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The Evaluation of Neutron Cross Section for Erbium-166 in the Resonance Energy Region

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1. Introduction

Erbium is one of the burnable poisoning in nuclear reactors. The abundance of Er-166 is 33.4% and is the biggest among the erbium isotopes. The resonance parameters of Er-166 in the ENDF/B-VI have been evaluated by R. Q. Wright in 1990. Since then the new results from the experiments and the evaluations were reported. K. Knopf measured the scattering radius, 7.6 fm in 1997[5]. The total cross sections from 0.001 to 20 eV were detected and the resonance parameters were evaluated by Y. Danon in 1998[3]. In 2000, A.K.M. Harun-Ar-Rashid measured the capture cross sections from 13.0 to 564.0 keV[6]. The thermal capture cross sections and resonance integrals have been evaluated by Mughabghab in 2003[4]. In this study, we have reevaluated the resonance parameters in the resonance energy region to provide more accurate nuclear data. Our evaluation procedures are described in the next section.

2. Evaluation Procedures

The neutron cross sections could be calculated with the R-matrix theory. The evaluation is to assign the resonance 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 for each resonance are assigned using the weight average method, the Porter-Thomas analysis and the Bayesian analysis. In the unresolved resonance region, the average level spacings, strength functions and the average radiative widths are determined on the basis of the resolved resonance parameters.

We used the evaluation procedure that has been established by 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 the 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. Otherwise, the value of angular momentums is 0. 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 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.

3. Results and Discussions

The 173 resonance peaks were parameterized up to 9.5 keV in the BNL compilation [2]. This data has been used in JENDL-3 and ENDF/B-VI. But the capture cross section calculated with the parameters of ENDF/B-VI was inconsistent with the experimental data in the unresolved resonance region. There are no the unresolved resonance parameters in the ENDF-VI.

In this evaluation, we reevaluated the resonance parameters in the resolved resonance region and adjusted the average resonance parameters in the unresolved resonance energy region. We used the parameters of the BNL compilation up to 9.5 keV and Danon on 15.57 eV. The orbital angular momentum was set to 0 on the basis of the ENDF/B-VI and the result of Bayesian analysis. The spin value of resonance is 0.5 when the orbital angular momentum is 0. The upper energy of the resolved resonance region was set to 2500 eV to make the smooth connection of the average capture cross section between the resolved and the unresolved resonance energy region. Fig. 1 shows the total cross section and the average total cross section. There were 64 resonances in the resolved resonance region. Table 1 shows the values of thermal characteristic. The thermal capture and scattering cross sections, and the effective scattering radius are the same as the reference values. -

The unresolved resonance region is from 2500 eV to 100 keV, the first exciting state energy of inelastic scattering. The average level spacings, strength functions and the average radiative widths were adjusted to reproduce the experimental capture cross section. 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 the URR.

Table 1. Thermal Characteristics of Er-166(E: the upper energy of the resolved resonance region, σ_γ: capture cross section, σ_s: scattering cross section, R': effective scattering radius, I_γ: integrated capture cross section)

	UNIT	Present	Reference	BNL[2]	JENDL-3	ENDF/B-6
E	eV	2476.2	-	9486.2±6.3	2931.8	2128.9
σ_γ	barns	16.2	16.2±0.2[3] 16.9±1.6[4]	19.6±1.5	16.8	19.6
σ_s	barns	12.0		14.2 ±2.1	12.4	17.2
R'	fm	7.6	7.6±2.0[5]	8.1±0.2	8.3	8.1
I_γ	barns	101.2	95.0±7.0[4]	96.0±12.0	112.16	99.2

Table 2. Average resonance parameters in the unresolved resonance region from 2.5 to 100 keV

	Unit	Present	BNL [2]
S_0	$\times 10^{-4}$	1.7	1.6±0.2
S_1	$\times 10^{-4}$	1.5	0.94±0.16
$\langle D_0 \rangle$	eV	38.4	38.0±3.0
$\langle D_1 \rangle$	eV	13.5	-
$\langle \Gamma_0 \rangle$	meV	100.0	-
$\langle \Gamma_1 \rangle$	meV	130.0	-

4. Conclusions

The resonance parameters of Er-166, one of the burnable poisoning in the nuclear reactor were evaluated in the resonance energy region. The evaluated resonance parameters were prepared in the format of ENDF file

Acknowledgement

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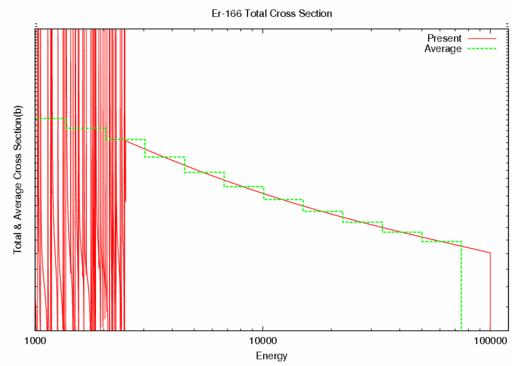

Fig 1. Total cross section and average total cross section

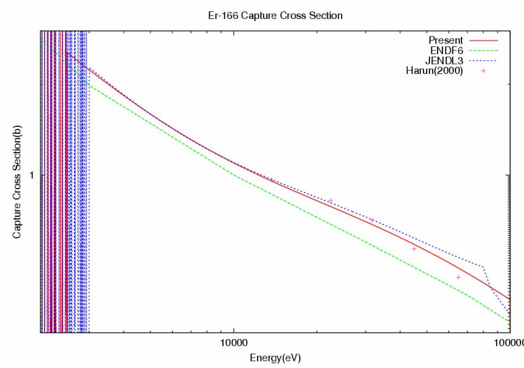

Fig 2. Comparison of capture cross section in the unresolved resonance region from 2500 eV to 100 keV