The Evaluation of Neutron Cross Section of Thorium-232 in the Resonance Energy Region

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1. Introduction

The neutron cross sections play a major role in the area of reactor physics and design, as well as safety analysis. Therefore, more accurate nuclear data are indispensable. Recently, the thorium fuel cycle has been interested as an alternative fuel option in the aspect of non-proliferation. In this study, neutron resonance parameters of thorium-232 are evaluated.

2. Evaluation Procedure

2.1 Evaluation Procedure

The resonance energy region consists of the 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, average level spacings, strength functions and average radiative widths are determined.

We used the evaluation procedure that has been established in 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 incident neutron and the total resonance spin(J) using ANAL code. The p-wave(l=1) resonances are distinguished from s-wave(l=0) resonances using the Bayesian method. The resonance spin is randomly assigned using the (2J+1) law. Third step is to check the thermal cross sections. The thermal characteristics are calculated by using PSY325 code. Last step is to average the level spacings and the neutron strength functions by using WRIURR code in the unresolved resonance region.

2.2 Evaluation of Thorium-232 Resonance Parameters

We used the resonance parameters of Thorium-232 from S.F. Mughabghab's data[2] and Kobayashi's data[3]. The atomic mass of Thorium-232 is 232.038 amu[4]. The thermal capture cross section is 7.35±0.03 barns and the integrated capture cross section is 85±3 barns[5].

3. Results

In resolved resonance region from 0 to 4 keV, the assignment of l values according to Bayesian approach resulted in 151 s-wave and 216 p-wave resonances. The resonance parameters such as neutron widths, gamma widths and energy are prepared in the format of ENDF file. In the thermal energy region it is shown that the evaluated capture and scattering cross sections are well agreed with ENDF/B-VI, JENDL-3, JEF-2 and CENDL-2 data. To reproduce the reference thermal characteristics, one bound level was invoked.

Table 1. Thermal Characteristics of Thorium-232(σ_γ: capture cross section, σ_s: scattering cross section, R': effective scattering radius, b': coherent scattering radius, I_γ: integrated capture cross section

	UNIT	JEF2	CENDL	JENDL-3	ENDF/B-6	Present
σ_γ	barns	7.4	7.4	5.107	7.4	7.35
σ_s	barns	11.817	13.705	12.721	12.948	12.043
R'	fm	8.987	10.250	10.010	9.72	9.65
B'	fm	8.533	9.776	9.536	9.253	9.789
I_γ	barns	85.414	84.240	83.289	85.889	84.626

In the unresolved resonance region form 4 keV to 50 keV, average level spacings, strength functions and average radiative widths are determined. Present evaluation adopted the values of strength functions and level spacings obtained from the analysis of resolved resonances without any adjustment. Instead of the assumed average capture width, 24.15 meV of the resolved resonances, it was adjusted to 30 meV for s-wave and 40 meV for p-wave to reproduce Wisshak's capture cross sections[6]. Fig. 3 shows capture cross sections constructed from the present resonance data as well as those in other existing libraries.

4. Conclusion

We have evaluated the neutron cross section of Thorium-232 in the resonance energy region. The quantum numbers and neutron reaction widths were assigned for each resonance in the resolved resonance region. In thermal region, thermal characteristics were calculated and one bound level was added to reproduce the thermal capture cross section. The averaged neutron strength functions and level spacings were calculated in the unresolved resonance region.

Table 2. Average Resonance Parameters for the Unresolved Resonance Region (S: Neutron Strength Function [10-4], <D>: Average Level Spacing [eV], < Γγ>: Average Capture Width [meV])

	Orbital Angular momentum, l	ENDF/B-VI	JENDL-3	JEF-2	Present
S	0	0.89	0.95	0.95	0.86
	1	1.53	2.01	2.01	2.11
<D>	0	17.0	18.0	18.0	14.0
	1	17.0	18.0	18.0	13.53
$<\Gamma_\gamma>$	0	21.3	21.2	21.2	30
	1	25.2	21.2	21.2	40

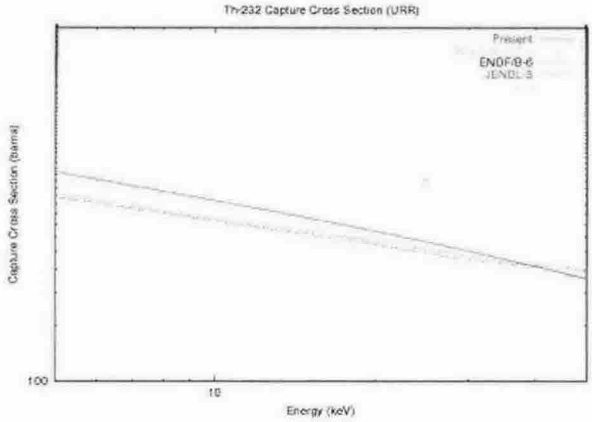

Fig. 3 Capture Cross Section in the Unresolved Resonance Region from 5 keV to 50 keV

REFERENCES

[1] Soo-Youl Oh, Jonghwa Chang, Said Mughabghab, Neutron Cross Section Evaluations of Fission Products Below the Fast Energy Region, BNL-NCS-67469(ENDF-362, KAERI/TR-1511/2000), KAERI and BNL, 2000

[2] S. F. Mughabghab, Neutron Cross Sections, Volume 1: Neutron Resonance Parameters and Thermal Cross Sections, Part B : Z=61-100, Academic Press, Inc., 1984

[3] Kobayashi, Ann. Nucl. Energy. vol. 15, no. 8, pp. 381-388, 1988

[4] Jonhwa Chang, Table of nuclides, KAERI/GP-106/95, KAERI, 1998

[5] S.F. Mughabghab, Thermal Neutron Capture Cross Sections Resonance Integrals and G-Factors, INDC(NDS)-440, 2003

[6] K. Wisshak, F. Voss, and F. Kappler, Neutron Capture Cross Section of ^{232}Th, Nucl. Sci. and Eng., vol. 137, 183-193, 2001