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

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Tantalum is a frequently used material in accelerator technology exploiting its proper physical characteristics. However, by irradiating it with energetic alpha particles several longlived radionuclides are produced. To estimate the possible activity produced during an irradiation, knowledge of the excitation functions of the possible reactions is required. In a literature survey, several experimental studies were found reporting data on different reactions. As significant difference exists in the peak position and amplitude among the different datasets, we decided to perform an experiment to investigate the ^{nat}Ta(α, x) reactions and to deduce more reliable cross-sections data of these reactions. Furthermore, the obtained results were compared with theoretical model prediction available in TENDL-2021 data library.[1)]

The experiment was performed at the AVF cyclotron of RIKEN RI Beam Factory employing the stacked-foil target, activation method and high-resolution γ-ray spectrometry. The target comprised pure metallic foils of ^{nat}Ta (nominal thickness 9 μm, 99.99% purity, from Goodfellow, UK) and ^{nat}Ti (nominal thickness 5 μm, 99.6% from Nilaco Co., Japan). The ^{nat}Ti foils served as catcher foils to stop and collect the recoiled reaction products and also as monitor foils for the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction. The average foil thickness was determined from the measured lateral size and weight of the original foils. The derived thicknesses of ^{nat}Ta and ^{nat}Ti foils were 14.37 and 2.24 mg/cm^2, respectively. Subsequently, the original foils were cut into a size of 10×10 mm and stacked into a target holder served as a Faraday cup to measure the incident beam intensity. Every Ta foil was set together with a Ti catcher foil. The other Ti foils were inserted into the stack at certain positions for monitoring, to obtain maximum information on the beam parameters and the energy loss of the beam in the target stack. The stacked target was irradiated 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.[2)] Energy degradation in the target was calculated using stopping power data derived from the SRIM code.[3)] The average beam intensity measured on the Faraday cup 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). The spectra of each foil were measured several times 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_γ = 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 thickness of the ^{nat}Ta foil was reduced by 0.12% to 14.36 mg/cm^2. Moreover, owing the escaping secondary electrons, the beam intensity was reduced by 3% to 197.2 nA. With these adopted changes, good agreement was reached with the recommended values.

Activation cross-sections can be deduced for several Re, W, Ta, Hf, and Lu reaction products. A preliminary result cross-section for the ^{nat}Ta$(\alpha, x)^{182g}$Re reaction is presented in Fig. 1 together with the previous experimental data and the TENDL-2021 values.[1)] Data were assessed using the γ-line at 1427.3 keV (I_γ = 9.8%) emitted following the decay of ^{182g}Re. Measurements were performed after a cooling time of 48 h. This gamma line can be considered as interference free, because only decay of possible co-produced ^{176}Ta may contribute above 38 MeV with a negligible, two orders of magnitude lower intensity. The earlier experimental data were consistent in terms of position of the maximum; however, certain differences exist in the am-

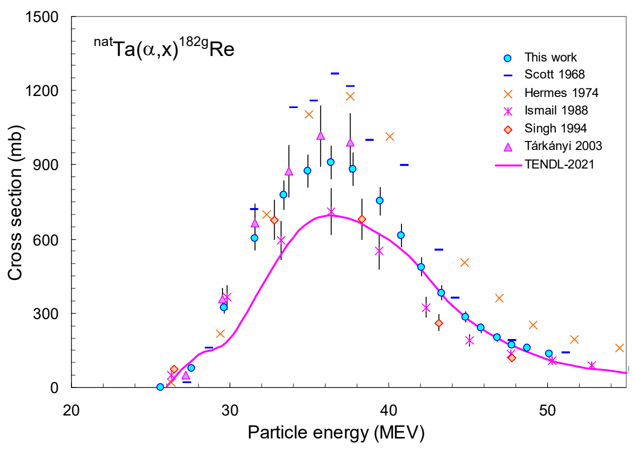

Fig. 1. Experimental cross-sections of the ^{nat}Ta$(\alpha, x)^{182g}$Re reaction in comparison with TENDL-2021 values.

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plitude. The TENDL-2021 values disagreed with the experimental data both in peak position and in amplitude. Preliminary results for the activation cross-sections have already been deduced for several reactions; however, owing to the long half lives of several reaction products, the γ-ray spectrometry measurements are still required and thus continued. Final results are expected in the second half of the year 2023.

References

1) A. J. Koning *et al.*, Nucl. Data Sheets **155**, 1 (2019).
2) T. Watanabe *et al.*, Proc. 5th Int. Part. Accel. Conf. (IPAC 2014), (2014), p. 3566.
3) J. F. Ziegler *et al.*, Nucl. Instrum. Methods Phys. Res. B **268**, 1818 (2010).
4) A. Hermanne *et al.*, Nucl. Data Sheets **148**, 338 (2018).