Study of ^{54,55,56}Sc in the shell model framework

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Introduction

In the neutron-rich *pf* shell, bounded by the proton and neutron numbers $Z = 20-28$ and $N = 28-40$, the emergence of new subshell closures at N = 32 and 34 has attracted significant interest in experimental and theoretical research. Different methods, such as β decay, multinucleon transfer, and nucleon-knockout reactions, have been used to study the structure of neutron-rich Sc isotopes over the last few years. Previously various groups have established the level scheme for ^{54,55,56}Sc isotopes. Crawford et. al. [1] reported the low-lying structure of isotopes ^{54}Sc and ^{56}Sc from isomeric state decays, as well as from the β decay of ^{54}Ca. Steppenbeck et. al [2] experimentally established $7/2^-$ as the ground state of ^{55}Sc and suggested the rapid quenching of N=34 subshell closure due to the relatively low energy of the first excited state. Steppenbeck et al [3] investigated the low-lying structure of ^{55}Sc using in-beam γ -ray spectroscopy and determined the energy of the first $3/2^-$ state.

In the present work, ground state nuclear structure properties of ^{54,55,56}Sc isotopes have been studied in the framework of the shell model by using different phenomenological interactions.

Theoretical Framework

Shell model calculations with four different effective interactions — CA48MH2G[4], CA48MH1G[4], CA48MH11 and are used to determine the energies and wavefunctions of the levels in ^{54,55,56}Sc isotopes. ^{48}Ca is used as the core for the shell model calculations, using the orbitals $\pi(p_{3/2}\ p_{1/2}\ f_{5/2}\ f_{7/2})$, $\nu(p_{3/2}\ p_{1/2}\ f_{5/2}\ g_{9/2})$. In the current work, the thick-restart Lanczos method is used to compute the energy levels of the ^{54,55,56}Sc isotopes using M-scheme representation. For the transition strength calculations, we use g factors $g_p^s = 5.585$, $g_n^s = -3.826$, $g_p^l = 1.000$, $g_n^l = 0.000$. Effective charges $e_\pi = 1.5e$ and $e_\nu = 0.5e$ are used for protons and neutrons, respectively, for all the interactions. The calculated results are compared with the experimental data.

Results and Discussion

We have presented here the theoretical results for the ground state nuclear structure properties of ^{55}Sc. All the three isotopes will be presented in the symposium.

In Fig. 1, experimental data [5] for ^{55}Sc are compared with the calculated energy levels using four different interactions. Experimentally, in ^{55}Sc, the ground and the first excited states have been assigned spins $J^\pi = \frac{7^-}{2}, \frac{3^-}{2}$, respectively. The experimental results are best reproduced by CA48MH2G interaction. On the contrary, the calculations with the other three interactions predict a ground state with $J^\pi = \frac{3^-}{2}$ and the first excited as $J^\pi = \frac{7^-}{2}$. Moreover, the present calculations have predicted many new energy states in the calculated results of all the four interactions. For example, energy states up to $J^\pi = \frac{15^-}{2}$ have been predicted by using CA48MH2G interaction and up to $J^\pi = \frac{13^-}{2}$ by using CA48MH1G, CA48MH11 and HYBRIDGXPF1ACAMH1G interactions. The experimentally observed $J^\pi = \frac{3^-}{2}$ state at 0.695 MeV is reproduced by the CA48MH2G interaction at 0.708 MeV. The absolute difference between the two values is 0.0013 MeV. The experimentally observed first excited $J^\pi = \frac{7^-}{2}$ state at 1.73 MeV is reproduced by CA48MH2G interaction at 1.777 MeV with an absolute difference of 0.047 MeV.

The transition probability calculated by using CA48MH2G interaction, for the decay to the ground state $B\left(E2; \frac{3^-}{2} \rightarrow \frac{7^-}{2}\right)$ is 9.52W.u. At present, the experimental data on transition probabilities is not available for comparison with the calculated values. The B(M1) values and quadrupole moments have also been predicted by using all the four interactions.

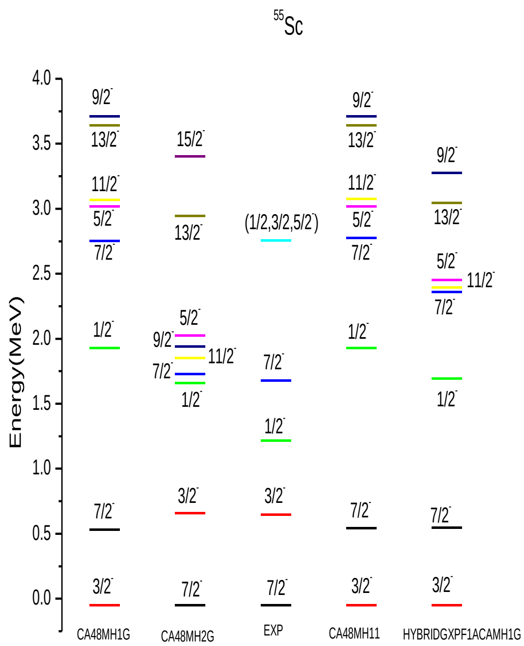

Fig. 1 Comparison of calculated energy levels for ^{55}Sc using the CA48MH1G, CA48MH2G, CA48MH11 and HYBRIDGXPF1ACAMH1G interactions with the available experimental data.

Conclusions

Shell model calculations have been employed to study the nuclear structure properties of neutron-rich $^{54,55,56}Sc$ isotopes. The overall calculated results for the energy levels are in good agreement with the experimental data. The B(E2) and B(M1) values are calculated using different interactions. The available experimental data are best reproduced by CA48MH2G interaction.

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