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Determination of the effects of nuclear level density parameters on photofission cross sections of ^{235}U up to 20 MeV

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Abstract. The level density models and level density parameters are two of important quantities for describing the properties of nuclei. Especially, the level density parameter has an important role as input in calculation of reaction cross sections. In this study, the cross sections on ^{235}U(g,f) reaction were calculated for different level density models using the TALYS 1.6 code up to 20 MeV gamma incident energies. First, it was determined the level density model that was the closest to the experimental data. Secondly, cross sections obtained for different level density parameters of this model were compared with experimental data from the EXFOR database. Thus it was determined the best level density parameter fit to experimental data.

1. Introduction

The level density and level density parameter are very important quantities in determination of the both structure and after reaction properties of nuclei. Especially, the level density parameter has a significant role in the theoretical evaluation of reaction cross sections. The theoretically calculated cross sections, especially nuclear fission cross sections, are important for some practical applications such as medical research, and reactor technology. There are many reliable computer codes to calculate the fission cross sections. TALYS 1.6 nuclear code is the primary ones [1].

In the literature, there are a lot of studies, depend on different model approximation, on theoretically nuclear data evaluation for fission cross section and fission yield. TALYS nuclear code has been developed to capture all nuclear reaction model calculation, allowing to provide nuclear reaction simulation in 1 keV–1 GeV energy range. TALYS is able to use neutron, proton, deuteron, photon, triton, ^{3}He and alpha particles as projectile and element of mass 12 and heavier as target [2]. TALYS' calculation results depend on great input parameter tuning based on experimental data using best curve fitting. At this point, available experimental data play an important role in TALYS evaluation to achieve better agreement with it [3,4]. Therefore, proper selection of reaction parameter and mechanism combined with parameter tuning would lead to better approximated calculation result.

In this study, the cross sections on^{235}U(g,f) reaction were calculated for different level density models, which are available in code, using the TALYS 1.6 nuclear reaction code [1]. All the calculations were compared with the experimental data obtained from EXFOR library [5].

2. Level densities

Effective level density models had no explicit dependencies with nuclear collective effect.

2.1. Constant Temperature Model (CTM)

This model divides energy region into two parts, low energy part from 0 to the matching energy E_m where Constant Temperature Law applied, and high energy part above E_m where Fermi Gas Model applied [6].

2.2. Back-Shifted Fermi Gas Model (BSFGM)

In this model, which is modifies version of Fermi Gas Model, Fermi gas expression is used in all energy range. As a consequence, pairing energy parameter should be adjustable [7].

2.3. Generalized Superfluid Model (GSM)

This model takes superconductive pairing correlation into account based on Bardeen-Cooper-Schrieffer theory [8,9].

3. The level density parameter

A specific constant value of the level density parameter a for each nuclide may be proposition for the form of word described and in fact the first level density analyses spanning an entire range of nuclides [6,7,9] treated a as a parameter independent of energy. After that, the correlation in the middle the parameter $a$and the shell correction term of the liquid-drop component of the mass formula was found by Ignatyuk et al. [8]. The researchers considered that a more reasonable level density, obtained by assuming Fermi gas formula given above, is still valid. However, the inclusion of energy-dependent shell effects is important for the efficiency. The existence of shell effects at low energy and their disappearance at high energy in a phenomenological manner considered for its appearance [11].

$$a = a(E_x) = \tilde{a}\left(1 + \delta W \frac{1 - exp(-\gamma U)}{U}\right) \quad (1)$$

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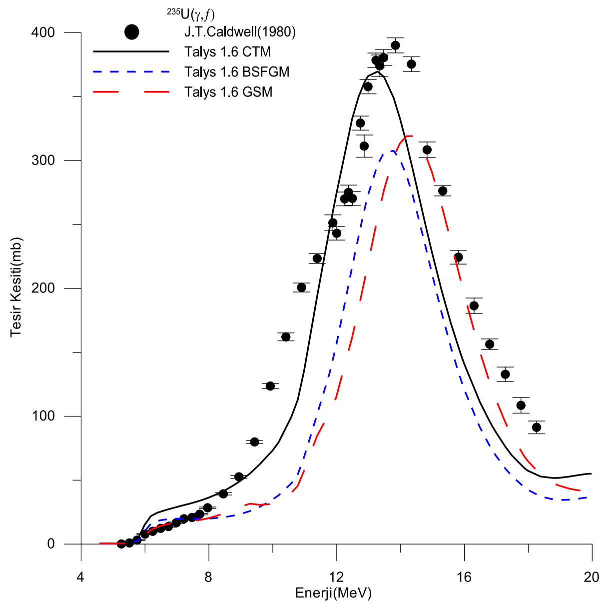

Figure 1. Theoretical calculations of ^{235}U(g,f) reaction cross section using level density models in TALYS. The experimental data are taken from EXFOR.

Table 1. Level density parameter values used in CTM model calculations.

^{235}U(g,f)	default	a−10a%	a+10a%	a−20a%	a+20a%
CTM	15.8128	17.3941	14.2316	18.9754	12.6504

Table 2. Level density parameter values used in BSFGM model calculations.

^{235}U(g,f)	default	a+10a%	a−10a%	a+20a%	a–20a%	a+35a%
BSFGM	12.9515	14.2467	11.6564	15.5418	10.3612	17.4845

Table 3. Level density parameter values used in GSM model calculations.

