Activation cross sections of α-particle-induced reactions on ^{nat}Ta[†]

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Cross sections of alpha-particle-induced reactions on natural tantalum targets were investigated up to 51 MeV. Because tantalum is a frequently used material in accelerator technology it is important to know the estimated amount of activity produced during an irradiation, for which knowledge of the excitation functions of the possible reactions is required. Among the relevant cross section data available in literature significant differences exist both in the peak position and in their amplitude. Therefore a new experiment was performed to investigate the ^{nat}Ta(α, x) reactions and to deduce more reliable cross sections data. The obtained cross section data are also essential for improving theoretical model predictions. The experiment was performed at the AVF cyclotron of RIKEN RI Beam Factory using the standard stacked-foil target arrangement, activation method and high-resolution γ-ray spectrometry technique. One complex target was irradiated, comprised with pure metallic foils of ^{nat}Ta (9 μm, 99.99% purity, from Goodfellow, UK) and ^{nat}Ti (5 μm, 99.6% from Nilaco Co., Japan). The ^{nat}Ti foils served as catcher foils to stop and collect the recoiled reaction products from Ta and were also used as monitor foils for the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction. The average foil thickness was determined from the lateral size and weight of a larger sheet of the foils. The derived thicknesses were 14.37 and 2.24 mg/cm^2 for the Ta and Ti foils, respectively. The target foil size was 10 × 10 mm. Foils were stacked into a target holder, served as a Faraday cup to collect the charge of the incident beam. Every Ta foil was paired with a Ti catcher foil. The foils were inserted in the stack in Ta-Ti-Ti sequence. Additional Ti foils were inserted into the stack at certain positions for monitoring the beam parameters and the energy loss of the alpha particles in the target stack. The irradiation was done with a 50.5 ± 0.2 MeV α-particle beam for 1 hour. The primary beam energy was measured employing the time-of-flight method.[1)] Energy degradation in the target was calculated using stopping power data derived from the SRIM code.[2)] The average beam intensity derived from the collected charge was 203 nA. The γ-ray spectra of the Ta and its Ti catcher foil pairs, as well as of the Ti monitor foils were measured by a high-resolution HPGe detector (ORTEC GEM-25185-P) and analyzed using dedicated software (SEIKO EG&G Gamma Studio and Genie2000). Several gamma-spectra were measured for each foil to follow the decay of the reaction products. To maintain a low dead time the detector to foil distance was adjusted.

The cross-sections of the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction were derived using the γ-line at 320.08 keV ($I_\gamma = 9.910\%$) from the decay of ^{51}Cr ($T_{1/2} = 27.7025$ d) and were compared with the recommended values of IAEA.[4)] Based on the comparison, the incident beam energy was increased by 0.13% to 50.6 MeV, and the thickness of the ^{nat}Ta foil was reduced by 0.12% to 14.36 mg/cm^2. Moreover, due to the escaping secondary electrons, the beam intensity was reduced by 3% to 197.2 nA. With these adopted changes, a good agreement was reached with the recommended values.

In principle, activation cross-sections could be deduced for several Re, W, Ta, Hf, and Lu reaction products. However, the experimental conditions were optimized for determination of the longer-lived reaction products. In those conditions determination of formation cross sections of ^{181,182m,182g,183,184m,184g}Re and ^{178g,182g}Ta was possible. Results on direct formation cross section for the ^{nat}Ta$(\alpha, x)^{184g}$Re reaction are presented in Fig. 1 together with the previous experimental data and the TENDL-2021 values.[4)] Data were assessed using the γ-line at 903.3 keV ($I_\gamma = 38.1\%$). Measurements were performed after a cooling time of more than 70 d. Data were corrected for contribution from decay of ^{184m}Re. The literature data are more or less consistent in position of the maximum, however, differences exist in the amplitude. The TENDL-2021 values disagree in amplitude around the maximum of the excitation function with the experimental data, however have good agreement above 30 MeV.

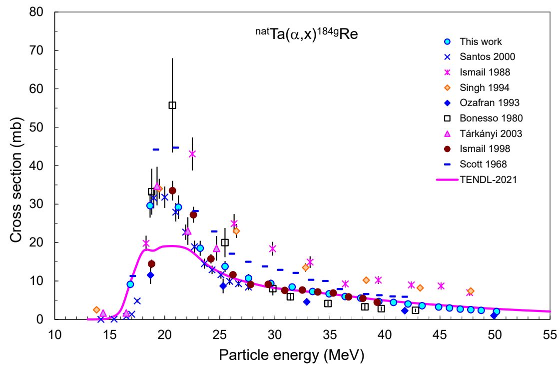

Fig. 1. Experimental cross-sections of the ^{nat}Ta$(\alpha, x)^{184g}$Re reaction in comparison with TENDL-2021[4)] values.

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