

Phenomenological Level Density Models in Photoneutron Reactions on ^{232}Th , ^{237}Np , ^{239}Pu and ^{241}Am Targets

Abdullah AYDIN¹, Ismail Hakki SARPÜN², Eyyup TEL³¹Kırıkkale University, Physics Department, Kırıkkale, Turkey.²Afyon Kocatepe University, Physics Department, Afyonkarahisar, Turkey.³Osmaniye Korkut Ata University, Physics Department, Osmaniye, Turkey.

ABSTRACT: In nuclear reactions, angular momentum effects the transition probability. Therefore, it is important to determine the nuclear level density with given angular momentum. The total reaction cross sections of ^{232}Th , ^{237}Np , ^{239}Pu and ^{241}Am target nuclei were calculated using TALYS 1.8 code for photoneutron reactions through the phenomenological level density models in the incident energy range 5 to 30 MeV. All calculations were compared with the available experimental data in EXFOR library.

KEYWORDS: Level density, Photoneutron, Phenomenological Models, Actinides.

I. INTRODUCTION

Photonuclear reaction data are very important in complementation of the structure and dynamics of the atomic nucleus. The photoneutron cross sections are also important for some applications, especially in reactor technology [1,2]. Besides, the cross sections improve theoretical nuclear level density models to illustrate nuclear reactions [3,4].

The theoretical nuclear reaction models are generally required in estimation of the reaction cross sections in the case of where no experimental data obtained or it is difficult to carry out the experiments [5–9]. Also, level density model studies have important applications in nuclear reactor design and so on. The (γ, n) and $(\gamma, 2n)$ cross-sections have been calculated in several structural fusion materials [10,11]. In this study, the theoretical (γ, n) reaction cross sections of some actinide nuclei such as ^{232}Th , ^{237}Np , ^{239}Pu and ^{241}Am in photon induced reactions have been examined. The calculations on photo-neutron cross sections of $^{232}\text{Th}(\gamma, n)^{231}\text{Th}$, $^{237}\text{Np}(\gamma, n)^{236}\text{Np}$, $^{239}\text{Pu}(\gamma, n)^{238}\text{Pu}$ and $^{241}\text{Am}(\gamma, n)^{240}\text{Am}$ reactions have been carried out for incident photon energies up to 30 MeV. The theoretical cross sections as a function of photon energy have been calculated using three phenomenological level density models of TALYS 1.8 [12] nuclear reaction codes. The theoretically calculated cross sections have been compared with each other and available experimental data existing in the EXFOR [13] nuclear data library.

II. CALCULATION METHODS

The photoneutron cross sections of some actinide nuclei as a function of incident photon energy have been theoretically calculated using TALYS 1.8 nuclear reaction codes for the three phenomenological level density models such as CTFGM, BSFM, and GSM.

TALYS [12] is a nuclear reaction code for the prediction and analysis of nuclear reactions that contain γ , n , p , t , d , ^3He , and alpha particles, in the 1 keV–1 GeV energy region. Therefore, TALYS 1.8 has sub-procedures, namely, the optical model, direct, pre-equilibrium, fission, and statistical nuclear reaction models in one calculation scheme and gives an estimation for all the open reaction channels. TALYS 1.8 has several options that are included for the choice of

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different parameters such as nuclear level densities, γ -strength functions, and nuclear model parameters [12]. The γ -ray strength function is obtained from the compilation by Kopecky and Uhl [14] and the nuclear level density is also dependent upon an approach using the Fermi Gas Model [15]. The descriptions of level density models can be found in [12, 16-19].

III. RESULTS AND DISCUSSION

In the present study, (γ, n) reaction cross sections of $^{232}\text{Th}(\gamma, n)^{231}\text{Th}$, $^{237}\text{Np}(\gamma, n)^{236}\text{Np}$, $^{239}\text{Pu}(\gamma, n)^{238}\text{Pu}$ and $^{241}\text{Am}(\gamma, n)^{240}\text{Am}$ reactions have been calculated up to 30-MeV incident energy using three phenomenological level density models of TALYS 1.8 nuclear reaction codes. The photo-neutron cross sections exhibited by (γ, n) reactions for ^{232}Th , ^{237}Np , ^{239}Pu and ^{241}Am target nuclei have been plotted as a function of incident photon energy in Figs. 1–4. All the experimental values used in this study have been taken from the EXFOR library.

