# The Evaluation of Neutron Cross Section for Palladium-107 in the Resonance Energy Region

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## 1. Introduction

The resonance parameters for the palladium-107, which contributes ~6% of the total fission product poisoning in fast reactors, were evaluated using the weight average method, the Porter-Thomas distribution and the Bayesian in the resonance energy region. The quantum numbers and neutron reaction widths were assigned for each resonance in the resolved resonance region. The neutron strength functions, the average level spacing and the average capture width were determined in the unresolved resonance region and were prepared in the format of ENDF file.

## 2. Evaluation Procedure

### *2.1 Evaluation Procedure*

The neutron cross sections could be calculated with the R-matrix theory. The evaluation is to assign the parameters included in the cross section equation. The resonance energy region consists of two parts, the resolved and unresolved resonance region. In the resolved resonance region, the orbital angular momentum and spin are assigned using the weight average method, the Porter-Thomas analysis and the Bayesian approach. In the unresolved resonance region, the average level spacings, strength functions and the average radiative widths are determined.

We used the evaluation procedure that has been established of the Korea Atomic Energy Research Institute [1]. First step is to retrieve the information on the nuclide from the CINDA (the Computer Index to Nuclear Data: neutron reaction data bibliography) or EXFOR (Experimental Nuclear Reaction Data) database. After reviewing the available measurements, numerical data of the resolved resonance parameters are prepared as an electronic file BNL325.txt using the ORDER code. Second step is to assign the orbital angular momentum ($l$) of the incident neutron and the total resonance spin ($J$) using the ANAL code. The p-wave ($l$=1) resonances are distinguished from s-wave ($l$=0) resonances using the Bayesian method. If the probability of being the p-wave is more than the s-wave, the angular momentums are assigned $l$=1. Else, the value of angular momentums is 0. The resonance spin is randomly assigned using the (2$J$+1) law. Third step is to check the thermal cross sections. The thermal characteristics are calculated by using the PSY325 code. Last step is to average the level spacings and the neutron strength functions by using the WRIURR code in the unresolved resonance region.

### *2.2 Neutron Cross Section Evaluation for Palladium-107*

In 1985, Macklin measured the capture cross section up to 3.5 keV [3]. One hundred thirty resonance peaks were parameterized up to 3.5 keV and the average cross section from 3 to 600 keV was derived. These data have been used the evaluation of JENDL-3 and ENDF/B-VI. But the capture cross section to be calculated with the parameters of JENDF-3 was inconsistent with the experimental data in the unresolved resonance region. There are no parameters in the unresolved resonance region in the ENDF-VI.

In this evaluation, we reevaluated the resonance parameters in the resolved resonance region and determined the average resonance parameters in the unresolved resonance energy region. We used the parameters of Macklin up to 1.4 keV. We used the thermal capture and elastic scattering cross section of BNL compilation [2] as a reference. The integrated capture cross section was calculated with the parameters of BNL compilation in this study.

## 3. Results and Discussions

The upper energy of resolved resonance region was set to 800 eV to adjust the average capture cross section between the resolved and the unresolved resonance energy region. Fig. 1 shows the capture cross section and the average capture cross section. The URR is up to 100 keV the first exciting state energy of inelastic scattering. There were 53 resonances in the resolved resonance region.

The orbital angular momentum was set to 0 on the basis of the ENDF/B-VI. The resonances of Pd-107 have two spin values, 2 and 3 when the orbital angular momentum is 0. Usually the spins of resonances were assigned randomly because the difference of the probability to distinguish the spin is very small. In this study, when the spins were assigned randomly, the thermal capture cross section was bigger than the reference. So, we assigned the spin according to the capture area parameters of Macklin et al. to reproduce the thermal cross section of reference [2]. The capture cross section of the resonance, which has the spin value J=3, was bigger than J= 2. The spin statistical factor ($g$) was 0.58333 for $J$=3 and 0.41667 for $J$=2. So, the 31 resonances of the total resonances were assigned $J$=3 and 12 resonances were assigned $J$=2. Table 1 shows the values of thermal characteristic.

