Single neutron hole entropy and entropy excess in ^{105}Cd Compared to ^{106}Cd

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Introduction

Study of nuclear level densities as a function of excitation energy is an important goal in nuclear physics for deduces the thermal quantities[1-3].

The first theoretical attempt to describe nuclear level densities was performed by Hans Bethe in 1936 [4].

In this work, level densities for ^{105,106}Cd isotopes within the two phenomenological models have been extracted according to the new experimental data by the Oslo group [5]. Then, the entropy of the even-odd and even-even nuclei has been deduced as a function of excitation energy.

Statistical Formula

Nuclear temperature T can be defined by nuclear level density ρ(E) [6]

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

Integration yields the constant temperature Fermi gas formula [7]

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

Nuclear temperature T and the ground state back-shift E_0 can be determined through experimental data on level density.

The Bethe formula of the level density for the back-shifted Fermi gas model [8] can be written

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

The level density parameter (a) and the ground state back-shift E_1 are obtained by fit to the experimental data.

Gilbert and Cameron calculated the spin cut-off parameter related to an effective moment of inertia [7],

$$\sigma^2 = 0.0888\, A^{2/3}\sqrt{a(E-E_1)} \qquad (4)$$

The level density ρ(E) is proportional to the number of states accessible to the nuclear system at a given excitation energy E. We may define the multiplicity of states as $\Omega(E)=\rho/\rho_0$ where ρ_0 is the level density close to the ground state in the even-even isotope. The entropy in the microcanonical ensemble is given by [7]

$$S(E)= k_B ln\Omega(E) \qquad (5)$$

Where k_B is the Boltzmann Constant. The single hole entropy is given by [8]

$$\Delta S\,(hole)= S\,(^{105}Cd) - S(^{106}Cd) \qquad (6)$$

Level density and Single hole entropy

Each of the two level density formulas has two free parameters. They may be obtained by fitting the measured level schemes experimentally. Our best fit values obtained using the level density formulas are listed in table 1.

Table 1: Best fit values obtained using the level density formulas

Nuclei	E_0 (MeV)	T (MeV)	a (MeV^{-1})	E_1 (MeV)
^{105}Cd	-0.982	0.742	12.06	0.126
^{106}Cd	-0.539	0.681	12.65	1.367

Using obtained parameters, the level densities as a function of excitation energy for isotopes ^{105}Cd and ^{106}Cd are extracted. The level density as a function of excitation energy for ^{105}Cd is shown in fig.1. We see good agreement between the calculated level density and the experimental level densities. According to equation (5), entropy is calculated for two nuclei. Entropy defined in canonical ensemble in fig. 2 was similar for two nuclei and in odd nuclei there is only some of entropy excess. Finally, according to equation (6) single hole entropy as a function of the excitation energy is extracted and is plotted in fig. 3.

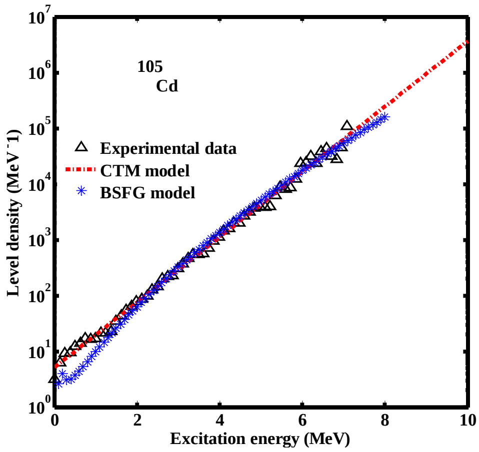

Fig. 1 Level density as a function of excitation energy for ^{105}Cd with experimental data [5].

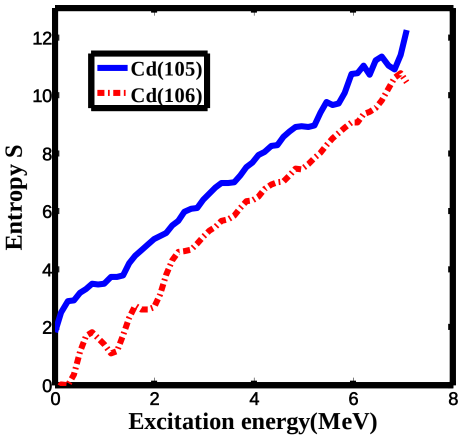

Fig. 2 plot of the entropy as a function of excitation energy for ^{105}Cd and ^{106}Cd.

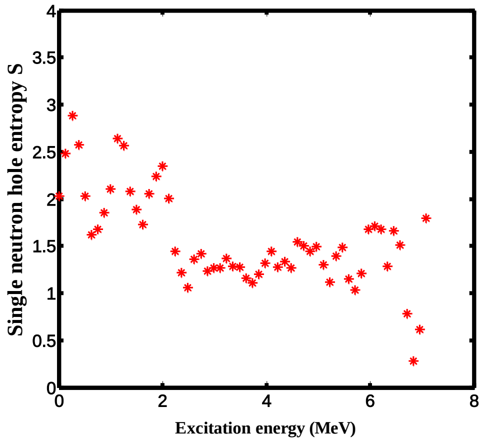

Fig. 4 plot of the single neutron hole entropy in ^{105}Cd

Conclusions

The nuclear level densities and entropies have been extracted for ^{105,106}Cd isotopes as a function of excitation energy within the macroscopic theory and canonical ensemble. The entropy of ^{105}Cd nuclei is seen to display an almost constant entropy excess compared to ^{106}Cd. The entropy excess has been calculated as a single hole entropy in ^{105}Cd. The single neutron hole is found to be 1.25 within the canonical ensemble.

References

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