Reexamination of production cross sections of ^{153}Sm via α-particle induced reactions on ^{nat}Nd†

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

Samarium radionuclides, ^{153}Sm ($T_{1/2}$ = 46.3 h) and ^{145}Sm ($T_{1/2}$ = 340 d), can be used in nuclear medicine.[1,2] Among the possible production routes of these medical radionuclides, we studied the α-particle-induced reactions on ^{nat}Nd.[3] However, the measured cross sections of the ^{nat}Nd$(\alpha, x)^{153}$Sm reaction were found to largely deviate from the data studied in a previous study.[4] The peak amplitude of the cross sections was very different in the two experiments. Therefore, we performed two additional experiments to determine the activation cross sections of the reactions with primary focus on the peak amplitude of the ^{nat}Nd$(\alpha, x)^{153}$Sm reaction.

Two experiments (#1 and #2) were conducted at the RIKEN AVF cyclotron. Well-established methods for activation cross section measurements were adopted, including the stacked-foil activation technique and high-resolution γ-ray spectrometry.

The two stacked targets comprised pure metallic foils of ^{nat}Nd (99% purity, Goodfellow Co., Ltd., UK) and ^{nat}Ti (99.6% purity, Nilaco Corp., Japan). The ^{nat}Ti foils were interleaved for the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction to assess the incident beam parameters and target thicknesses. The average thicknesses of the foils were derived from the measured size and weight of the original ^{nat}Nd and ^{nat}Ti foils. The derived thicknesses were 16.7 and 2.25 mg/cm^2, respectively. The foils were cut into a size of 10×10 mm to fit the target holders served as Faraday cups.

Both targets were independently irradiated for 33 min with α-particle beams. The measured incident beam energy of both beams was 28.9 MeV. The energy degradation of the beams in the stacked targets was calculated using the stopping powers obtained from the SRIM code.[5] The average beam intensities measured by the Faraday cups were 103 nA (#1) and 104 nA (#2). The γ rays emitted from the irradiated foils were measured without chemical separation using high-purity germanium detectors.

Cross sections of the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction were used for final assessment of the beam parameters and target thicknesses. Based on the comparison with the recommended values,[6] the measured values were corrected within their uncertainties. The thickness of the ^{nat}Nd foil was decreased by 2% and the initial beam energy was increased by 0.2 MeV. In addition, the beam intensity of the second experiment (#2) was corrected by +2%.

The activation cross sections of ^{153}Sm were determined using the spectra measured after cooling times of 6.0–19.5 h (#1) and 10.9–24.9 h (#2) when the parent ^{153}Pm ($T_{1/2}$ = 5.25 min) had completely decayed to ^{153}Sm. The net counts of the γ line at 103.18 keV (I_γ = 29.25%) emitted from the decay of ^{153}Sm were measured. The low energy γ rays were expected to be absorbed in the ^{nat}Nd foil. The absorption probability of 2.1% was calculated using the target thickness and mass attenuation coefficients.[8] The cumulative cross sections were then determined using the counts corrected for absorption. The results are shown in Fig. 1 along with the experimental data published earlier[3,4] and the TENDL-2021 values.[7] The results obtained in this work are consistent with each other and also with our previous study.[3] In contrast, the other literature data[4] are inconsistent. The TENDL-2021 values are slightly deviated from our data, however, they support the smaller amplitude. The experimental cross sections derived in this work can increase the reliability of the excitation function of this reaction.

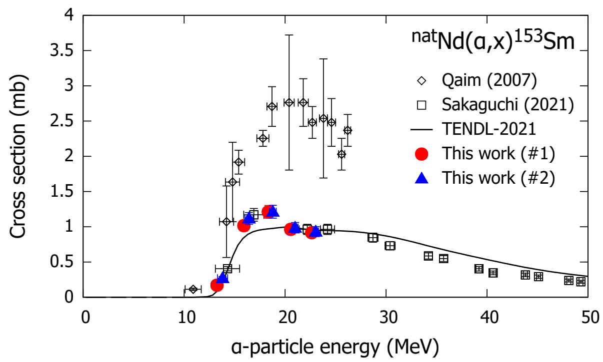

Fig. 1. Cross sect ions of the ^{nat}Nd$(\alpha, x)^{153}$Sm reactioreaction with previous experimental data data[3,4] and the TENDL TENDL-20 21 values.[7]

References

1) I. G. Finlay *et al.*, Lancet Oncol. **6**, 392 (2005).
2) R. G. Fairchild *et al.*, Phys. Med. Biol. **32**, 847 (1987).
3) M. Sakaguchi *et al.*, Appl. Radiat. Isot. **176**, 109826 (2021).
4) S. M. Qaim *et al.*, Radiochim. Acta **95**, 313 (2007).
5) J. F. Ziegler *et al.*, SRIM: the Stopping and Range of Ions in Matter (2008), `http://www.srim.org/`.
6) A. Hermanne *et al.*, Nucl. Data Sheets **148**, 338 (2018).
7) A. J. Koning *et al.*, Nucl. Data Sheets **155**, 1 (2019).
8) J. H. Hubble *et al.*, X-Ray Mass Attenuation Coefficients, NIST Standard Reference Database **126**, `https://dx.doi.org/10.18434/T4D01F`.

† Condensed from the article in Appl. Radiat. Isot. **187**, 110345 (2022)

*1 Faculty of Science, Hokkaido University
*2 RIKEN Nishina Center
*3 Graduate School of Biomedical Science and Engineering, Hokkaido University
*4 Advanced Clinical Research Center, Fukushima Medical University
*5 Nuclear Data Section, International Atomic Energy Agency
*6 Institute for Nuclear Research (ATOMKI)