Production cross sections of ^{153}Sm via alpha-particle-induced reactions on natural neodymium

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

Samarium radionuclides ^{153}Sm ($T_{1/2}$ = 46.3 h) and ^{145}Sm ($T_{1/2}$ = 340 d) can be used to treat bone metastases[1)] and for brachytherapy,[2)] respectively. We investigated the production of the radionuclides via alpha-particle-induced reactions on natural neodymium.[3)] However, the measured cross sections of the ^{nat}Nd$(\alpha,x)^{153}$Sm reaction exhibit significant deviations from a previously published experimental study.[4)] More specifically, the peak amplitude of the cross sections was different from each other by a factor of more than two. Therefore, we performed additional experiments to measure the activation cross sections of the reactions with an emphasis on the peak amplitude of the ^{nat}Nd$(\alpha,x)^{153}$Sm reaction.

Accordingly, two experiments (#1 and #2) were performed at the RIKEN AVF cyclotron using the stacked-foil activation technique and high-resolution gamma-ray spectrometry. Two targets of the experiments were composed of 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 utilized for monitoring the beam via the ^{nat}Ti$(\alpha,x)^{51}$Cr monitor reaction and for beam-energy degradation. The average foil thicknesses, derived from the size and weight of the original ^{nat}Nd and ^{nat}Ti foils, were 16.7 and 2.25 mg/cm^2, respectively. The original foils were cut into a size of 10×10 mm. The two stacked targets with different configurations of six ^{nat}Nd and fourteen ^{nat}Ti target foils were placed in target holders that served as Faraday cups.

Both stacked targets were irradiated for 33 min with 28.9 $\pm$ 0.2-MeV alpha-particle beams. The energy degradation of the beams in the stacked targets were computed using 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), respectively. Gamma rays emitted from the irradiated foils were measured without chemical separation using high-purity germanium detectors. To deduce activation cross sections, nuclear data were retrieved from the online database, NuDat 3.0.[6)]

Cumulative cross sections of ^{153}Sm including contribution form decay of ^{153}Pm ($T_{1/2}$ = 5.25 min) via the alpha-particle-induced reactions on natural neodymium were determined. The cross sections were derived from measured net counts of the gamma line at 103.18 keV (I_γ = 29.25%), which was emitted from the decay of ^{153}Sm. The attenuation of the low-energy gamma rays in the ^{nat}Nd foil was calculated using the X-ray mass attenuation coefficients[7)] and estimated to be 2.1%. The cross sections were determined using the corrected counts. The preliminary results are depicted in Fig. 1 along with the experimental data published earlier[3,4)] and the TENDL-2019 values.[7)] The present results conform with each other and also with our previous study,[3)] however the other literature data[4)] are inconsistent. Based on our new results, the smaller cross sections would be more reliable. The TENDL-2019 values are even smaller than the experimental data.

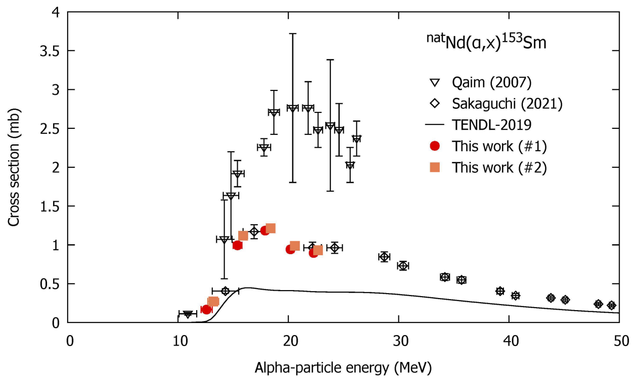

Fig. 1. Cross sections of the ^{nat}Nd$(\alpha,x)^{153}$Sm reaction with previous experimental data[3,4)] and a theoretical prediction of the TENDL-2019 values.[7)]

In addition to the cross sections of the ^{nat}Nd$(\alpha,x)^{153}$Sm reaction, those of the ^{nat}Nd$(\alpha,x)^{145}$Sm reaction will also be determined. There are no experimental data on the ^{nat}Nd$(\alpha,x)^{145}$Sm reaction other than our previous study. The cross sections derived in this work will increase the reliability of the cross sections.

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

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