In the unresolved resonance region from 800 eV to 100 keV, the average level spacings, strength functions and the average radiative widths were determined. Present evaluation adopted the values of the strength functions from the BNL compilation and level spacings from the Macklin et al.. The average capture widths were adjusted to reproduce the capture cross section of the experiment. Fig. 2 shows the capture cross sections constructed from the present resonance data as well as those in JENDL-3. Table 2 shows the average resonance parameters in URR.

Table 1. Thermal Characteristics of Palladium-107(E: the upper energy of the resolved resonance region, $\sigma_\gamma$: capture cross section, $\sigma_s$: scattering cross section, R': effective scattering radius, $I_\gamma$: integrated capture cross section)

| | UNIT | Present | Random spin assignment | BNL[2] | JENDL-3 | ENDF/B-6 |
|---|---|---|---|---|---|---|
| E | eV | 800 | 700 | 653 | 1000 | 1000 |
| $\sigma_\gamma$ | barns | 1.94 | 2.34 | 1.80 | 2.00 | 2.07 |
| $\sigma_s$ | barns | 4.46 | 2.57 | 4.65 | 3.32 | 3.07 |
| R' | fm | 6.64 | 6.64 | - | 6.5/6.025 | 5.73 |
| $I_\gamma$ | barns | 110.89 | 111.82 | 98.04 | 111.28 | 99.25 |

Table 2. Average resonance parameters in the unresolved resonance region

| | Unit | Present | BNL [2] | JENDL-3 |
|---|---|---|---|---|
| $S_0$ | $\times 10^{-4}$ | 0.56 | - | 0.81 |
| $S_1$ | $\times 10^{-4}$ | 5.80 | - | 3.03 |
| $S_2$ | $\times 10^{-4}$ | 0.56 | - | 0.96 |
| $\langle D_0 \rangle$ | eV | 10.6 | 15±3 | - |
| $\langle D_1 \rangle$ | eV | 5.3 | - | - |
| $\langle \Gamma_0 \rangle$ | meV | 280.0 | - | 125.0 |
| $\langle \Gamma_1 \rangle$ | meV | 230.0 | - | 125.0 |
| $\langle \Gamma_2 \rangle$ | meV | 230.0 | - | 125.0 |

## 4. Conclusion

We have evaluated the neutron cross section of Palladium-107 in the resonance energy region. In this evaluation, the upper energy of resolved resonance region was set to 800 eV and the spin of resonances was assigned according to the capture area parameters. Also, the average resonance parameters in the unresolved resonance region were determined and were prepared in the format of ENDF file.

**Acknowledgement**

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## REFERENCES

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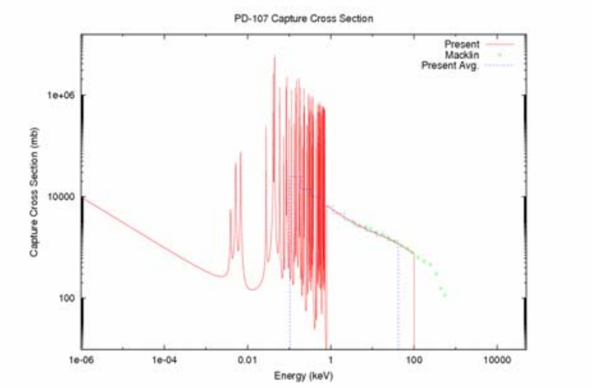


Fig 1. Capture cross section and average cross section

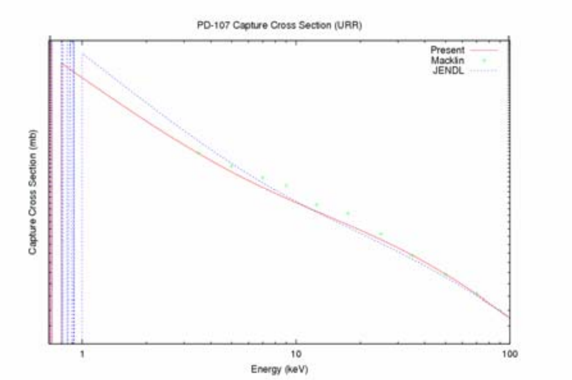


Fig 2. Comparison of capture cross section in the unresolved resonance region from 800 eV to 100 keV