^{235}U(g,f)	default	a+10a%	a−10a%	a+20a%	a−20a%	a+35a%
GSM	13.4189	14.7608	12.0770	16.1027	10.7351	18.1155

4. Methods

In this study, three level density models have been compared with each other and also with experimental values taken from the EXFOR nuclear data library for ^{235}U(g,f) reaction [5]. The TALYS 1.6 code was used in theoretical calculations created by Koning and his colleagues at NRG Petten, Netherlands and CEA Bruyéres-le-Châtel, France to provide a complete and accurate simulation of nuclear reactions involving n, gamma, p, d, t, ^{3}He, and α projectiles in the 1 keV–1 GeV energy range, through an optimal combination of nuclear models. Nuclear structure and model parameters are implemented through Reference Input Parameter Library (RIPL) [10].

5. Results

In this work, cross sections of ^{235}U(g,f) reaction were calculated for three level density models using TALYS 1.6 code in incident gamma-ray energy range of 4–20 MeV. The calculated results and available experimental data are presented in Figs. 1–4.

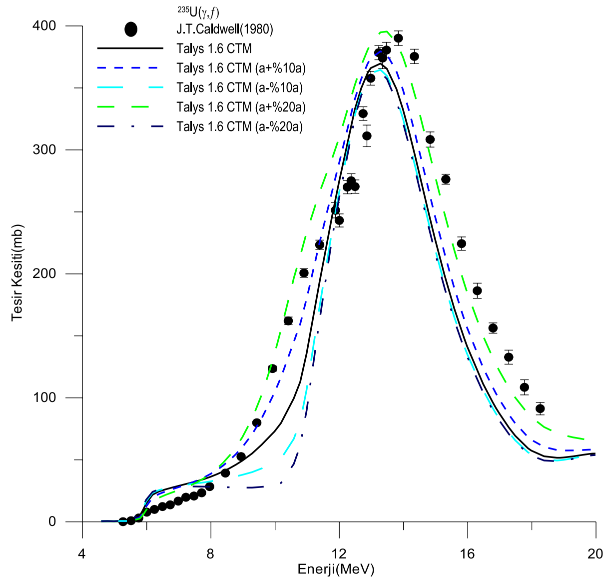

Figure 2. Theoretical calculations of ^{235}U(γ,f) reaction cross section using CTM level density model. The experimental data are taken from EXFOR.

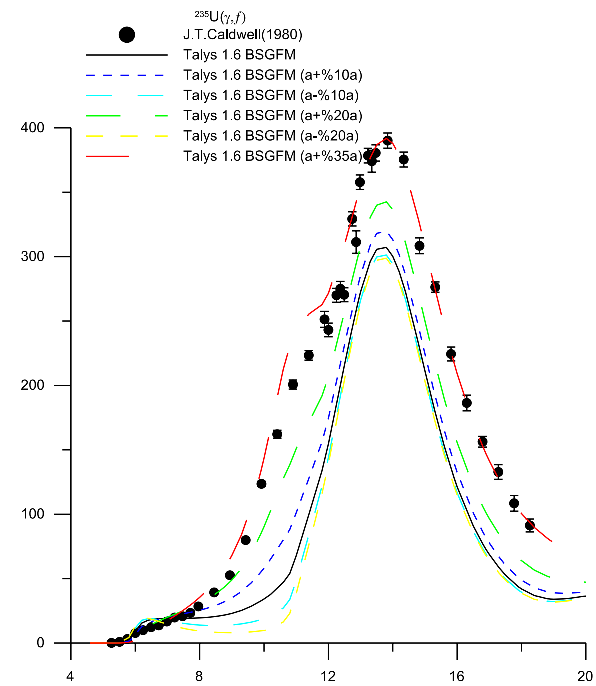

Figure 3. Theoretical calculations of ^{235}U(g,f) reaction cross section using BSFGM level density model. The experimental data are taken from EXFOR.

Experimental cross-section values of ^{235}U(g,f) reaction have been compared with theoretically calculated values for three level density models with TALYS 1.6 code in Fig. 1.

Experimental cross section values are compared with the theoretically calculated cross section values using CTM, BSFGM and GSM model of TALYS code in Fig. 1. According to Fig. 1, CTM model calculations have similar results with experimental cross section values than other models calculations. Figures 2–4 have been plotted to show the effects of the level density model parameter on the theoretical calculations for each level density model. The aim of these graphs is to obtain best level density

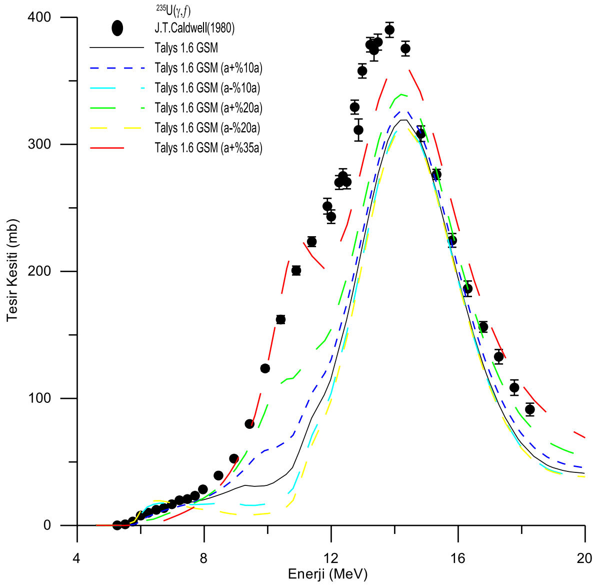

Figure 4. Theoretical calculations of ^{235}U(g,f) reaction cross section using GSM level density model. The experimental data are taken from EXFOR.

model parameter in each model. Tables 1–3 show the level density parameter values of CTM, BSFGM and GSM model calculations, respectively.

6. Conclusion

In this study, it has been showed that how the level density parameter effects theoretical calculations of reaction cross sections depend on the level density models.

CTM model calculations show best compatibility with experimental results and when the similar results obtained by changing a parameter in other models, then level density parameter of that model approaches the value of CTM model parameter.

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