Analysis of the thermal neutron capture cross sections and resonance integrals of the ^{80}Se(n,γ)^{81m,g}Se reactions

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Introduction

Knowledge of neutron physics quantities plays an important role in development of nuclear energy, national security and nuclear astrophysics applications[1,2,3,4]. Measurements of thermal neutron capture cross sections (σ_0) and resonance integrals (I_0) of most nuclide's 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. Neutron cross-section data are important for two purposes: first they provide insight into the nature of matter, increasing our understanding of fundamental physics. Second, they are needed for practical applications (e.g., for calculating when and how a reactor will become critical, or how much shielding is needed for storage of nuclear materials, or for medical applications). The thermal neutron capture cross section of a specific nuclide cannot be predicted by theoretical calculations. For energies near the first neutron absorption resonance, the order of magnitude of the energy separation between bound states embedded in the continuum is 1 keV, and the thermal cross-section can be sensitive to changes of a few eV in the position of the first resonance. The currently available nuclear models cannot predict neither which will be the first level above the neutron separation energy nor the position of a level with such precision. An analogous comment can be made on the resonance integral cross- section, which is the nuclide average cross-section in a 1/E neutron kinetic energy spectrum, because the resonances in the first few keV represent the major part of its value. Therefore, the thermal and resonance integral cross-sections can be assessed only by experimental methods. After these quantities were measured, nuclear model calculations can predict at least partially the cross-section energy dependence.

TABLE I: Reported data for the ^{80}Se(n,γ)^{81m,g}Se reactions cross sections in barns

Author	Year	σ_0(b)	I_0(b)	Isomer ratio
Pomerance	1952	0.59±0.06		
Apers	1957			0.12±0.03
Keisch	1963			0.17±0.02
Bishop	1964			0.12±0.01
Goldberg	1966	0.61±0.05		
Ricabarra	1968		1.43±0.16	
Van der Linden	1972	0.08	0.50±0.02	
Heft	1978		1.57±1.0	
Mughabghab	1981	0.08±0.01	0.34±0.09	
		0.53±0.04		
		0.61±0.05	2.0±0.6	
Mughabghab	2003	0.61±0.05	1.6±0.2	
JENDL-3.3	2014	0.610	0.9740	

TABLE II: Neutron flux at Dhruva reactor

	ϕ_1 or ϕ_1'(10^{12}n/cm^2.sec)	ϕ_2 or ϕ_2'(10^{12}n/cm^2.sec)
without the Cd	ϕ_1=10^{12}n/cm^2.sec	ϕ_2=0.019
with Cd	ϕ_1'=0.031	ϕ_2'=0.036

1. Results and discussion

From the above motivation, I have analysed the thermal neutron capture cross sections and resonance integrals of the ^{80}Se(n,γ)^{81m,g}Se reactions with JENDL-3.3 and available experimental data.

Selenium-79 is one of the most important long-lived fission products (LLFP's) because of its extremely long half-life (4.8×10^5 years) and

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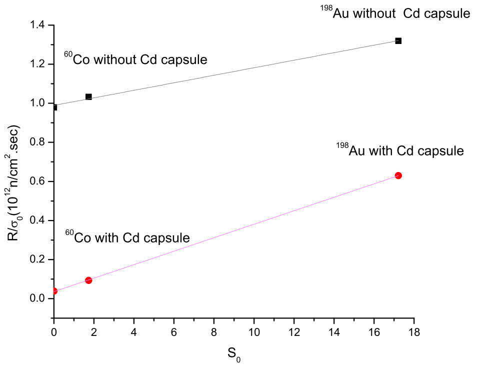
*Electronic address: `satheesh.b4@gmail.com` radio toxicity remaining for more than 10^6 years, though the fission yield of ^{79}Se is as small as 0.10%. Therefore, the problem of waste disposal for such LLFP's is a matter of great concern. Transmutation is one of the options for this waste management, since it makes it possible to reduce the volume of the repository for packages of nuclear wastes as well as the long term risk. In the study of transmutation of ^{79}Se, accurate cross-section data are required. However, other Se isotopes in addition to ^{79}Se are also generated as fission products with the following fission yields: ^{78}Se (0.06%), ^{80}Se (0.18%), ^{82}Se (0.38%), and so on. The effective cross section σ is defined by equating the reaction rate R to the product of σ and n_0, where n_0 is the neutron flux in the Westcott's[5] convention with the neutron density n, including thermal and epithermal neutrons, and with the velocity of neutron $\nu_0 = 2,200 m/s$,(thermal neutrons, 0.025 eV). To discuss effective use of neutrons in transmutation, accurate cross-section data are also required for the Se isotopes. Table 1 shows a compilation of the evaluated and experimental data for the ^{80}Se cross section.) There have been only two measurements of the thermal-neutron capture cross section (σ_0) by Pomerance and Goldberg et al. in the 1950-60's. As seen in Table 1, the formation cross sections ($\sigma_{0,m}$ and $\sigma_{0,g}$) for the isomeric and ground states of ^{81}Se have not been measured separately; only the isomer ratio has been measured. The resonance integral (I_0) measurements were done in the 1960-1970's, but there were large discrepancies among the data. In the cross-section evaluation of ^{80}Se, one has to rely on very poor data points, and the quality and quantity of the data are not always enough for waste management investigation. Also the present status of experimental data for neutron capture cross sections is still inadequate both in quality and quantity. Therefore, it is important to perform precise measurements of capture cross sections and resonance cross sections for this nuclide. The relation between R/σ_0 (or R'/σ_0) and S_0 is shown in Fig.1, here R is the reaction rate, σ_0 is the thermal neutron capture cross section and S_0 is the parameter in terms of neutron temperature. The neutron flux will be monitored using ^{197}Au(n,γ)^{198}Au(T1/2 =2.6948 d, decay gamma energy=411.802 keV, with 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. Table 2 presents the thermal and epithermal neutron flux, ^{59}Co and ^{197}Au have different sensitivities to thermal and epithermal neutrons, these wires are appropriate to determine the thermal and the epithermal fractions of neutron flux with and without Cd capsule. Pomerance measured the thermal cross section of ^{80}Se relative to gold by the pile oscillator method. It may seem that the isomeric and ground states of ^{81}Se are included in their formation cross sections ($\sigma_{0,m+g}$). The isomer ratios $\sigma_{0,m}/(\sigma_{0,m} + \sigma_{0,g})$, as seen in the Table 1. are given as 0.12±0.03,0.17±0.02 and 0.12±0.01. The details will be presented.



Experimental relations between R/σ_0 (or R'/σ_0) and s_0

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