# Transmutation half-life of the fission product, $^{107}$Pd

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## Introduction

Nuclear power is widely regarded as a crucial component of national energy systems in many countries due to its economic competitiveness and its significant role in reducing carbon emissions. In present times, the management of high-level radioactive waste from reactors has become a major issue and numerous research and technological developments are being carried out to address this challenge. The nuclear waste constitutes two major components: minor actinides and long-lived fission products (LLFPs), which when disposed off in stable deep geological repository by conventional methods would remain radioactive for a very long period of time. One way to address this issue is the transmutation of LLFPs into stable or short-lived isotopes, leading to reduction in the radioactive waste inventory and long-term hazard for future generations [1–4]. Although LLFPs constitute only about 0.2% of radioactive waste, they should be eliminated because of their long-term risk and high radiotoxicity. The transmutation of LLFPs has not been extensively studied. In this abstract, we report on the investigations leading to the calculated cross section and effective half-life of transmutation for one such nuclei, $^{107}$Pd, which has a half-life of $6.5\times10^6$ y, using (p,n) reactions.

After isotopic separation of the spent fuel obtained from nuclear reactors is carried out, the Pd isotopes remaining will include the stable, $^{102,104,105,106,108}$Pd and radioactive, $^{107}$Pd ones. Since the effective transmutation half-life, $T_{1/2}^{eff}$, depends on the cross section, reactions must be chosen such that the cross sections are higher and thereby, lower $T_{1/2}^{eff}$ is achieved. The thermal neutron-capture cross section for $^{107}$Pd is relatively high with a value of 2.79 b [2]. In addition, this reaction leads to the formation of $^{108}$Pd, which is a stable isotope, however, $^{106}$Pd present along with $^{107}$Pd in the waste creates $^{107}$Pd, which is the nuclei we want to transmute. Therefore, neutron-capture reactions are not acceptable and we must explore other reactions. The (p,n) reactions on stable and unstable nuclei present in the waste, on the other hand, leads to stable and short-lived Ag nuclei. The proton-induced reaction cross sections are not as high as that of the neutron-capture reactions, and the further investigations would reveal their feasibility.

## Formalism

The cross sections for (p,n) reactions on stable and the unstable, $^{107}$Pd isotopes have been calculated using the latest and modular TALYS-2.0 [5] code for the incident proton energies up to 20 MeV. The cross-section calculations in the compound nuclear theory are based on Hauser-Feshbach formalism. The detailed methodology has been given in Ref. [1, 6]. We have explored both the optical models available in the code *i.e.,* the global Koning-Delaroche and the extended Jeukenne-Lejeune-Mahaux. The statistical nature of the compound nuclear decay is determined using the phenomenological Back-shifted Fermi gas (BFM) level density model, which is the default one provided in the code. Although, we have explored other level density models, we have reported the results from only the BFM. The masses of the nuclei necessary for the calculations are taken from the experimental values, and for those not available, predicted values have been used. All the other models and parameters used for the calculations are the default ones from the code.

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## Results and Discussion

The (p,n) reaction cross sections, $\sigma_{(p,n)}$, for all the stable isotopes and LLFP, $^{107}$Pd, have been calculated and compared with data [7] and nuclear data library, TENDL-2023. The calculated differential elastic scattering and total reaction cross sections were also compared with the available data [7]. In the absence of data, we have predicted the respective cross sections as described in [8, 9]. The (p,n) reaction cross sections for only $^{104,106}$Pd isotopes are presented in Fig. 1.

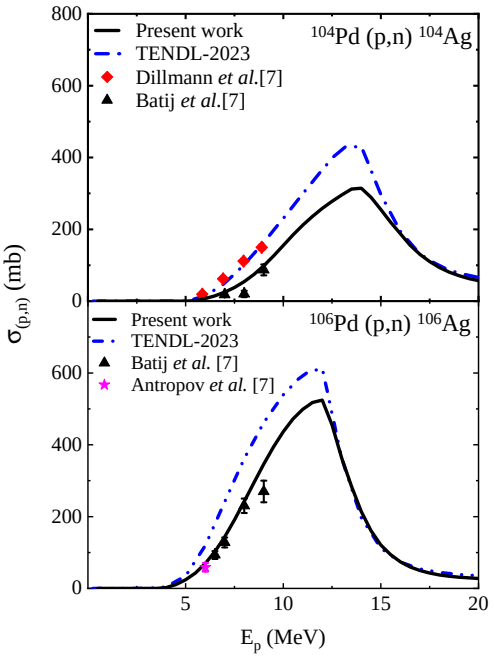


FIG. 1: Calculated cross sections, $\sigma_{(p,n)}$, for $^{104,106}$Pd(p,n) reactions.

As can be seen from the figure, the calculated $\sigma_{(p,n)}$ is lower than that calculated from TENDL, but agrees with the data from Batij *et al.* [7], while, the TENDL-calculated $\sigma_{(p,n)}$ agrees with the data from Dillmann *et al.* [7] for $^{104}$Pd. In the case of $^{106}$Pd, our calculated $\sigma_{(p,n)}$ shows good agreement with data from Batij *et al.* [7] and Antropov *et al.* [7]. Both our calculation and TENDL show differences up to the peak region and beyond this energy, they are similar. More precise data for $\sigma_{(p,n)}$ for both the isotopes are required. Once the calculated cross sections are finalized for the stable isotopes, $\sigma_{(p,n)}$ will be predicted for $^{107}$Pd and $T^{eff}_{1/2}$ will be determined.

The $T^{eff}_{1/2}$ for the transmutation of $^{107}$Pd, in addition to the dependence of the reaction cross section, is also dependent on the beam flux and decay constant. Selecting nuclear reactions with high cross sections and appropriate beam flux is important for reducing the transmutation half-life. For the transmutation of $^{107}$Pd, the $T^{eff}_{1/2}$ will be calculated using the formula given in Ref. [1]. This method will verify the feasibility of the proton-induced reactions on LLFP, $^{107}$Pd.

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