Nuclear Structure of ^{89}Y and excitation function in ^{89}Y(p,n)^{89}Zr reaction

F. Taheri[1], A. Rahmatinejad[1], R. Razavi[2,*], T. Kakavand[3]
[1]Physics Group, Science Department, Zanjan University, Zanjan, Iran.
[2]Department of physics, Faculty of Science, Imam Hossein Comprehensive University, Tehran, Iran
[3]Department of Physics, Faculty of Science, Imam Khomeini International University, Qazvin, Iran
* email: rrazavin@ihu.ac.ir

Introduction

One of the most important quantities in studies on nuclear structure and its applications is nuclear level density. For example nuclear level density plays an important role in statistical calculations of nuclear reaction cross sections. Most of these calculations are at excitation energies where discrete level information is not available. Nuclear models are useful tools to calculate the nuclear level densities in these regions of excitation energies.

In this work two different macroscopic nuclear level density models: Constant Temperature Model (CTM) and Back-Shifted Fermi Gas Model (BSFGM) are parameterized using experimental data on nuclear level density of ^{89}Y nuclei.

Then the calculated parameters are used to extract excitation curves for ^{89}Y(p,n)^{89}Zr reaction over the proton energy from 6 to 30 MeV, by TALYS-1.6 Nuclear Reaction Code. The results have been compared with the corresponding experimental data.

Statistical formulas

Nuclear temperature T can be defined by nuclear level density ρ(E) [1]:

$$\frac{1}{T} = \frac{d}{dE} ln\,\rho\left(E\right) \quad (1)$$

Integrating of above equation, give the Fermi Gas formula in constant temperature [2]:

$$\rho\left(E\right) = \frac{1}{T} exp\left(\frac{E-E_0}{T}\right) \quad (2)$$

The Bethe formula of the level density for the back-shifted Fermi gas model [3, 4] can be written as

$$\rho(E) = \frac{\exp(2\sqrt{a(E-E_1)})}{12\sqrt{2}\sigma^4\sqrt{a(E-E_1)^5}} \quad (3)$$

Here σ is the spin cut-off parameter.

Nuclear temperature (T) and the ground state back-shift (E_0) in CTM, level density parameter (a) and ground state back-shift (E_1) in BSFGM are adjustable parameters and can be determined through experimental data on the nuclear level density.

Extracted level density parameters can be used to calculate nuclear reaction cross sections. In this work cross section of ^{89}Y(p,n)^{89}Zr reaction have been calculated by TALYS-1.6 Nuclear Reaction Code.

In this evaluation the width fluctuation correction of compound nucleus, E1 gamma-ray strength function and optical model that have been applied are Hafman-Richert-Tepl-Weidenmüller (HRTW)[5], Brink-Axel Lorentzian[6] and Semi-microscopic optical model (JLM)[7], respectively.

HRTW is based on the assumption that the main effect of the correlation between incident and outgoing waves is in elastic channel.

The width fluctuation correction can be written as follow:

$$W_{ab} = \frac{V_a V_b}{\sum_c V_c}\left[1+\delta_{ab}\left(W_a - 1\right)\right]\frac{\sum_c T_c}{T_a T_b} \quad (4)$$

Where V_i's and T_i's are effective transmission coefficients and transmission coefficient, respectively, that take into account the correlations. For

$$W_a = 1 + \frac{2}{1+T_a^F} + 87\left(\frac{T_a - \overline{T}}{\sum_c T_c}\right)^2\left(\frac{T_a}{\sum_c T_c}\right)^5 \quad \text{with}\ \overline{T} = \frac{\sum_c T_c^2}{\sum_c T_c} \quad (5)$$

In Brink-Axel Lorenzian strengh function for E1 gamma-ray emission, a standard Lorentzian form describes the giant dipole resonance shape:

$$f_{Xl}\left(E_\gamma\right) = K_{Xl} \frac{\sigma_{Xl} E_\gamma \Gamma_{Xl}^2}{\left(E_\gamma^2 - E_{Xl}^2\right)^2 + E_\gamma^2 \Gamma_{Xl}^2} \quad (6)$$

And the exponent,

$$F = \frac{4\frac{\overline{T}}{\sum_c T_c}\left(1+\frac{T_a}{\sum_c T_c}\right)}{1+\frac{3\overline{T}}{\sum_c T_c}} \quad (7)$$

Where σXl, EXl and ΓXl are the strength, energy and width of the giant resonace, respectively, and

$$K_{Xl} = \frac{1}{(2l+1)\pi^2\hbar^2c^2} \quad (8)$$

Result and conclusion

Adjustable parameters of CTM and BSFGM have been extracted for ^{89}Y nuclei by fitting experimental data on nuclear level density with the formulas. Calculated level density parameters have been used to obtain excitation function for ^{89}Y(p,n)^{89}Zr reaction.

Extracted excitation curves are shown in Fig.1 along with corresponding experimental data [8, 9] for comparison.

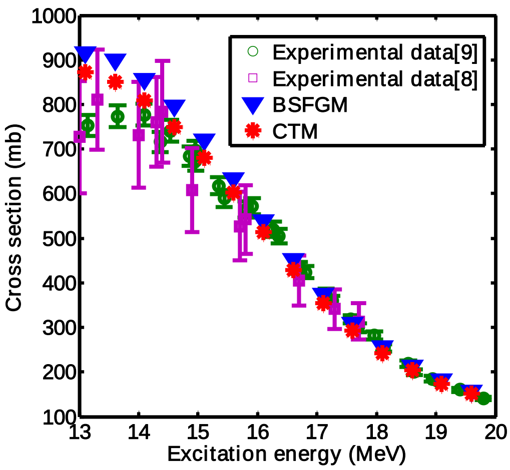

Fig.1 Extracted excitation function for ^{89}Y(p,n)^{89}Zr reaction by obtained level density parameters for the CTM and the BSFGM.

The comparison shows good agreement between the calculated results and experimental data.

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