Effective Moments of Inertia and Spin Cut off Parameters in Hf Isotopes

R. Razavi[1]*, N. Sharifzadeh [2], and M. R. Farahmand [3]
[1]*Department of Physics, Yasooj Branch, Islamic Azad University, Yasooj, Iran*
[2] *Physics Group, Payam Noor University, Mahabad, Iran*
[3]*Shiraz Electronic Industrial, Shiraz, Iran*
* *Email: ariarazavi@yahoo.com*

Introduction

In all statistical theories the nuclear level density is the most characteristic quantity and plays a major role in the study of nuclear structure. Most experimental data on nuclear level density have been analyzed with analytical functions of the level density.

On the basis of statistical models, the effective moments of inertia and spin cut off parameters have been determined for ^{176}Hf, ^{178}Hf and ^{180}Hf nuclei from extensive and complete level schemes and neutron resonance densities in low excitation energy levels. Then, moments of inertia of these nuclei have been determined by Nuclear Rotational model. The results have been compared with their corresponding rigid body value.

Statistical formula

The nuclear temperature T can be defined by the nuclear level density $\rho(E)$ [1].

$$\frac{1}{T} = \frac{d}{dE} Ln\rho(E) \tag{1}$$

Integration yields the constant temperature Fermi gas formula

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

The nuclear temperature T and the ground state back shift E_0 can be determined with experimental data.

The Bethe formula of the level density [2] for the back-shifted Fermi gas model can be written

$$\rho(E) = \frac{e^{2\sqrt{(E-E_1)}}}{12\sqrt{2}\sigma \ a^{1/4}(E-E_1)^{5/4}} \tag{3}$$

In this case the level density parameter a and the ground state back shift E_1 are obtained by a fit to experimental results.

The distribution of spins J is determined by the spin cut-off parameter σ^2.

$$f(J) = \frac{2J+1}{2\sigma^2}\exp\left[-\frac{(J+1/2)^2}{2\sigma^2}\right] \tag{4}$$

With this spin distribution, the spin-dependent level density is

$$\rho(E,J) = \rho(E)\, f(J) \tag{5}$$

where σ^2 is related to an effective moment of inertia I_{eff} and to the nuclear temperature T

$$\sigma^2 = \frac{I_{eff}T}{\hbar^2} \tag{6}$$

The nuclear moment of inertia for a rigid body is $I_{Rigid} = (2/5)MR^2$ (where M=A, the amu nuclear mass; R=1.25A1/3 fm, the nuclear radius) resulting in [3]

$$\sigma^2 = 0.0150\, A^{5/3}T \tag{7}$$

Gilbert and Cameron [4] calculated the spin cut-off parameter for the Bethe formula with the reduced moment of inertia,

$$\sigma^2 = 0.0888A^{2/3}\sqrt{a(E-E_1)} \tag{8}$$

The nuclear moment of inertia from Rotational Model can be written

$$\frac{2I_{rot}}{\hbar^2} = \frac{2(2J+3)}{E_{J+2}-E_J} \tag{9}$$

Figures and Tables

The parameter a and E_1 of the level density formula of Bethe and the parameters T and E_0 of the constant temperature formula have been determined by least squares fits to the experimental data [5] for the ^{176}Hf, ^{178}Hf and ^{180}Hf nuclei (reported in table 1).

Table 1: Level density parameters for the ^{176}Hf, ^{178}Hf and ^{180}Hf nuclei.

Nuclei	a [MeV^{-1}]	E_1 [MeV]	T [MeV]	E_0 [MeV]
^{176}Hf	10.64	0.072	0.571	0.295
^{178}Hf	11.96	0.279	0.532	0.367
^{180}Hf	11.15	0.075	0.603	0.645

The number of levels N (E) up to the energy E for ^{176}Hf with fitted curves calculated with the Bethe and constant temperature formulae have shown in Fig. 1.

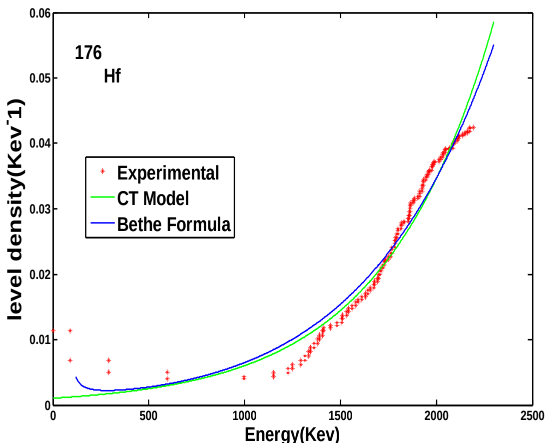

Fig. 1 Plot of the number of levels N (E) up to the energy E for ^{176}Hf together with the fitted curves calculated by the Bethe formula and CT model.

Furthermore, the spin cut-off parameter has been obtained by fitting the known spin distribution (reported in table 2), and effective moment of inertia for each nuclei are determined.

Table 2: Spin cut-off parameter for the Hf Isotopes.

Nuclei	σ_{Rigid}^2	σ_{eff}^2
^{176}Hf	31.4862	11.5773
^{178}Hf	26.3192	10.75
^{180}Hf	30.6272	11.5391

Then, moments of inertia of these nuclei have been determined by Nuclear Rotational model. The results have been compared with their corresponding rigid body value (shown in fig. 2.)

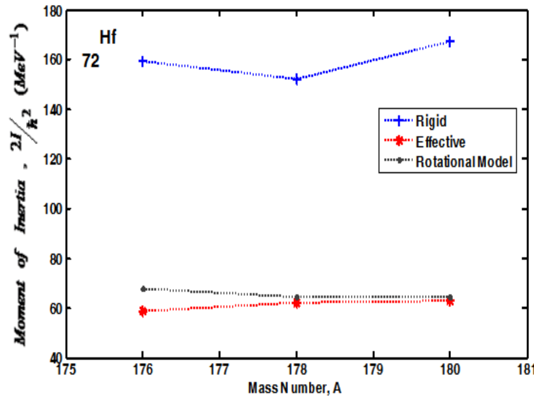

Fig. 2 Moment of inertia (effective, Rigid and from Rotational Model) vs. mass number for the Hf Isotopes.

Conclusion

The Level density and spin cut-off parameters and effective moment of inertia for Hf Isotopes were determined. The level densities near the ground state are well reproduced by the Bethe formula and CT model if two free parameters are fitted.

The moment of inertia from rotational model and effective moment of inertia are comparable. It is not confirmed with its corresponding rigid body value.

References

[1] R. Razavi, Proc. DAE Symp. 55, 144 (2010).

[2] H. A. Bethe, Rev. Mod. Phys. 9, 69 (1937).

[3] R. Razavi and T. Kakavand, Nuclear Technology & Radiation Protection, 26, 1, 69 (2011).

[4] A. Gilbert and A. G. W. Cameron, Can. J. Phys. 43, 1446(1965).

[5] R. Capote, M. Herman, P. Oblozinsky, "Nuclear Data sheets for A= 176 & A=178 and A=180"; Nuclear Data Sheets 110, 12, 3107 (2009).