STUDY OF LEVEL DENSITY AND REACTION CROSS SECTIONS IN THORIUM ISOTOPES

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Introduction

The knowledge of nuclear level density (NLD) provides information about the internal structure of any nucleus, which determines the manner in which the nucleus participates in a physical process. This work is a theoretical study of NLD of Thorium nuclei that exist on and off the line of stability. There are no experimental as well as theoretical data available for isotopes other than ^{232}Th. These evaluated data are useful in understanding the mechanism of nuclear reactions taking place under extreme conditions in nucleosynthesis. A statistical method using computational code TALYS 1.6 has been used for the calculation of nuclear level densities. In the present study the level density of different isotopes of Thorium in the range $216 \leq A \leq 270$, from neutron drip line to proton drip line is estimated. It also describes the nuclear model calculation of (n,p) and (n,α) reaction cross sections for $^{204-270}$Th.

Theory

NLD has been extensively studied, using both phenomenological [?] as well as microscopic models. The most frequently used empirical models are the Fermi Gas Model [?] and the Gilbert-Cameron [?] model. Other two phenomenological models are Back shifted Fermi Gas Model [?] and Generalized Superfluid Model [?]. The Fermi gas level density $\rho_F(E_x, J)$ for a given spin J at excitation energy E_x is given by,

$$\rho_F(E_x, J) = \frac{1}{2}\left[\frac{(2J+1)\exp\left[-\frac{(J+\frac{1}{2})^2}{2\sigma^2}\right]}{2\sigma^2}\right] \times \left[\frac{1}{\sqrt{2\pi}\sigma}\frac{\sqrt{\pi}}{12}\frac{\exp\left[2\sqrt{aU}\right]}{a^{\frac{1}{4}}U^{\frac{5}{4}}}\right] \quad (1)$$

The level density parameter a is energy dependent and takes into account the damping of shell effects at high excitation energy [?].

$$a(E_x) = \tilde{a}\left[1 + \delta W \frac{1 - \exp(-\gamma U)}{U}\right] \quad (2)$$

The spin cut-off factor σ^2 is given by,

$$\sigma_F^2 = R_\sigma \frac{A^{\frac{5}{3}}}{\tilde{a}}\sqrt{aU} \quad (3)$$

with $R_\sigma = 0.01389$. The spin-cut off parameter σ characterizes the width of the distribution of the z-component of the nuclear angular momentum. It depends on the excitation energy.

Results and Discussion

The calculated level density parameter for Thorium isotopes from different models are plotted in figure 1. Spin cut off factor σ is calculated by using equation 3. The σ values are computed from this for all nuclei at neutron separation energy. These spin cutoff factor σ of all nuclei are calculated under different models and are plotted in figure 2.

Here we calculated the cross section of Thorium isotopes for the reactions in which neutron is a projectile and a charged particle is an ejectile. Three phenomenological and

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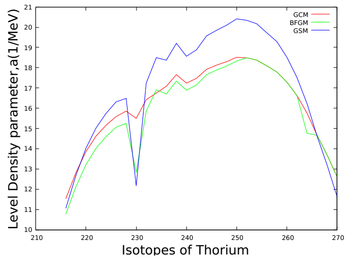

FIG. 1: Comparison of level density parameter a, from different models for Thorium isotopes.

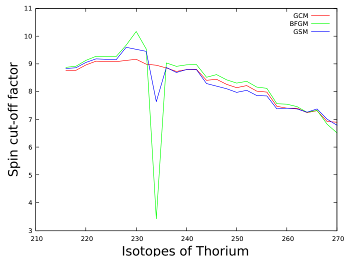

FIG. 2: Comparison of spin cutoff factor σ, from different models for Thorium isotopes

one microscopic models are applied here also. The experimental data on nuclear reaction are not available for Thorium isotopes except for ^{232}Th. The calculated cross section for this nucleus from different level density models are in good agreement with the experimental data available in the EXFOR Data base. Figures 3 and 4 show the comparison between evaluated data from EXFOR Data Library and calculated data from TALYS 1.6. The (n, α) reaction cross sections calculated under different level density models for ^{232}Th are in good agreement with the experimental data available for ^{232}Th.

Conclusion

The level density parameter a and spin cut-off factor σ for the isotopes $^{216-270}$Th decrease towards neutron drip line and proton drip line. In addition to this, the observed dip in the level density parameter and spin cut-off factor around mass number 230 can be attributed to the observed deformation for these nuclie in this mass region. Cross section for

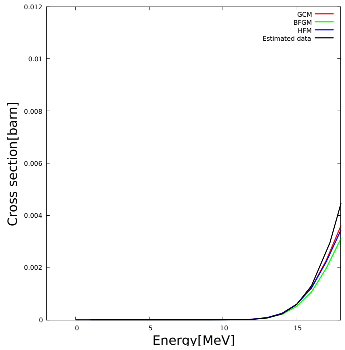

FIG. 3: Comparison of evaluated data and calculated data from TALYS 1.6 (n,p) reaction cross section for ^{232}Th

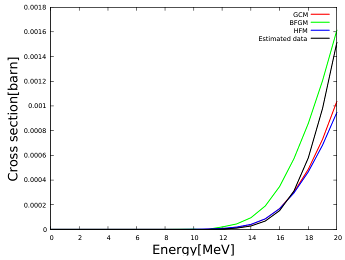

FIG. 4: Comparison of evaluated data and calculated data from TALYS 1.6 (n,α) reaction cross section for ^{232}Th.

(n,p) and (n,α) reaction for Thorium isotopes are also calculated. In the case of (n,p) reaction, the values obtained under different level density models are comparable. The calculated and experimental values of cross section for ^{232}Th are also comparable. Hence we assume that the values estimated for other isotopes are reasonable.

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