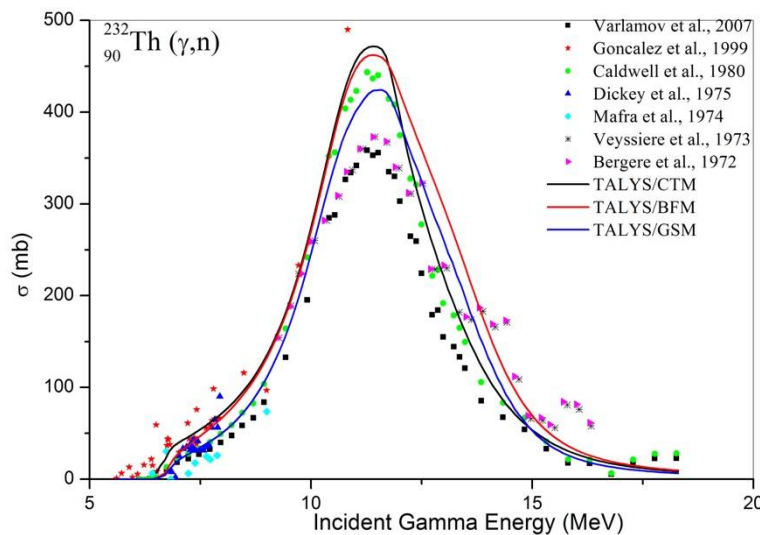


Fig. 1. Total cross section of (γ, n) reactions for ^{232}Th nucleus according to different level density models [20–26].

The (γ, n) cross-section calculations of $^{232}\text{Th}(\gamma, n)^{231}\text{Th}$ reaction have been compared with the experimental values of Varlamov et al. [20], Gonzalez et al., [21], Caldwell et al. [22], Dickey et al. [23], Mafra et al. [24], Veyssiere et al. [25] and Bergere et al. [26] in Fig. 1. All the theoretical level density model cross-section calculations are in good agreement with the experimental results. The GSM results are in better agreement than the other TALYS code calculations.

$^{237}\text{Np}(\gamma, n)^{236}\text{Np}$ reaction cross-section calculations have been compared with the experimental values in Fig. 2. The calculated reaction cross sections are higher than the experimental data for all level density models. The Giant Dipole Resonance (GDR) splits into two components for even-odd ^{237}Np nucleus.

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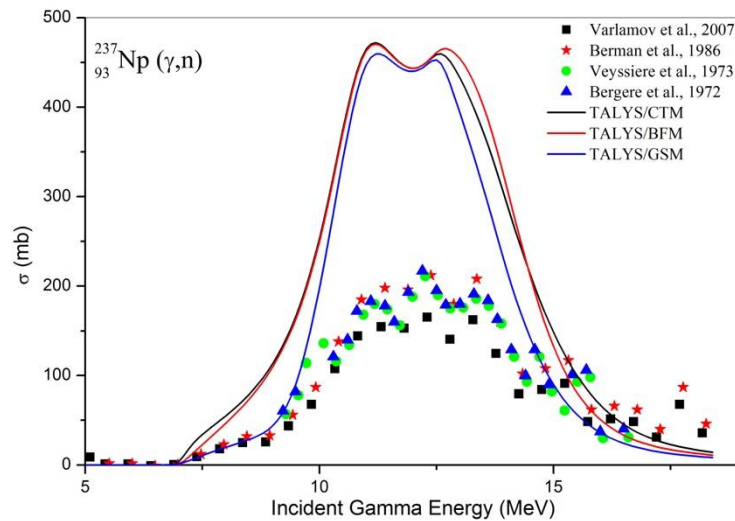


Fig. 2. Same as in Fig. 1, but for ^{237}Np [20, 25-27].

