Shell model study of odd mass Titanium isotopes

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Introduction

The neutron rich titanium isotopes are the focus of many studies during recent years. Previously various groups have identified the level scheme for ^{55,57,59}Ti isotopes. Crawford et. al. [1] experimentally determined the low-energy levels of neutron-rich ^{53,55,57}Ti through the β-decay of the parent nuclides ^{53,54}Ca and $^{53-57}$Sc and suggested a spin and parity of $J^\pi = \frac{5^-}{2}$ for the ground state of ^{57}Ti. Kameda et. al. [2] observed a new isomeric γ-ray at 109.0 keV with a half-life of $0.587^{+0.057}_{-0.051}$μs for ^{59}Ti and assigned $J^\pi = \left(\frac{5^-}{2}\right)$ for the ground state of ^{59}Ti and proposed $\left(\frac{1^-}{2}\right)$ for isomer. Wimmer et.al. [3] studied isomeric decay of ^{59}Ti and predicted $J^\pi = \frac{1^-}{2}$ for the ground state and $J^\pi = \frac{5^-}{2}$ for the first excited state of ^{57,59}Ti using large-scale shell model calculations based on the modified LNPS interaction. Recently, Porter et.al. [4] performed mass measurements of neutron-rich ^{55}Ti isotope and does not support the presence of an N = 34 shell closure. In the present work, ground state nuclear structure properties of ^{55,57,59}Ti isotopes have been studied in the framework of shell model by using different phenomenological interactions.

Theoretical Framework

Four interactions—GXPF1[5], GXPF1A [6], KB3 [7], and FPD6 [8] are used to determine the energies and wavefunctions of the levels in ^{55,57,59}Ti isotopes by using the shell model code KSHELL [9]. The inert ^{40}Ca is used as the core for the shell model calculations, using the orbitals $1p_{3/2}$, $1p_{1/2}$, $0f_{7/2}$ and $0f_{5/2}$ in the pf model space. In the current work, the thick-restart Lanczos method was used to compute the energy levels of the ^{55,57,59}Ti isotopes using M-scheme representation. All these interactions predict the energy levels, B(E2) and B(M1) values by using g factors $g_p^s = 3.910$, $g_n^s = -2.677$, $g_p^l = 1.000$, $g_n^l = 0.000$. Effective charges e_π = 1.5e and e_ν= 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 ground state nuclear structure properties of ^{57}Ti. All the three ^{55,57,59}Ti isotopes will be presented in the symposium.

In Fig. 1, experimental data [10] for ^{57}Ti are compared with the calculated energy levels using four different interactions. In ^{57}Ti, only two states with negative parity are known experimentally. The ground state had been assigned $J^\pi = \frac{5^-}{2}$ with an excited $J^\pi = \frac{1^-}{2}$ state. The experimental results are predicted well by using GXPF1, KB3 and FPD6 interactions. On the contrary, the calculations with the GXPF1A interaction predicts a ground state with $J^\pi = \frac{1^-}{2}$ and the first excited $J^\pi = \frac{5^-}{2}$ state which agrees with ref. [3]. Moreover, the present calculations predicted many new states in all the four interactions up to $J^\pi = \frac{17^-}{2}$ using GXPF1and GXPF1A interactions and up to $J^\pi = \frac{15^-}{2}$ using FPD6 and KB3 interactions. The experimentally observed $J^\pi = \frac{5^-}{2}$ state at 0.364 MeV is reproduced by the GXPF1 interaction at 0.422 MeV. The absolute difference between the two values is 0.058 MeV.

Using GXPF1A interaction, the calculated transition probability for the decay to the ground state $B\left(E2; \frac{5^-}{2} \rightarrow \frac{1^-}{2}\right)$ is 0.9 W.u. whereas using GXPF1 interaction, the calculated transition probability for the decay to the ground state

$B\left(E2; \frac{1}{2}^- \rightarrow \frac{5}{2}^-\right)$ is 1.7 W.u. At present the experimental data is not available on transition probabilities for comparison.

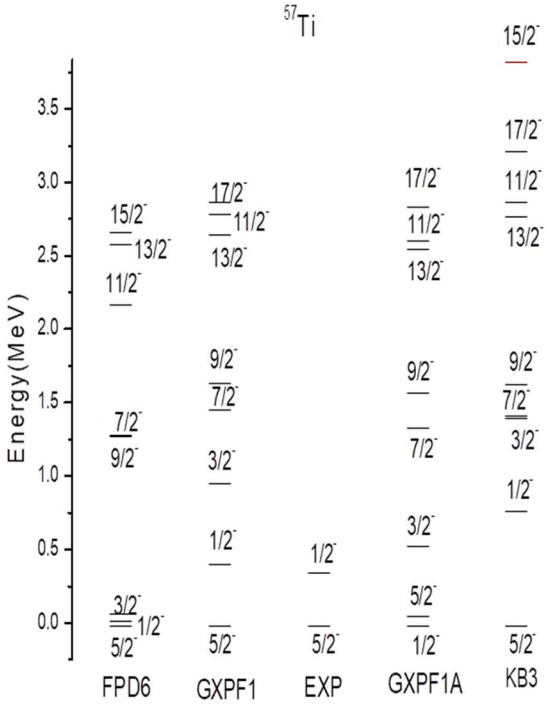

Fig. 1 Comparison of calculated energy levels for ^{57}Ti with the available experimental data [10].

Conclusions

KSHELL code has been employed to study the nuclear structure properties of neutron-rich ^{55,57,59}Ti isotopes. The overall calculated results for the energy levels values are in good agreement with the experimental data. B(E2) and B(M1) values are calculated using different interactions. The results are best reproduced by GXPF1 and GXPF1A interactions and the results reproduced by FPD6 and KB3 interactions are reasonable.

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