Nuclear level density and spin cut off parameter

T. Kakavand[1]* ,R. Razavi[2] and A. N. Behkami[3]
[1] *Physics Group, Science Department, Zanjan University, Zanjan, Iran*
[2] *Department of physics, Imam Hussein University, Tehran, Iran*
[3]*Physics Department, Shiraz University, Shiraz Iran*
** Email: t_kakavand472@yahoo.com*

Introduction

In all statistical theories the nuclear level density is the most characteristic quantity and plays an essential role in the study of nuclear structure. In this work the Bethe formula for the back-shifted Fermi gas model and the constant temperature model are compared with the experimental level densities and then we have determined the spin cut off parameters.

Statistical formula

The nuclear temperature 'T' can be defined by the nuclear level density $\rho(E)$ [1].

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

Integration yields the constant temperature Fermi gas formula [2]

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

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 for the back-shifted Fermi gas model [3, 4] can be written

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

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

The distribution of spins J is determined by the spin cut-off parameter σ^2 [3, 4].

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

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

$$\sigma^2=\frac{I_{eff}T}{\eta^2} \qquad (5)$$

The nuclear moment of inertia for a rigid body is $I_{Rigid}=\frac{2}{5}MR^2$ (where M=A, the amu nuclear mass; R=1.25A $^{1/3}$ fm, the nuclear radius) resulting in

$$\sigma^2=0.0150A^{5/3}T \qquad (6)$$

Gilbert and Cameron [2,3] calculated the spin cut-off parameter for the Bethe formula with reduced moment of inertia,

$$\sigma^2=0.0888A^{2/3}\sqrt{a(E-E_1)}\ . \qquad (7)$$

Fit of level density formulae

Each of the two level density formulas has two free parameters. They may be obtained by fitting the experimentally measured level schemes [4, 5]. We have applied these formulas and our best fit values reported in Table 1 and Table 2. The agreement between theory and experiment is very good and both formulas fit the measured level scheme equally well. Furthermore the spin cut off parameter σ^2 has

been obtained by fitting the spin distribution with the theoretical expression (4).
Our best fit values of this parameter are given in Table 3. These deduced values are very different from their corresponding rigid body values (Table 3.). These fittings are contrary to the claim made by some authors that the spin cut off parameter reduces to its rigid body value at lower energies.

Table 1: parameters for CT Model

Nuclei	T[Mev]	E_0 [Mev]
^{36}Cl	1.953	-2.662
^{40}K	1.369	-1.5891
^{60}Co	1.190	-2.6747
^{61}Ni	1.342	-1.9634
^{71}Ge	1.689	-4.4134
^{73}As	1.617	-4.7911

Table 2: parameters for Bethe Formula

Nuclei	a[Mev^-1]	E_1 [Mev]
^{36}Cl	3.460	-1.503
^{40}K	4.9	-0.875
^{60}Co	6.2	-1.789
^{61}Ni	5.1	-1.345
^{71}Ge	5.38	-2.196
^{73}As	5.26	-2.839

Table 3: Spin cut off parameter

Nuclei	σ^2	σ^2 rigid body
^{36}Cl	5.38	8.27
^{40}K	4.32	6.91
^{60}Co	7.3	10.92
^{61}Ni	6.4	11.92
^{71}Ge	5.54	10.96
^{73}As	7.82	14.6

Conclusion

Complete and extensive nuclear level schemes provide a sufficient basis for statistical interpretations of low energy nuclear level schemes and for various tests of statistical theories. The level densities near the ground state and near the neutron binding energy are well reproduced by the Bethe formula and as well as the constant temperature formula if two free parameters are fitted.
Then spin cut-off parameters have been determined from analyses of the experimental data on spins of low-lying states. They are not confirmed with their corresponding rigid body values. Most determinations of the moments of inertia lead to values between half-rigid and rigid –body values.

References

[1] T. Ericson, Nucl. Phys. 11, 481 (1959).
[2] A. Gilbert and A. G. W. Cameron, Can. J. Phys. 43, 1446 (1965).
[3] T. von Egidy, H. H. Schmidt and A. N. Behkami, Nucl. Phys. A 481, 189 (1988).
[4] T. Kakavand, R. Razavi and A. N. Behkami, Proc. DAE Symp. (Nucl. Phys.) 52, 272 (2007).
[5] Privet communication, Wang Shu Neun, China's Atomic Energy.