Critical analysis for nuclear data of thermal neutron capture cross section and the resonance integral for the reaction ^{238}U(n,γ)^{239}U from library based on neutron activation measurements

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1. Introduction

The nuclear data is a fundamental data base for nuclear technology and science. It has played an important role in the knowledge of neutron physics, development of nuclear energy, national security and nuclear astrophysics applications [1]. Measurements of thermal neutron capture cross sections (σ_0) and resonance integrals (I_0) of most nuclides are currently necessary for the calculations of neutron transport, assessments of reactor safety, investigations of high burn-up core characteristics, decay heat power predictions and for nuclear transmutation studies. Despite of the critical analysis currently available in the literature, it is very important to check frequently the nuclear data using a technical sense criteria and whenever possible based on quality tools. The main purpose of this work is to make an assessment of nuclear data for ^{238}U(n,γ)^{239}U nuclear reactions, through the neutron activation and gamma ray measurements. The impact of the difference among the nuclear data libraries was examined based on neutron activation equation with appropriate methodology. From the above motivation, I have analysed the nuclear data of thermal neutron capture cross section and the resonance integral for the reaction ^{238}U(n,γ)^{239}U.

2. Theoretical methodology

The relationship between activation rate, the number of target nuclei and the neutron flux is expressed as $A_0 = \sigma_0 \phi w N_A \theta / A$, where A_0 is the activation rate, σ_0 is the capture cross section, ϕ is the neutron flux, w is the mass of the element, N_A is the Avogadro's number, θ is the isotopic abundance and A is the atomic weight of the element. The neutron cross section for a particular nucleus will depend on the energy of the neutron. Many nuclei, particularly of low atomic number absorb thermal neutrons with cross sections which decrease linearly with increasing velocity of the neutron, the $1/v$ absorbers. But not all target nuclei are $1/v$ absorbers and there are many examples of nuclei which preferentially absorb epithermal neutrons. At these higher energies the neutron cross section is referred to as resonance integral and the radioactive capture resonance integral I_0 is used. In these cases it is important to include the resonance integral term in the above equation: $A_0 = \sigma_0 \phi_t N + I_0 \phi_e N$, where N is the number of target nuclei and equal to $w N_A \theta / A$, ϕ_t is the thermal neutron flux and ϕ_e is the epithermal neutron flux. If the activation product is radioactive and decays with its characteristic half-life, the activity at the end of the irradiation time t can be expressed after some mathematical manipulation by: $A_0 \equiv (\sigma_0 \phi_t + I_0 \phi_e)(1 - e^{-\lambda t})N$. A two terms simple separation in the above equation was used in this work for theoretical comparison with experimental data with $\sigma_0 \phi_t + I_0 \phi_e = \frac{A_0}{N(1-e^{-\lambda t})}$. The left term of this equation was identified as the theoretical data from library, DL, and the right term identified as the experimental data, ED. In order to check the nuclear data, the nuclear reactions is selected in this work, namely, ^{238}U(n,γ)^{239}U and their thermal neutron capture cross section (σ_0) and the resonance integral (I_0) from different libraries were used for comparative analysis. The neutron flux will be monitored using ^{197}Au(n,γ)^{198}Au($T_{1/2}$=2.6948d, decay gamma energy = 411.802 keV, with

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TABLE I: Thermal cross section and resonance integral data from library. (*) Calculated values, (**) Cross sections are calculated from JENDL-3.3 at 300 K

Target ^{238}U	σ_0 (barn)	I_0 (barn)	Ref
	2.75±0.05	284±7	2,3
	2.68±0.019	277±3	4
	2.74±0.06	280±10, 281±20	5
	2.71±0.02	287	
	2.71±0.02	279±7*	
	2.74±0.06	279±7*	
	2.70±0.03	277±8	6
	2.717	278.1±7	7
	2.70±0.02	275±5	8
	2.70±0.02	275±5	9
	2.724 JENDL-3.3**	278.1 JENDL-3.3**	10

intensity 95.62%) and ^{59}Co(n,γ)^{60}Co, standard cross section of ^{197}Au(n,γ)^{198}Au and ^{59}Co(n,γ)^{60}Co by the ENDF/B-7.1 will be used for normalization.

3. library data

Nuclear data from library used for the comparative analysis for thermal neutron cross section and resonance integral are given in Table 1. Different methodologies for thermal neutron cross section and resonance integral measurements experimented by the authors basically were carried out using neutron activation and gamma ray measurements.

4. The experimental data for ^{238}U$(n,\gamma)^{239}$U reaction

The values of experimental data for ^{238}U(n,γ)^{239}U reaction were determined by using the activity of ^{239}Np, measured by gamma spectrometry analysis, according to nuclear reaction, ^{238}U(n,γ)^{239}U$\xrightarrow{\beta}{}^{239}N_p$ $\xrightarrow{\beta}{}^{239}P_u$ and $A_U = \lambda_U \left[\frac{N-N^0e^{-\lambda t}}{(1-e^{-\lambda_U t})e^{-\lambda t}}\right]$ where A_U is the specific activity of ^{239}U at the end of activation, λ_U is the decay constant of ^{239}U, λ is the decay constant of ^{239}Np, N and N^0 are the number of atoms of ^{239}Np in the beginning of gamma ray measurements and at the end of activation, respectively, and t is the time elapsed between the final of activation and the start of the gamma counting.

TABLE II: Thermal cross section and resonance integral data from library.

Target	LD average (n/s)	ED average (n/s)
^{238}U	0.119±0.0001	0.120±0.010

5. Results

The results of the experimental measurements are compared with the data library calculated in the following equations and are listed in Table 2. LD=$(\sigma_0\phi_t + I_0\phi_e)\times10^{-10}$, ED=$\frac{A}{N(1-e^{-\lambda t})}\times10^{-10}$. According to the data of the Table 1 and 2 and the equations it is possible to realize that the thermal cross section and resonance integral data listed by the most of the authors are in a good agreement with the experimental data. Further, the result averages of authors data are in a good agreement with the experimental data. The details will be presented.

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