CHALLENGES FOR NUCLEAR STRUCTURE: FROM STABLE TO WEAKLY BOUND NUCLEI

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Physical properties, such as masses and life-times, of very short-lived, and hence very rare, nuclei are important ingredients that determine element production mechanisms in the universe. Given that present nuclear structure research facilities and the proposed Rare Isotope Accelerator will open significant territory into regions of medium-mass and heavier nuclei, it becomes important to investigate theoretical methods that will allow for a description of medium-mass systems that are involved in such element production. Such systems pose significant challenges to existing nuclear structure models, especially since many of these nuclei will be unstable and short-lived. How to deal with weakly bound systems and coupling to resonant states is an unsettled problem in nuclear spectroscopy.

The ab initio coupled cluster theory is a particularly promising candidate for such endeavors due to its enormous success in quantum chemistry. Refs. [1, 2, 3] describe applications of coupled cluster techniques to nuclear structure. The coupled-cluster methods are very promising, since they allow one to study ground- and excited-state properties of nuclei with dimensionalities beyond the capability of present shell-model approaches, with a much smaller numerical effort when compared to the more traditional shell-model methods aimed at similar accuracies. For the weakly bound nuclei to be produced by the proposed Rare Isotope Accelerator it is almost imperative to increase the degrees of freedom under study in order to reproduce basic properties of these systems.

Here we present several results from recent calculations with singles, doubles, and noniterative triples and their generalizations to excited states applied to ^{16}O. A comparison of coupled cluster results with the results of the exact diagonalization of the Hamiltonian in the same model space shows that the quantum chemistry inspired coupled cluster approximations provide an excellent description of ground and excited states of nuclei. How to derive effective interactions for weakly bound systems to be used in coupled-cluster calculations will also be addressed [4, 5].

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