SHELL-MODEL MONTE CARLO INVESTIGATION OF RARE-EARTH NUCLEI

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Our goal is to develop an improved microscopic understanding of the structure of rare-earth nuclei; i.e. an understanding based on the behavior of individual nucleons in the nucleus. Toward that end we solve the shell model systematically in a full oscillator shell basis with intruders for the first time in rare-earth nuclei using the shell-model Monte Carlo (SMMC) technique; calculations using other methods have been restricted to a severely truncated model space. SMMC allows us to trace structural rearrangements within nuclei induced by changes in temperature and spin, so that we may obtain a clearer microscopic picture of general structural features in this region of the periodic table.

We assume an effective two-body nucleon-nucleon interaction and perform a Hubbard-Stratonovich transformation to obtain a path integral representation for the partition function, which is then evaluated by Monte Carlo methods to produce an exact shell-model solution within statistical errors; this substantially enhances the predictive power of the nuclear shell model for some observables. Indeed, direct diagonalizations of the shell-model Hamiltonian in a full basis have been limited to A $\sim$ 50, while we present calculations for A $\sim$ 150.

We examine how the phenomenologically motivated “pairing-plus-quadrupole” interaction compares in exact shell-model solutions vs. the mean-field treatment. We also examine how the shell-model solutions compare with experimental data; static path approximation (SPA) calculations are also shown. There have been efforts recently by others to use SPA calculations since it is simpler and faster (see Refs. 2 and 3 as examples). However, the SPA results are not consistently good. In particular, it is useful to know not only if phenomenological pairing-plus-quadrupole-type interactions can be used in exact solutions for large model spaces, but also if the parameters require significant renormalization because this affects the accuracy of the SPA.

We study a range of dysprosium isotopes (Z = 66, 86 $\leq$ N $\leq$ 96), which exhibit a rich spectrum of the behaviors such as shape transitions, level crossings, and pair transfer that have been observed in the rare earths. These results should therefore apply quite generally in the rare-earth region, although the immediate work focuses on dysprosium. We have selected this element since the half-filled proton shell makes the model spaces particularly large.

This work entails part of Jody White’s Ph. D. thesis at Caltech, which she obtained at Caltech in 1998, and is the basis for a manuscript recently submitted to Physical Review C.

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