Correlations between the level density parameters in light nuclei A=20-39

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Introduction

The level density is a fundamental property of a many-body system as all thermodynamical quantities can be derived from it. The nuclear level density is important and critical for estimating nuclear reaction rates in nuclear physics. It can be obtained from experimental data on neutron and proton resonances.

In this work we have determined the nuclear level density parameters of the Bethe formula and constant temperature model for 68 nuclei between ^{20}F and ^{39}Ca and then investigated the correlations between the level density parameters.

Level density formulas

The exponential increase of the level density can be described by the Back-Shifted Fermi Gas formula (BSFG) with the two free parameters a and E_1 or by the Constant Temperature formula (CT) with the parameters T and E_0. These two free parameters can be determined for each nucleus by a fit to the known individual levels in a given energy and spin range at low excitation energies and by the neutron resonance density at the neutron binding energy. Additionally a formula for the spin distribution has to be assumed. We have done this for some nuclei between ^{20}F and ^{39}Ca.

The nuclear temperature T can be defined by the nuclear level density $\rho(E)$ [1,2] .

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

Integration yields the constant temperature Fermi gas formula [3]

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

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 [1] for the back-shifted Fermi gas model can be written

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

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 spin dependence was assumed to be [4]

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

with σ^2 being the spin cut-off parameter.

Gilbert and Cameron [5] calculated the spin cut-off parameter for the Bethe formula with reduced moment of inertia,

$$\sigma^2=0.0888A^{2/3}\sqrt{a(E-E_1)}\ . \qquad (5)$$

Fit of level density formulae

The parameter a and E_1 of the level density formula of Bethe (eq.(3)) with σ^2 from eq. (5) and the parameters T and E_0 of the constant temperature formula have been determined by least squares fits to the experimental data.

The nuclear temperature and nuclear level density parameter as a function of mass number are plotted in figs. 1 and 2.

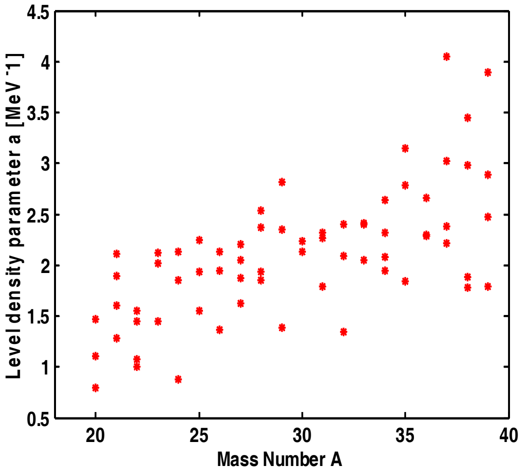

Fig. 1 The Nuclear Level Density parameter Vs. Mass Number.

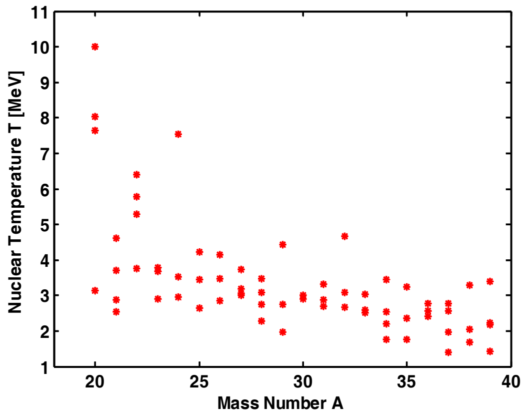

Fig. 2 The Nuclear Temperature parameter Vs. Mass Number.

Furthermore, we investigated the correlations between the level density parameters of the BSFG and CT formulas and found the simple relations:

$$T = 6.506a^{-1.0854} \quad (6)$$

These simple formulas are close to the T. von Egidy Formulas [6] shown in fig. 3.

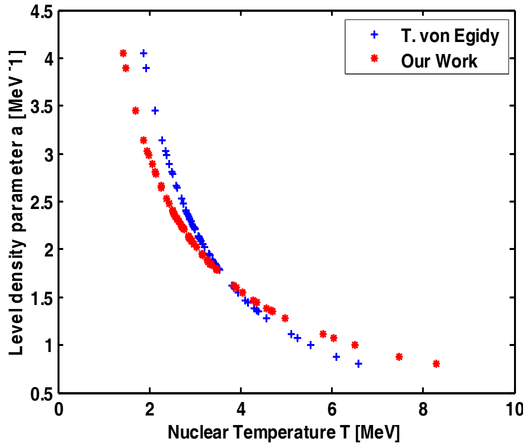

Fig. 3 Correlations between the level density parameter and the Nuclear Temperature.

Conclusion

A new set of level density parameters were determined. The level density near the ground state is well reproduced by the Bethe formula and by the constant temperature formula if two parameters are fitted. Then, Very simple formula is proposed for correlations of the level density parameter with the Nuclear Temperature. The formula can be used to predict level densities where experimental data does not exist.

References

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