Production cross sections of ^{68}Ga and radioactive by-products in deuteron-induced reactions on natural zinc[†]

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^{68}Ga ($T_{1/2} = 68$ min), a positron emitter, is a valuable medical isotope used for positron emission tomography (PET).[1)] Charged-particle-induced reactions using cyclotrons are preferable routes for ^{68}Ga production. One of the routes is the deuteron-induced reaction on zinc. Our literature survey revealed three experimental studies on the cross sections of the ^{nat}Zn$(d,x)^{68}$Ga reaction were found,[2–4)] and there is a large discrepancy among their experimental data. Therefore, we measured the cross sections of ^{68}Ga via the deuteron-induced reaction on natural zinc. In addition, we measured the cross sections of co-produced radioisotopes to investigate possible radioactive impurities.

The experiment was performed at the AVF cyclotron of RIKEN RI Beam Factory. The stacked-foil activation technique and γ-ray spectrometry were used to measure the activation cross sections. The target was composed of metallic foils of ^{nat}Zn (17.64 mg/cm^2, 99.9% purity, Nilaco Corp., Japan) and ^{nat}Ti (9.13 mg/cm^2, 99.6% purity, Nilaco Corp., Japan) and irradiated for 22 min by a 24-MeV deuteron beam. The incident beam energy was measured using the time-of-flight method. The energy degradation in the stacked target was calculated using the SRIM code.[5)] A beam intensity of 96 nA was measured using a Faraday cup.

The γ-ray spectra of the activated foils without chemical separation were measured using a high-resolution high-purity germanium (HPGe) detector. The detector was calibrated using a multiple γ-ray point source. The dead time was kept less than 7% in the measurement. Each foil was measured several times after cooling times ranging from 40 min to 18 d for different half-lives of products.

The cross sections of the ^{nat}Ti$(d,x)^{48}$V monitor reaction were derived to assess the beam parameters. A comparison of the measured cross sections with the recommended values[6)] showed that the beam intensity was increased by 6.6% relative to the measured value and corrected to 102.4 nA.

The cross sections of the ^{nat}Zn$(d,x)^{68}$Ga reaction were derived from the measurement of the 1077.34-keV γ-line ($I_\gamma = 3.22\%$) from the ^{68}Ga decay. The measured excitation function is shown in Fig. 1 in comparison with previous data[2–4)] and the theoretical estimation of TENDL-2017.[7)]

Our result agrees with the data reported by Šimečková *et al.*[3)] and the normalized data for the $(d,2n)$ reaction on ^{68}Zn reported by Gilly *et al.*[4)] However, the data reported by Nassiff and Münzel[2)] are much lower than the present data in the entire energy range. The TENDL-2017 data overestimate the experimental data around the peak in the energy range of 8–18 MeV. The contribution of the ^{67}Zn$(d,n)^{68}$Ga reaction is small, and the ^{68}Zn$(d,2n)^{68}$Ga reaction is dominant above the threshold energy of 6.1 MeV based on the TENDL-2017 prediction. The production cross sections of co-produced radionuclides ^{65,66,67}Ga, ^{63,65,69m}Zn, ^{61}Cu, and ^{58}Co were also determined. Enriched ^{68}Zn is preferable for the production of ^{68}Ga because radioactive isotopic impurities are not produced below 14.6 MeV, which is the threshold energy of the ^{68}Zn$(d,3n)^{67}$Ga reaction.

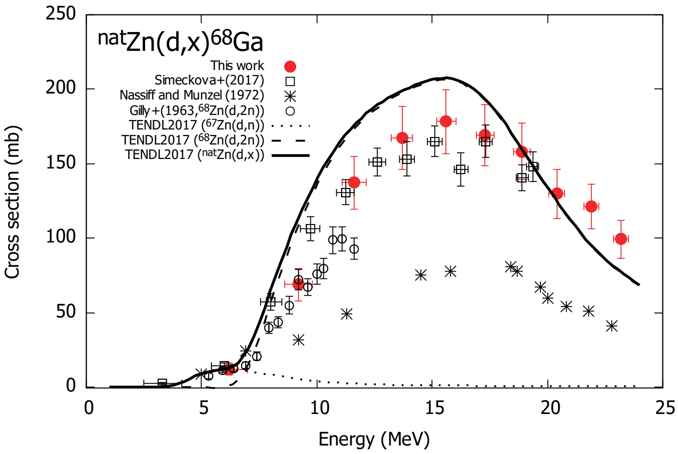

Fig. 1. Excitation function of the ^{nat}Zn$(d,x)^{68}$Ga reaction in comparison with previous data[2–4)] and the TENDL-2017 data.[7)]

The physical yield of the ^{nat}Zn$(d,x)^{68}$Ga reaction was deduced from the spline-fitted curve of the measured excitation function. The derived yield reaches 2.37 GBq/μAh at 23.2 MeV.

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