TENSOR EFFECTS IN SHELL EVOLUTION AT Z, N = 8, 20, AND 28

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Nuclear Structure

The tensor component is a noncentral contribution of the nucleon-nucleon interaction, which has been extensively discussed in the past years. Ab initio calculations based on realistic nucleon-nucleon interactions have demonstrated the important role played by the bare tensor force in the description of the binding energy of nuclei [1,2]. In spite of this, the tensor term of the interaction has been usually neglected so far in effective theories at the mean-field level.

In this work, we discuss how the tensor component contributes to the shell evolution in some regions of the nuclear chart at the mean-field level, using nonrelativistic Skyrme and Gogny-HF models, as well as RHF models. In particular, we are interested in the behavior of the proton (neutron) gaps at magic numbers Z(N) = 8, 20, and 28.
In the evolution of these magic gaps we are mainly interested in the effects owing to the neutron-proton interaction related to the tensor contribution, that is, the effects on proton (neutron) levels owing to the filling of neutron (proton) orbits. The theoretical gaps obtained with and without the tensor contribution are compared with the experimental ones, when available, to evidentiate the cases where the tensor effects are unambiguously important (or not) in determining the shell evolution. One of the motivations for this systematic analysis is to eventually find the best regions for performing parametrization fits in mean-field models including the tensor component.

Hartree-Fock calculations with Skyrme[4-6] and Gogny[7,8] interactions are performed where the tensor term has a zero and finite range, respectively. Results obtained with and without the tensor component are compared between them and with the experimental data [3], when available. To complete this analysis, the tensor effect is also investigated within the relativistic Hartree-Fock model [9-11], where the exchange of ρ mesons and pions is taken into account. It turns out that the tensor effect in the evolution of the magic gaps can be more easily identified in the cases Z,N = 8 and 20, whereas the interpretation of the effect is more complicated for Z or N = 28.

We restrict our analysis to relatively light nuclei and we had to neglect pairing correlations in our analysis and perform only HF calculations for all nuclei, both closed and open-shell. The main reason for this is that the GT2 parametrization [12-15] that we adopt in the Gogny case (and which is the only available Gogny parametrization containing also a tensor term) has been fitted at the HF level. In general, we would expect that pairing correlations would modify and reduce the predicted effects in some cases.

Theoretically, it is found that the evolution of the gaps in these regions is actually affected by the tensor contribution. However, the tensor contribution with the adopted parametrizations globally acts in the opposite direction with respect to what would be expected to better reproduce the experimental trends. Nonetheless, in the two nonrelativistic cases, we have observed that it is possible to modify the theoretical trends by changing the signs of the parameters of the tensor term.

Since the evolution of the gaps is an important feature characterizing exotic nuclei, we conclude that the observables related to this feature should be included in the fit procedures when the tensor terms have to be constrained. It is also important to properly choose the regions where to perform these fits and Z,N = 8 and 20 seem to be suitable regions where the role played by the tensor force can be less ambiguously identified in the mean-field framework.

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