

EFFECTIVE AND COLLECTIVE LEVEL DENSITY PARAMETERS FOR THORIUM ISOTOPES

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Introduction

Theoretical study of level density of excited nuclei is of interest in the study of nuclear reactions because experimental data of level density is not available for certain nuclei. The present work is a theoretical study of the effective and collective nuclear level density of thorium nuclei ranging from A=194 to 306. Experimental level density of only ^{230}Th is available [1]. In this study we have also included the estimation of the level density parameter of few other isotopes also. We computed these values with and without adding the collective effects and checked for the collective enhancement effect. These evaluated data are useful for understanding the nuclear reactions taking place in nucleosynthesis under extreme conditions.

The level density parameter depends on the shell correction energy. The variation of shell correction energy of these isotopes also studied. We also compared the collective enhancement effect with varying excitation energy. A statistical method is used for the calculation of nuclear level densities.

Theory

Nuclear Level Density (NLD) is the number of energy levels per unit excitation energy. Level density parameter is a fundamental quantity for the calculation of NLD. Two types of approaches are followed in estimating it, depending on whether the collective effects are considered or not. If the collective effects are not explicitly included, we get the effective level density (ELD) and if they are included, we get the collective level density (CLD). All

phenomenological expressions of level density at high excitation energies follow the Fermi Gas model. The expression for level density in the Fermi Gas model was proposed by Bethe in 1937 [2]. The level density parameter a , is given as [3].

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

The collective enhancement in level density originate from the rotational and vibrational enhancement effect. Rotational effect is more stronger than the vibrational effect. Then collective level density

$$\rho_{F,Coll}(E_x, J, \pi) = K_{rot}(E_x) K_{vib} \rho_{F,int}(E_x, J, \pi) \quad (2)$$

Here K_{rot} and K_{vib} are called rotational and vibrational enhancement factors.

Results and Discussion

The effective and collective level density parameters for thorium nuclei with A=194 to 306 are plotted in Fig 1. Here the collective

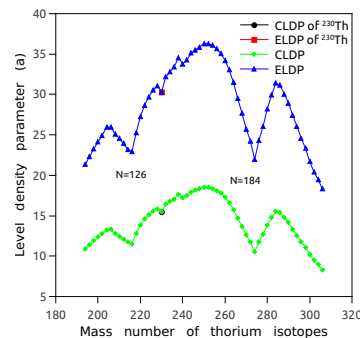


FIG. 1: Comparison of effective and collective level density parameter a of Thorium isotopes.

level density parameter is less than the effective

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tive level density parameter. The experimental value of ^{230}Th is compared with the calculated value. Collective effects lowered the value of level density parameter. Here both the collective and effective nuclear level density parameters decrease towards the neutron magic numbers $N=126$ and 184 . (also towards the drip line). This is due to shell closure property. The level density parameter depends on the shell correction energy. The variation of shell correction energy with mass number of thorium isotopes is plotted in Fig 2. Variation

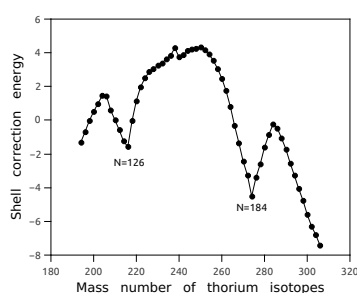


FIG. 2: Variation of shell correction energy with mass number of thorium isotopes

of level density parameter and shell correction energy shows same behaviour. So the shell effect mainly depends on level density parameter.

Here we also studied the variation of collective enhancement factor with excitation energy. At higher excitation energy the collective effect become low and the maximum collective behavior was shown at 20-25 MeV range of the excitation energy. Also the collective effect is low for the neutron magic nuclei. The variation of collective effect with excitation energy for thorium isotopes around the region of neutron magic numbers is plotted in Fig 3 and Fig 4 (for two separate mass regions).

Conclusion

The effective and collective level density parameter of thorium isotopes are estimated by using Gilbert Cameron model. The collective level density parameter is less than the effective level density parameter. Both the effective

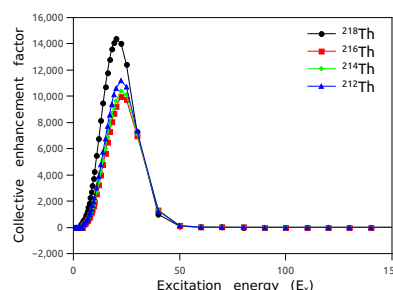


FIG. 3: Variation of collective enhancement factor with excitation energy $^{218-212}\text{Th}$

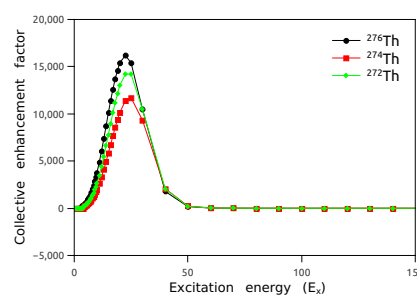


FIG. 4: Variation of collective enhancement factor with excitation energy $^{276-272}\text{Th}$

tive and collective level density parameters are lower at neutron magic number $N=126$ and 184 . This is due to shell closure property and collective effect at these magic numbers. Also collective behaviour is maximum at 20-25 MeV excitation energy range and it becomes less at higher excitation energy.

Acknowledgments

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References

- [1] E.Gadioli et al., Nucl. Phys. A138, 321 (1969)
- [2] H.A.Bethe, Nuclear Dynamics - Theoretical, Revs. Modern Phys. 9,69 (1937)
- [3] A.R. Junghans et al., Nucl. Phys. A629, 635 (1998)