Single Neutron Hole Entropy in 105Cd and 111Cd (Postprint)

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Abstract

The nuclear level density and entropy were calculated for 105Cd, 106Cd, 111Cd and 112Cd based on the Back Shifted Fermi Gas (BSFG) model and the Constant Temperature (CT) model. Then, the entropies were extracted in the microcanonical ensemble according to recent experimental data on nuclear level density measured by the Oslo group for these nuclei and are compared with their corresponding macroscopic calculations. Entropies of the neutron hole were estimated from the entropy difference between the odd-mass and even-even nuclei. The results reveal that the CT model describes better the extracted microcanonical results.

Full Text

Preamble

Fig. 1 [Figure 1: see original paper]. (Color online) Experimental and calculated level density as a function of excitation energy in (a) ^{105}Cd, (b) ^{106}Cd, (c) ^{111}Cd and (d) ^{112}Cd.

The level density is proportional to the number of states accessible at a given excitation energy. The multiplicity of states is defined as $/_0$, where $_0$ is the level density close to the ground state. Thus, the entropy in the microcanonical ensemble is given by S = K_B · ln($/_0$), where K_B is the Boltzmann constant. The single neutron hole entropy is given by [13] ΔS = S(Odd-A) − S(A + 1).

III. RESULTS AND DISCUSSION

Nuclear level densities of ^{105}Cd, ^{106}Cd, ^{111}Cd and ^{112}Cd are extracted using the CT and BSFG models, based on experimental data on nuclear level density measured by the Oslo group [9]. Two nuclear level density formulas are parameterized and the results are tabulated in Table 1 . The level densities as a function of excitation energy are shown in Fig. 1 [Figure 1: see original paper], with their corresponding experimental values [9] plotted for comparison. As can be seen from Fig. 1, the overall agreement between the experimental level densities and theoretical results is satisfactory. However, the CT model reproduces better level densities for these nuclei than the BSFG model.

According to Eq. (8), the entropy is calculated from the computed level density. The entropies are also extracted from experimental data on nuclear level density in the microcanonical ensemble framework. The calculated entropies in the microcanonical ensemble are shown in Fig. 2 [Figure 2: see original paper] for ^{111}Cd and ^{112}Cd, respectively, with their corresponding values obtained from the phenomenological models plotted for comparison. It can be seen that the microcanonical entropy corresponds well with the calculated entropy within the CT model.

Fig. 2 [Figure 2: see original paper]. (Color online) The entropy as a function of excitation energy for (a) ^{111}Cd and (b) ^{112}Cd.

The entropy is related to the number of microstates accessible to a system. The entropy of the ^{105}Cd (^{111}Cd) nucleus follows closely the entropy for ^{106}Cd (^{112}Cd), but the even-odd system has an entropy excess. The single neutron hole entropy is defined as the difference between the entropy of the even-odd and even-even neighboring nuclei, and this entropy difference represents the entropy carried by the neutron hole coupled to the ^{106}Cd (^{112}Cd) core.

Finally, the calculated entropy excess in even-odd nuclei compared to nearby even-even nuclei, according to Eq. (9), is interpreted as the single neutron hole entropy in even-odd nuclei and is plotted in Fig. 3 [Figure 3: see original paper]. More information on the calculation procedure can be found in our previous publications [1–3, 11, 13]. An examination of Fig. 3 reveals that the single neutron hole entropy in ^{105}Cd differs from that in ^{111}Cd, due to different accessible microstates in each system. The different predictions of the number of accessible microstates in the two models lead to different results for the single neutron hole entropies. Also, when the number of accessible microstates versus excitation energy oscillates, so does the single neutron hole entropy. The calculated single neutron hole entropy from the CT model agrees well with the extracted results in the microcanonical ensemble framework.

Fig. 3 [Figure 3: see original paper]. (Color online) Calculated single neutron hole entropy in (a) ^{105}Cd and (b) ^{111}Cd.

In summary, the nuclear level densities for ^{105,106,111,112}Cd have been extracted within two phenomenological models, the Constant Temperature (CT) and the Back Shifted Fermi Gas (BSFG) models, using the new experimental data on nuclear level density measured by the Oslo group. Then the entropies have been extracted for these nuclei in both models and also in the microcanonical ensemble framework. Finally the entropies of the neutron hole are estimated. The results reveal that the CT model can reproduce microcanonical results for these nuclei better than the BSFG model.

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Note: Figure translations are in progress. See original paper for figures.