Activation cross sections of ^{7}Li-induced reactions on ^{nat}Sm

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Terbium radionuclides can be used for nuclear medicine.[1)] High specific activities of the Tb radionuclides can be obtained using charged-particle-induced reactions on neighbor elements, such as Gd, Er and Sm. We focused on ^{7}Li-induced reactions on Sm. We found two experimental studies for fusion reactions on ^{144,152}Sm enriched targets in a literature survey.[2,3)] The data shortage of the experimental cross sections motivated us to experiment with ^{7}Li-induced reactions on ^{nat}Sm. Due to the isotopic ratio of ^{nat}Sm (^{144}Sm 3.08%, ^{147}Sm 15.00%, ^{148}Sm 11.25%, ^{149}Sm 13.82%, ^{150}Sm 7.37%, ^{152}Sm 26.74% and ^{154}Sm 22.74%), the reactions can produce Tb radionuclides simultaneously.

The experiment using a ^{7}Li beam was conducted at the RIKEN AVF cyclotron. We adopted well-established methods, such as stacked-foil activation technique and γ-ray spectrometry, to determine activation cross sections.

Two ^{nat}Sm (5-μm thick, 99% purity, Nilaco Corp., Japan) and one ^{27}Al (5-μm thick, >99% purity, Nilaco Corp., Japan) foils were purchased for the stacked target. The size and weight of the foils were measured to derive the average thicknesses. The measured thicknesses of the two ^{nat}Sm and ^{27}Al foils were 4.07, 4.20, and 1.21 mg/cm^2, respectively. The foils were cut into a size of 10 × 10 mm. Nineteen sets of Sm-Sm-Al-Al foils were stacked in a target holder that served as a Faraday cup.

Irradiation with a 72-MeV ^{7}Li beam on the stacked target lasted for 48 min. The incident beam energy was measured using the time-of-flight method. The beam energy degraded at each foil was calculated using the measured foil thicknesses and stopping powers retrieved from the SRIM code.[4)] The average beam intensity measured using the Faraday cup was 48.9 nA.

The γ rays emitted from the irradiated foils were measured using a high-resolution HPGe detector (ORTEC GMX30P4-70) and dedicated software (SEIKO EG&G Gamma Studio). The γ-ray measurements of the ^{nat}Sm foils were repeated five times with a cooling time of 1.1 h–2.7 d. The associated dead time was less than 2.2%. The nuclear data required for the deduction of the cross sections were retrieved from NuDat 3.0.[5)]

The cross sections of the ^{nat}Sm(^{7}Li$, x$)^{152}Tb reaction were determined from net counts of the γ line at 344.2785 keV (I_γ = 63.5%) emitted from the decay of ^{152}Tb ($T_{1/2}$ = 17.5 h). The spectra measured with the cooling time of 9.6–27.4 h were adopted. Possible interferences in the γ line were assessed. The ground state ($T_{1/2}$ = 13.517 y) and excited state of ^{152}Eu ($T_{1/2}$ = 9.3116 h) emit the same energy γ rays in the decay. The long-lived ^{152g}Eu decayed less during the measurements. The contribution from ^{152m}Eu (I_γ = 2.4%) could be neglected because no peak of the more intense γ line (I_γ = 14.2%) was found. Another possible interference of the 344.90-keV γ line (I_γ = 2.12%) from ^{151}Pm ($T_{1/2}$ = 28.40 h) was negligibly small because the more intense γ line at 340.08 keV (I_γ = 22.5%) was missing in the spectra. The count rate of the 344.3-keV γ peak decreased with the half-life of ^{152}Tb, indicating less contribution from other radionuclides.

The result is shown in Fig. 1. No previous study of the reaction was found. According to the threshold energies (Table 1), the first peak at 40 MeV comprises reactions on several Sm isotopes. Above 60 MeV, the reaction on ^{154}Sm can be dominant. We will finish analyses to determine the cross sections of ^{152}Tb and other Tb radionuclides.

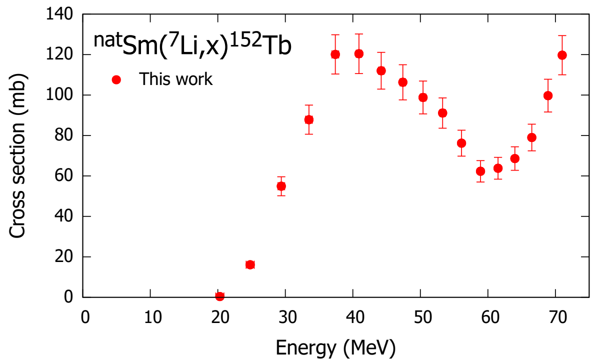

Fig. 1. Measured cross sections of the ^{nat}Sm(^{7}Li$, x$)^{152}Tb reaction.

Table 1. Q value and threshold energy (E_{th}) of the reaction on each Sm isotope target for ^{152}Tb production.

Reaction	Q value (MeV)	E_{th} (MeV)
^{147}Sm(^{7}Li,2n)^{152}Tb	−5.7	6.0
^{148}Sm(^{7}Li,3n)^{152}Tb	−13.9	14.5
^{149}Sm(^{7}Li,4n)^{152}Tb	−19.8	20.7
^{150}Sm(^{7}Li,5n)^{152}Tb	−27.7	29.1
^{152}Sm(^{7}Li,7n)^{152}Tb	−41.6	43.6
^{154}Sm(^{7}Li,9n)^{152}Tb	−55.4	58.1

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