Calculations of (γ,n) Reaction Cross Sections using Different Level Density Models for Some Lanthanide Nuclei

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The discrete level information deficiency requires usage of level density models in cross section calculations. The total reaction cross sections for gamma-induced reactions through the six level density models with a consistent parameterization of some lanthanides (^{141}Pr , ^{142}Nd , ^{144}Sm , ^{153}Eu , ^{159}Tb , ^{160}Gd , ^{165}Ho , ^{175}Lu) were calculated using TALYS 1.6 in the incident energy range from 5 to 30 MeV. All calculations from the present study were compared with each other and with data available in the literature.

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1. Introduction

Level densities are essential at excitation energies, where discrete level information is missing. To obtain reliable theoretical cross section calculations, different level density models were suggested in the past, such as constant temperature model, back-shifted Fermi-gas model, generalized superfluid model, microscopic level density Goriely's table, microscopic level density Hilaire's table. All these models are realized in TALYS 1.6 [1] software. Recently a new model, microscopic level densities (temperature dependent HFB, Gogny force) from Hilaire's combinatorial tables was implemented into TALYS 1.6 code. The detailed information about the models is available in [2–4]. In the present study gamma-induced reaction cross sections for several lanthanides, ($^{141}\text{Pr}(\gamma,n)^{140}\text{Pr}$, $^{142}\text{Nd}(\gamma,n)^{141}\text{Nd}$, $^{144}\text{Sm}(\gamma,n)^{143}\text{Sm}$, $^{153}\text{Eu}(\gamma,n)^{152}\text{Eu}$, $^{159}\text{Tb}(\gamma,n)^{158}\text{Tb}$, $^{160}\text{Gd}(\gamma,n)^{159}\text{Gd}$, $^{165}\text{Ho}(\gamma,n)^{164}\text{Ho}$, $^{175}\text{Lu}(\gamma,n)^{174}\text{Lu}$) were calculated for all level density models, using TALYS 1.6 code.

2. Calculation method

TALYS 1.6 code was used in the calculations, which includes photon, neutron, proton, deuteron, triton, ^3He , and α -particles as both the projectiles and the ejectiles. The cross section calculations are performed through an input file, where nuclear structure and model parameters are described. The input file should be formed to include appropriate input and output keywords to address various nuclear models and parameters for fine tuning of calculations to experimental data in the output file [1, 3].

3. Results and discussion

The total (γ,n) reaction cross sections of ^{141}Pr , ^{142}Nd , ^{144}Sm , ^{153}Eu , ^{160}Gd , ^{159}Tb and ^{165}Ho targets were calculated for six level density models using

Fig. 1. Comparison of the calculated Talys 1.6 $^{141}\text{Pr}(\gamma,n)^{140}\text{Pr}$ reaction cross section data with data from [5, 6, 14].

Fig. 2. Comparison of the calculated Talys 1.6 $^{142}\text{Nd}(\gamma,n)^{141}\text{Nd}$ reaction cross section data with data from [11, 12, 14].

TALYS 1.6 code in 5 to 30 MeV incident gamma energy range. The calculated results and available experimental data are presented in Figs. 1–7. The calculated $^{141}\text{Pr}(\gamma,n)^{140}\text{Pr}$, $^{144}\text{Sm}(\gamma,n)^{143}\text{Sm}$, $^{159}\text{Tb}(\gamma,n)^{158}\text{Tb}$ and $^{160}\text{Gd}(\gamma,n)^{159}\text{Gd}$ reaction cross sections are compared with the available experimental data [5–10]. Even though

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Fig. 3. Comparison of the calculated Talys 1.6 $^{144}\text{Sm}(\gamma, n)^{143}\text{Sm}$ reaction cross section data with data from [7, 14].

Fig. 4. Comparison of the calculated Talys 1.6 $^{153}\text{Eu}(\gamma, n)^{152}\text{Eu}$ reaction cross section data with data from [10, 14].

all models are in good agreement with the experimental data, the newly implemented level density model, namely the microscopic level densities (temperature dependent HFB, Gogny force) from Hilaire's combinatorial tables, has a better agreement (see Figs. 1, 3, 5 and 6). The calculated $^{142}\text{Nd}(\gamma, n)^{141}\text{Nd}$, $^{153}\text{Eu}(\gamma, n)^{152}\text{Eu}$ and

Fig. 5. Comparison of the calculated Talys 1.6 $^{159}\text{Tb}(\gamma, n)^{158}\text{Tb}$ reaction cross section data with data from [8, 9, 14].

$^{165}\text{Ho}(\gamma, n)^{164}\text{Ho}$ reaction cross sections were compared with the available experimental data [11–12]. In general our calculations for all level density models are in good agreement with experimental data obtained from EXFOR [13]. However, the cross section results obtained using different level density models have minimal discrepancies (Figs. 2, 4, 7).

Fig. 6. Comparison of the calculated Talys 1.6 $^{160}\text{Gd}(\gamma, n)^{159}\text{Gd}$ reaction cross section data with data from [10, 14].

Fig. 7. Comparison of the calculated Talys 1.6 $^{165}\text{Ho}(\gamma, n)^{164}\text{Ho}$ reaction cross section data with data from [10, 8, 14].

4. Conclusion

The presented calculation results indicate an overall better agreement with the experimental data and the theoretical data previously reported at TENDL-2013 [14], for all reactions. Also, the newly implemented level density model, namely the temperature dependent HFB, Gogny force from Hilaire's combinatorial tables, yields results which are more compatible with the experimental cross sections, reported in literature. In general, the results calculated using different models have minor deviations above 17 MeV, where $(\gamma, 2n)$ reaction channel threshold begins (see Figs. 1–7).

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