{nat}Nd(α, x) reactions up to 51 MeV.

The experiment was performed at the RIKEN AVF cyclotron. The standard stacked-foil activation technique was adopted for this experiment. The target was composed of twenty-one ^{nat}Nd foils (purity: 99.0%; thickness: 16.68 mg/cm^2; Goodfellow Co., Ltd., UK) and fourteen ^{nat}Ti foils (purity: 99.6%; thickness: 2.35 mg/cm^2; Nilaco Corp., Japan). The thicknesses of these foils were derived by measuring their weights and surface areas. The ^{nat}Ti foils were used for the ^{nat}Ti(α, x)^{51}Cr monitor reaction to assess the initial beam parameters and the energy loss of the beam in the target. The stacked target was irradiated in a target holder, which served as a Faraday-cup, with an alpha-particle beam for 1 h. The primary incident energy and average beam intensity were 51.1 MeV and 172 nA, respectively. Energy degradation through the stacked target was calculated using the SRIM code.[3)]

After a cooling time of approximately 30 min, the target was disassembled, and the gamma-ray spectrometry of the foils was started. The gamma-ray spectra were measured using a high-purity germanium (HPGe) detector (ORTEC GMX30P4-70) without chemical separation and analyzed using the Gamma Studio (SEIKO EG&G) software for each foil.

The cross sections of the ^{nat}Ti(α, x)^{51}Cr monitor reaction were derived from the 320.1-keV gamma-line (I_γ = 9.910%), and the experimental excitation function was compared with the IAEA recommended values.[4)] The thickness of the ^{nat}Nd foils was adjusted by −1.5% to fit the recommended values and found to be 16.43 mg/cm^2 according to the comparison. The thickness of ^{nat}Ti foils and the beam parameters were unchanged.

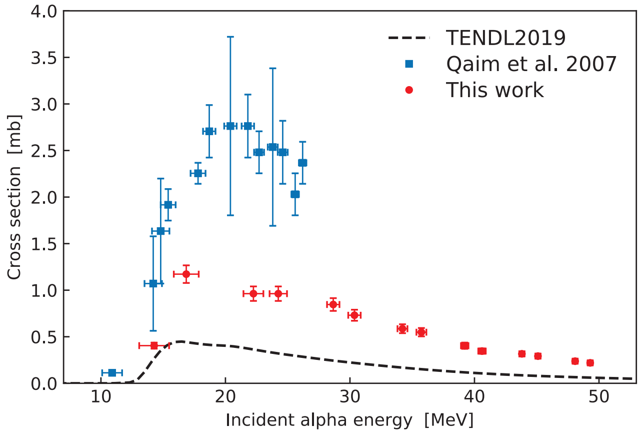

Fig. 1. Excitation function for the ^{nat}Nd(α, x)^{153}Sm reaction compared with previous experimental data[2)] and the TENDL data.[6)]

The excitation function of the ^{nat}Nd(α, x)^{153}Sm reaction was determined using gamma rays with the relatively low energy of 103.18 keV (I_γ = 29.25%). Therefore, the attenuation effect in the metallic Nd foil was considered and calculated from X-ray mass attenuation coefficients.[5)] As a result of the calculation, the net counts of the gamma rays were corrected by +2.1%. Figure 1 shows the corrected cross sections in comparison with the results of a previous study[2)] and the TENDL-2019 data.[6)] The previous data are not consistent with our experimental data and the TENDL data, underestimate both experimental data. The maximum cross section in this work is 1.1 mb, which indicates that this reaction may be unsuitable for the mass production of ^{153}Sm.

This work was supported by JSPS KAKENHI Grant Number 17K07004.

References

1) I. G. Finlay *et al.*, Lancet Oncol. **6**, 392 (2005).
2) S. Qaim *et al.*, Radiochim. Acta **95**, 313 (2007).
3) J. F. Ziegler *et al.*, Nucl. Instrum. Methods Phys. Res. B **268**, 1818 (2010).
4) A. Hermanne *et al.*, Nucl. Data Sheets **148**, 338 (2018).
5) J. H. Hubbell, S. M. Seltzer, X-Ray Mass Attenuation Coefficients, https://dx.doi.org/10.18434/T4D01F.
6) A. J. Koning *et al.*, Nucl. Data Sheets **113**, 2841 (2012).

*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 Nuclear Data Section, International Atomic Energy Agency
*6 Institute for Nuclear Research, ATOMKI