Nuclei towards drip-line: A shell model study

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Introduction

Despite the progress in the experimental side, we need theoretical estimates for energy levels, electromagnetic properties, $B(GT)$ strengths, spectroscopic factor strengths and single β-decay half-lives of neutron rich nuclei especially those belonging to the island of inversion.

The aim of the present thesis [1] is to test the suitability of chosen valence spaces and effective interactions for various regions of nuclear chart; to make predictions for the unknown energy levels and electromagnetic properties which can serve as basis for future experiments; to compare experimental $B(GT)$ strengths and single β-decay half-lives with theoretical shell-model results; to identify proton and neutron pair breakings to obtain the high spin states; to study the spectroscopic factor strengths for recently available experimental data using *ab initio* approaches.

Details of present thesis work

A systematic shell model description of the Gamow-Teller transition strength distributions in ^{42}Ti, ^{46}Cr, ^{50}Fe and ^{54}Ni are presented in ref. [2]. These transitions have been recently measured via β^--decay of these T_z = -1 nuclei, produced in fragmentation reactions at GSI and also with (^3He,t) charge-exchange (CE) reactions corresponding to $T_z = +1$ to $T_z = 0$ carried out at RCNP-Osaka. The calculations are performed in the pf model space, using the GXPF1a and KB3G effective interactions. Qualitative agreement is obtained for the individual transitions, while the calculated summed transition strengths closely reproduce the observed ones. The theoretical strengths are larger than the experimental value. It may mean that a substantial amount of strength has not been experimentally measured. In all cases the calculations predict the existence of a fragmented but observable $B(GT)$ strength at excitation energies between 6 to 12 MeV, which could become observable in future experiments.

Results for the allowed β^--decay half-lives of nuclei with Z = 20 - 30 and N $\leq$ 50 systematically study under the framework of the nuclear shell model [3]. A recent study shows that some nuclei in this region belong to the island of inversion, such as $^{63-66}$Mn and ^{67}Co. We perform calculation for fp shell nuclei using the KB3G effective interaction. In the case of Ni, Cu, and Zn, we used the JUN45 effective interaction. Theoretical results of Q-values, half-lives, excitation energies, logft values, and branching fractions are discussed and compared with the experimental data. In the Ni region, we also compared our calculated results with recent experimental data. The present results agree with the experimental data of half-lives in comparison to QRPA. The present shell model results will add more information to the earlier QRPA results due to Möller *et al.* The QRPA results for half-lives are larger because it is pushing down GT-strength at low energies. Further experimental half-lives measurement for very neutron-rich fp and $f_{5/2}pg_{9/2}$ shell nuclei are strongly desired to test shell model effective interaction.

Large scale shell model calculations for $^{124-127}$Te isotopes have been studied in ref. [4]. In the present work recently available experimental data for high-spin states of four nuclei, ^{124}Te, ^{125}Te, ^{126}Te, and ^{127}Te have been interpreted using state-of-the-art shell model calculations. The calculations have been performed in the $50 - 82$ valence shell composed

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of $1g_{7/2}$, $2d_{5/2}$, $1h_{11/2}$, $3s_{1/2}$, and $2d_{3/2}$ orbitals. We have compared our results with the available experimental data for excitation energies and transition probabilities, including high-spin states. The results are in reasonable agreement with the available experimental data. The wave functions, particularly, the specific proton and neutron configurations which are involved to generate the angular momentum along the yrast lines are discussed. We have also estimated overall contribution of three-body forces in the energy level shifting; results with modified effective interaction are also reported. The electric transition probabilities are in reasonable agreement with the experimental data with $e_p = 1.5e$ and $e_n = 1.0e$. High-spin states in nuclei Z $\sim$ 50 are expected from breaking of neutron/proton pairs. Experimentally it is difficult to detect the de-excitation of these high-spin states through long-lived isomers.

For ^{77,79,81,83}As, ^{79,81,83}Se and ^{86,87,88,89}Y isotopes, we performed shell model calculations in $p_{3/2}$, $f_{5/2}$, $p_{1/2}$ and $g_{9/2}$ valence space with two recent effective interactions JUN45 and jj44b using ^{56}Ni as a core. The overall results for the energy levels and magnetic moments are in rather good agreement with the available experimental data [5–7]. Further theoretical development is needed by enlarging model space by including $\pi 0 f_{7/2}$ and $\nu 1 d_{5/2}$ orbitals. In the case of As isotopes, to study the importance of the proton excitations across the $Z = 28$ shell in this region. We have also performed calculation in $fpg_{9/2}$ valence space using an fpg effective interaction with ^{48}Ca core and imposing a truncation.

The comprehensive analysis of shell model results for high-spin states of ^{87}Sr and ^{87}Zr for recently available experimental data within the full $f_{5/2}pg_{9/2}$ model space using JUN45 and jj44b effective interactions developed for this model space reported in ref. [8]. In this work we have compared the energy levels, electromagnetic transition probabilities, quadrupole and magnetic moments with available experimental data. We have confirmed structure of high-spin states of these two nuclei which were tentatively assigned in the recent experimental work.

We have calculated the spectroscopic factor strengths for the one-proton and one-neutron pick-up reactions ^{27}Al(d,^{3}He)^{26}Mg and ^{27}Al(d,t)^{26}Al within the framework of the shell model. We employed two different *ab initio* approaches : an in-medium similarity renormalization targeted for a particular nucleus, and the coupled- cluster effective interaction. We also compared our results with recently determined experimental spectroscopic factors [9].

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