Activation cross sections of ^{7}Li-induced reactions on ^{nat}Cu for monitor reactions†

M. Aikawa,[*1,*2,*3] S. Goto,[*3,*2] D. Gantumur,[*3,*2] D. Ichinkhorloo,[*4,*2] N. Ukon,[*5,*2] N. Otuka,[*6,*2] S. Takács,[*7,*2] and H. Haba[*2]

Production of radionuclides via charged-particle-induced reactions plays a pivotal role in nuclear medicine for imaging and therapy. Among the radionuclides, ^{211}Rn is desirable for its application in the ^{211}Rn/^{211}At generator. A promising approach to producing ^{211}Rn involves lithium-induced reactions on a ^{209}Bi target. Effective production requires careful optimization of beam parameters to maximize the yield while minimizing the amount of unnecessary by-products. The optimization requires monitor reactions. Because of the lack of established monitor reactions for the lithium isotopes, we initiated a systematic study to explore potential target materials.

Copper is commonly employed as a target material in charged-particle-induced reactions. In this study, we focused on ^{7}Li-induced reactions on ^{nat}Cu. A literature survey using the EXFOR library revealed only a single experimental study on this target material.[1)] To accumulate the experimental data, we conducted experiments using 72-MeV ^{7}Li beams to obtain the activation cross sections and physical thick target yields of the reactions.

Three experiments were conducted: two to determine excitation functions and one to measure thick target yields. The experiments were performed at the AVF cyclotron, RIKEN. For our study, we adopted stacked-foil activation combined with γ-ray spectrometry.

Three targets were prepared for the experiments. Targets #1 and #2, used for the excitation function measurements, comprised pure metallic foils of ^{nat}Cu (4.49 ± 0.04 mg/cm^2), ^{nat}Ti (2.34 ± 0.02 mg/cm^2), and ^{27}Al (1.21 ± 0.01 mg/cm^2). Seventeen sets of Cu-Al-Ti-Al and Ti-Al-Cu-Al foils were stacked to form targets #1 and #2, respectively. Target #3, prepared for the thick target yield measurement, consisted of thick ^{nat}Cu foils (21.5 ± 0.2 mg/cm^2).

The three targets were irradiated with 71.6-MeV ^{7}Li beams for 60 min (targets #1 and #2) and 30 min (target #3). The average beam currents of 314 ± 16 nA (#1), 321 ± 16 nA (#2), and 309 ± 15 nA (#3) were measured using Faraday cups. Energy degradation through the stacked targets was calculated using stopping powers derived using the SRIM code.[2)]

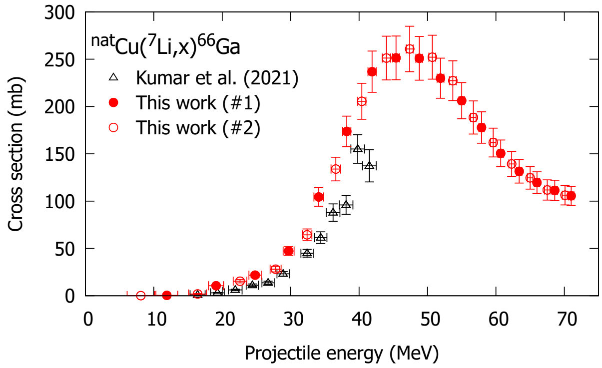

Fig. 1. Cross sections of ^{nat}Cu(^{7}Li, x)^{66}Ga reaction.

The γ rays emitted from each activated foil were measured using two high-purity germanium detectors four times to follow the decay of the products with different half-lives. One detector was used for targets #1 and #3, and the other for targets #2 and #3. The nuclear data for the analysis were retrieved from the NuDat 3.0[3)] and LiveChart online databases.[4)]

Direct and cumulative cross sections, and physical thick target yields, were determined for ^{69,68}Ge, ^{67,66}Ga, and ^{69m,65}Zn. The cross sections obtained using targets #1 and #2 showed good agreement. Furthermore, the experimental physical thick target yields derived using target #3 were consistent with the calculated yields based on the experimental cross sections.

The cumulative cross sections for ^{66}Ga ($T_{1/2} =$ 9.304 h) are presented in Fig. 1 together with data published by earlier studies. The cross sections were determined using the 1039.22-keV γ line ($I_\gamma = 37.0\%$) associated with the decay of ^{66}Ga. The cross sections derived in earlier studies are smaller than those obtained in the present study. The excitation function for the ^{nat}Cu(^{7}Li, x)^{66}Ga reaction exhibits a favorable shape and sufficiently high values, making it suitable for beam monitoring. Additionally, reactions leading to the production of ^{67}Ga and ^{65}Zn are also found to be promising candidates for monitor reactions.

References

1) R. Kumar *et al.*, Phys. Rev. C **104**, 064606 (2021).
2) J. F. Ziegler *et al.*, Nucl. Instrum. Methods Phys. Res. B **268**, 1818 (2010).
3) National Nuclear Data Center, The NuDat 3.0 database, http://www.nndc.bnl.gov/nudat3/ .
4) International Atomic Energy Agency, LiveChart of Nuclides, https://www-nds.iaea.org/livechart/ .

† Condensed from the article in Nucl. Instrum. Methods Phys. Res. B **554**, 165441 (2024)

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

DOI:10.34448/RIKEN.APR.58-025