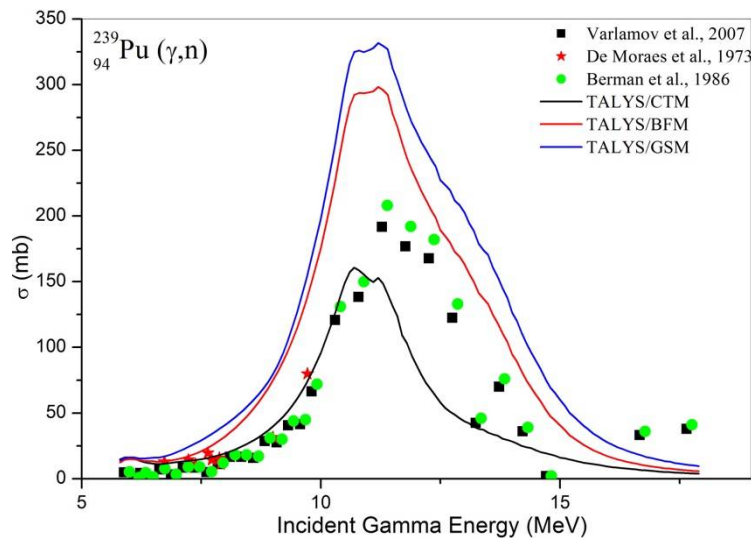


Fig. 3. Same as in Fig. 1, but for ^{239}Pu [20,27,28].

The comparison of theoretical and available experimental data of $^{239}\text{Pu}(\gamma,n)^{238}\text{Pu}$ reaction has been given in Fig. 3. All the model calculations are in shape-agreement with the experimental results. The CTM results are the nearest to the experimental data. The GDR splits into two components also for even-odd ^{239}Pu nucleus.

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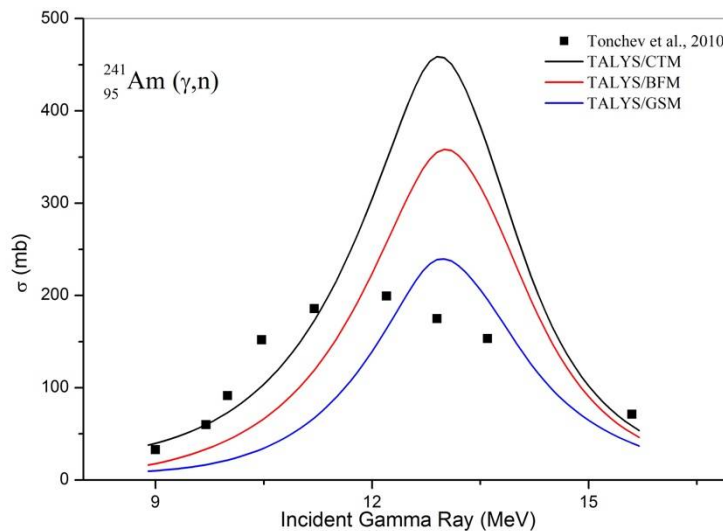


Fig. 4. Same as in Fig. 1, but for ^{241}Am [29].

In general all the calculations follow the experimental results from above but the GSM calculations are in agreement with the experimental values for $^{241}\text{Am}(\gamma, n)$ ^{240}Am reaction in Fig. 4.

IV. CONCLUSION

The (γ, n) reaction cross sections as a function of photon energy have been calculated using three phenomenological level density models of TALYS 1.8 nuclear reaction codes for some actinide nuclei. The level density model cross-section calculations show a similar structure with the experimental data for all reactions.

As expected, the cross section results for even-even nucleus shows clearly the GDR does not split into two or more components (Fig. 1) whereas it splits into two components for even-odd nuclei (Figs. 2,3), except for ^{241}Am (Fig. 4).

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