# Production cross sections of $^{198g}$Au in proton-induced reactions on $^{nat}$Pt†

G. Damdinsuren,[*1,*2] M. Aikawa,[*1,*2,*3] Kh. Tegshjargal,[*4] N. Erdene,[*4] N. Ukon,[*5,*2] and H. Haba[*2]

Gold-198 has two long-lived states, the ground state $^{198g}$Au ($T_{1/2}$ = 2.6941 d, $\beta^-$: 100%) and the excited state $^{198m}$Au ($T_{1/2}$ = 2.272 d, IT: 100%). The ground state $^{198g}$Au can be used in nuclear medicine, such as brachytherapy[1] and nanoparticles.[2] The neutron capture reaction on the monoisotopic element $^{197}$Au in a reactor can produce a considerable amount of $^{198g}$Au. However, this method yields only the low specific activity of $^{198g}$Au owing to the difficulty encountered in separating $^{198g}$Au from the Au target. The high specific activity $^{198g}$Au can be produced using charged-particle-induced reactions on platinum. In this study, the proton-induced reactions on $^{nat}$Pt targets were investigated. Moreover, the literature survey, only two experimental studies of cross sections of the $^{nat}$Pt$(p,x)^{198g}$Au reaction were found.[3,4] The literature data have large uncertainties and show discrepancy. Therefore, we conducted an experiment to provide reliable cross sections of the $^{nat}$Pt$(p,x)^{198g}$Au reaction. Thus, the results of this study were compared with the previous data and theoretical model calculation in the TENDL-2019 library.[5]

The stacked-foil activation technique and high-resolution $\gamma$-ray spectrometry were used for cross section. Pure metallic foils of $^{nat}$Pt (20-$\mu$m thick, 99.95% purity) and $^{nat}$Ti (5-$\mu$m thick, 99.6% purity) were purchased from Nilaco Corp., Japan. The stacked target was composed of $^{nat}$Pt and $^{nat}$Ti foils. The $^{nat}$Ti foils were used for the $^{nat}$Ti$(p,x)^{48}$V monitor reaction for assessment of the beam parameters and the target thicknesses. Size and weight of the original foils were measured and the average foil thicknesses were derived. The derived average thicknesses of the $^{nat}$Pt and $^{nat}$Ti foils were 39.2, and 2.24 mg/cm$^2$, respectively. Both original foils were cut into a size of 10 × 10 mm. Twenty-five sets of Pt-Pt-Ti-Ti foils were stacked in a target holder served as a Faraday cup.

The stacked target was irradiated with a proton beam. The irradiation lasted for 30 min. The primary beam energy measured by the time-of-flight method[6] was 30.1 ± 0.1 MeV. Consequently, the beam energy at each foil was calculated using stopping powers derived from the SRIM code.[7] The average beam intensity was 101 nA, which was derived from irradiation period and charge collected by the Faraday cup.

$\gamma$ rays emitted from irradiated foils were measured by a high-resolution HPGe detector (ORTEC GEM-25185-P) and analyzed using dedicated software (SEIKO EG&G Gamma Studio). Only the second foil of the same element pairs was measured because products recoiled from the second foil were assumed to be compensated from the first foil. The dead time throughout the measurement was less than 4.7%.

Cross sections of the $^{nat}$Ti$(p,x)^{48}$V monitor reaction were derived using the $\gamma$ line at 983.5 keV ($I_\gamma$ = 99.98%) from the decay of $^{48}$V ($T_{1/2}$ = 15.9735 $d$). The derived cross sections were consistent with the IAEA-recommended values.[8] Thus, the measured beam parameters and target thicknesses were adopted without corrections for deduction of cross sections.

The cross sections of the $^{nat}$Pt$(p,x)^{198g}$Au reaction were determined using the measurement of the $\gamma$ line at 411.80205 keV ($I_\gamma$ = 95.62%) from the decay of $^{198g}$Au. The measurement was performed following a cooling time of 13 d. The possible contribution through decay of $^{198m}$Au ($T_{1/2}$ = 2.272 d, IT: 100%) was negligibly small because intense $\gamma$ lines of $^{198m}$Au could not be found in any spectra. Figure 1 shows the derived cross sections in comparison with the previous experimental data[3,4] and TENDL-2019 values.[3] The excitation function exhibited a smooth curve and was consistent with previous experimental data within the uncertainty; although certain data points of Tárkányi *et al.*[3] were deviated. The peak amplitude and position of the TENDL-2019 values were slightly different from the experimental cross sections although the trend was similar.

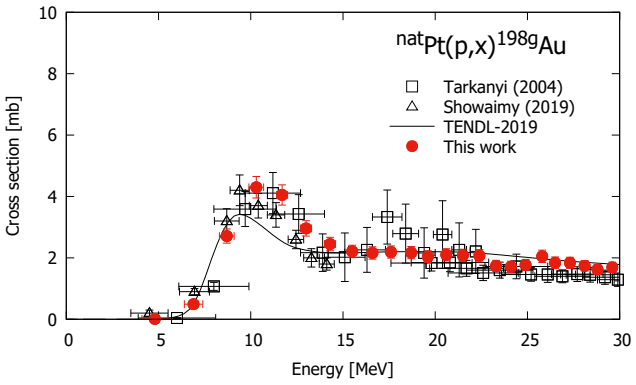


Fig. 1. Excitation function of the $^{nat}$Pt$(p,x)^{198g}$Au reaction.

† Condensed from the article in Appl. Radiat. Isot. **192**, 110621 (2023)

*1 Graduate School of Biomedical Science and Engineering, Hokkaido University
*2 RIKEN Nishina Center
*3 Faculty of Science, Hokkaido University
*4 School of Engineering and Applied Sciences, National University of Mongolia
*5 Advanced Clinical Research Center, Fukushima Medical University

G. Damdinsuren was granted a scholarship by the M-JEED project (Mongolian-Japan Engineering Education Development Program, J11B16). This work was partially supported by JSPS KAKENHI Grant No. 22H04961.

References

1) M. Konishi *et al.*, J. Radiat. Res. **62**, 871 (2021).
2) R. Chakravarty *et al.*, Nucl. Med. Biol. **72**, 1 (2019).
3) F. Tárkányi *et al.*, Radiochim. Acta **92**, 223 (2004).
4) H. Showaimy *et al.*, Radiat. Phys. Chem. **157**, 97 (2019).
5) A. J. Koning *et al.*, Nucl. Data Sheets **155**, 1 (2019).
6) T. Watanabe *et al.*, Proc. 5th Int. Part. Accel. Conf. (IPAC 2014), (2014), p.3566.
7) J. F. Ziegler *et al.*, Nucl. Instrum. Methods Phys. Res. B **268**, 1818 (2010).
8) F. Tárkányi *et al.*, IAEA-TECDOC-1211 (2007).