Evolution of Nuclear Level Densities

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The energy dependence of nuclear level densities can be described with rather simple formulae using only two free parameters for each nucleus, such as those of the back-shifted Fermi gas (BSFG) model, or the constant temperature (CT) model. These parameters can be obtained from fits to the complete level scheme at low excitation energy (≤3 MeV) *and* the s-wave neutron resonance spacings at the neutron binding energies [1]. As theoretical predictions of the level density parameters are not reliable, it is of interest to be able to extrapolate the experimental ones to nuclei further away from stability, for which resonance data cannot be determined. We determined (i) new level density parameters for 290 nuclei, using the latest nuclear level schemes and neutron resonance data [2], and (ii) new presentations of these parameters which can be used to predict trends for other nuclei.

The experimental parameters are a and C_1 of the BSFG and T and C_0 of the CT. The back shifts E_1 and E_0 in the density formulae are corrected with the pairing energies Δ from mass tables [3] ($C_1 = E_1 - \Delta$ and $C_0 = E_0 - \Delta$); this allows to put even-even, odd and odd-odd nuclei together. In the figure the general dependence on mass A was taken into account by dividing a by $A/9.5$, C_1 by $6.6A^{-1/3}$, T by $18A^{-2/3}$ and C_0 by $12A^{-1/3}$. It has to be noted that low T, C_0 and C_1 values and a large a value indicate large level densities and vice versa.

The evolution of both BSFG and CT parameters with A shows oscillations around smoothly changing curves, which are correlated with the shell fillings, therefore the use of the valence correlation scheme (VCS) appears useful. We present our parameters as a function of $(N_p + N_n)$, where N_p and N_n are the numbers of active particles counted with respect to the classical magic numbers. Some representative results are shown in fig. 1 for $Z = 42$ to 83. They cover all types of structures from closed shell to well deformed nuclei. The parameters were found to vary in a very interesting way with $(N_p + N_n)$. a and T exhibit three branches: (i) vibrational (close to U(5) in the IBA), and transitional (between U(5) and SU(3) or O(6), but not deformed yet) nuclei, with $Z = 42$ to 62 and $(N_p + N_n)$ below 17, (ii) deformed nuclei (close to SU(3)) with $Z = 62$ to 74 and $(N_p + N_n) > 17$, and (iii) near-closed shell and transitional nuclei (between SU(3) and O(6)) with $Z = 74$ to 83. The C_1 and C_0 parameters show also structures for different regions and mass chains, but they have more fluctuations especially for low $(N_p + N_n)$ values. The nuclei not presented in the figure (our set ranges from mass 20 to 250) have parameters which show similar patterns. Consequently, the demonstrated structures of the level density parameters indicate a global behaviour for most of the nuclei.

References

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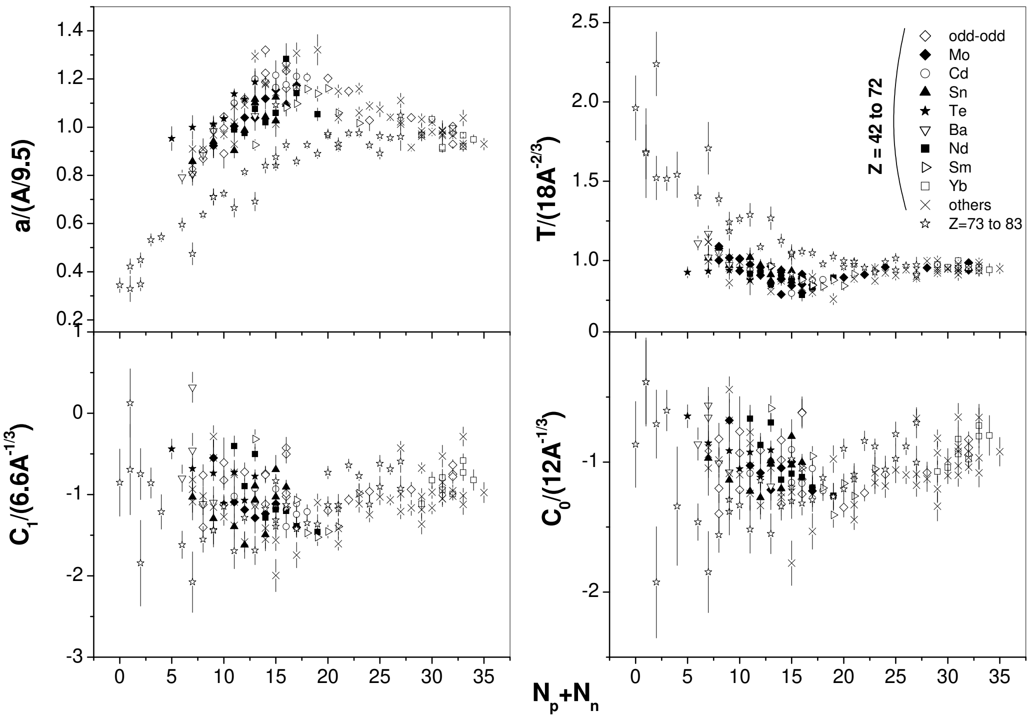

Fig. 1: Systematics of level density parameters with the total number of active particles $N_p + N_n$, for nuclei with Z = 42 to 83.