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

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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.\(^1\) $^{153}\text{Sm}$ is typically obtained via the neutron capture reaction on enriched $^{152}\text{Sm}$ in nuclear reactors, but its specific activity is rather low.\(^2\) For the practical use of $^{153}\text{Sm}$ in radiotherapy, other production routes of $^{153}\text{Sm}$ 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 $^{\text{nat}}\text{Nd}(\alpha,x)^{153}\text{Sm}$ 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 $^{\text{nat}}\text{Nd}(\alpha,x)^{153}\text{Sm}$ 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 $^{\text{nat}}\text{Nd}$ foils (purity: 99.0%; thickness: 16.68 mg/cm\(^2\); Goodfellow Co., Ltd., UK) and fourteen $^{\text{nat}}\text{Ti}$ 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 $^{\text{nat}}\text{Ti}$ foils were used for the $^{\text{nat}}\text{Ti}(\alpha,x)^{51}\text{Cr}$ 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 $^{\text{nat}}\text{Ti}(\alpha,x)^{51}\text{Cr}$ monitor reaction were derived from the 320.1 keV gamma-line \((I_\gamma = 9.91\%)\), and the experimental excitation function was compared with the IAEA recommended values.\(^4\) The thickness of the $^{\text{nat}}\text{Nd}$ 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 $^{\text{nat}}\text{Ti}$ foils and the beam parameters were unchanged.

The excitation function of the $^{\text{nat}}\text{Nd}(\alpha,x)^{153}\text{Sm}$ reaction was determined using gamma rays with the relatively low energy of 103.18 keV \((I_\gamma = 29.25\%)\). 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 $\pm 2.1\%$.

![Fig. 1. Excitation function for the $^{\text{nat}}\text{Nd}(\alpha,x)^{153}\text{Sm}$ reaction compared with previous experimental data\(^5\) and the TENDL data.\(^6\)](https://dx.doi.org/10.18434/T4D01F)

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

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