Production cross sections of ^{28}Mg via the α-particle-induced reaction on aluminum

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The radionuclide ^{28}Mg has a half-life of $T_{1/2}$ = 20.915 h and decays with the emission of a β^- particle and γ rays. These nuclear properties are appropriate for radiotracers in a wide range of applications.[1)] One of its promising production reactions is the α-particle-induced reaction on aluminum. We found ten experimental studies in the production cross sections of ^{28}Mg in a literature survey in the EXFOR library.[2)] However, the cross sections of the previous studies are largely scattered. Therefore, we conducted an experiment to determine reliable cross sections of the ^{27}Al$(\alpha, 3p)^{28}$Mg reaction.

The experiment to measure the activation cross sections of the reaction was performed at the RIKEN AVF cyclotron. The stacked-foil activation technique and high-resolution γ-ray spectrometry were used. Pure metal foils of ^{27}Al (>99% purity) and $^{\rm nat}$Ti (99.6% purity) were purchased from Nilaco Corp., Japan. The Ti foil was used for the $^{\rm nat}$Ti$(\alpha, x)^{51}$Cr monitor reaction. The average thicknesses of the Al and Ti foils were 13.7 and 2.23 mg/cm^2, respectively, which were derived from the measured size and weight of each foil. After the thickness measurement, the foils were cut into small pieces of 10 × 10 mm^2 to fit a target holder that served as a Faraday cup. The stacked target consisted of ten Al foils upstream and seven sets of Ti-Ti-Ti-Al foils downstream of the beam line. The upstream Al foils were used to derive activation cross sections of the ^{27}Al$(\alpha, 3p)^{28}$Mg reaction, the threshold energy of which is 24.8 MeV. The following Ti-Ti-Ti-Al foils were stacked for the $^{\rm nat}$Ti$(\alpha, x)^{51}$Cr monitor reaction in a lower-energy region. The stacked target was irradiated for 30 min with an α-particle beam. The initial energy of the α-particle beam was determined using the time-of-flight method.[3)] The average beam intensity was measured using the Faraday cup and found to be 216 nA. The energy degradation of the α-particle beam in the target foils was calculated using stopping powers obtained from the SRIM code.[4)] The γ-ray spectrometry was performed using a high-purity germanium detector (ORTEC GEM30P4-70) and dedicated analysis software (SEIKO EG&G Gamma Studio). γ rays emitted from each irradiated foil were measured without chemical separation three times (Ser. 1: 2.7–7.5 h, Ser. 2: 8.0–32 h, Ser. 3: 1.9–3.6 d). The dead time was kept below 1.4% throughout the measurements. Nuclear data used for cross-section derivation were retrieved from the online database, NuDat 3.0.[5)]

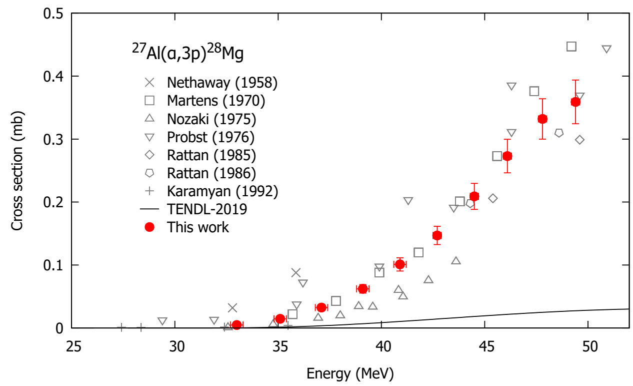

Fig. 1. Excitation function of the ^{27}Al$(\alpha, 3p)^{28}$Mg reaction in comparison with the previous studies found in the EXFOR library[2)] and the TENDL-2019 values.[6)]

The γ line at 1342.2 keV (I_γ = 54%) emitted with the decay of ^{28}Mg ($T_{1/2}$ = 20.915 h) was measured during the cooling time of 8.0–32 h (Ser. 2). The cross sections of the ^{27}Al$(\alpha, 3p)^{28}$Mg reaction were determined using the measured spectra. Figure 1 compares our preliminary result with the experimental data in the EXFOR library[2)] and the TENDL-2019 values.[6)] The cross section at the highest energy may be affected by the recoil effect and slightly decreased. The previous data of Martens *et al.*[7)] and Rattan *et al.*[8)] are consistent with our data, although their data deviate from each other in the higher-energy region. The other previous data are systematically larger or smaller than our data. The TENDL-2019 values are fairly smaller than all the experimental data. We will finish analyses of the measured γ-ray spectra and determine the production cross sections of radioactive products in the reaction.

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