Study of nuclear structure properties of some neutron-rich titanium nuclei

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Introduction

The study of neutron-rich Titanium (Ti) isotopes constantly attract interest both in experimental and theoretical research. Previously, various groups identified the level scheme for ^{52,54,56}Ti [1-3]. Zhu et.al. [4] further expanded the ^{52}Ti level scheme and also determined the lifetimes of some of the identified states for the first time. Recently, Goldkhule et.al. [5] measured the lifetimes of yrast states in ^{52,54}Ti and deduced E2 transition strengths and $B(E2; J_1^+ \rightarrow (J-2)_1^+)$ values. Further, Ohkuba [6] calculated $B(E2; J_1^+ \rightarrow (J-2)_1^+)$ values for ^{52}Ti and compared them with the previous work [5]. With the availability of high-performance computing facilities, now it has become possible to study the nuclear structure of neutron-rich nuclei in the shell model framework. Therefore, in the present work, ground state nuclear structure properties of ^{52,54,56}Ti isotopes have been studied in the framework of shell model by using different phenomenological interactions.

Theoretical Framework

The shell model code KSHELL [7] is used to calculate energies and wavefunctions of the levels in ^{52,54,56}Ti isotopes using four interactions, GXPF1[8], GXPF1A [9], KB3 [10] and FPD6 [11].

In the shell model, the valence nucleons can move in a finite number of j-orbits and the Hamiltonian of the valence nucleons is given as following [12]

$$H = E_0 + \sum_i \varepsilon_i a_i^+ a_i + {}^1/_2 \sum_{ijkl} \langle ij|V|kl\rangle \; a_i^+ a_j^+ a_l a_k$$

Here, E_0, ε_i and $\langle ij|V|kl\rangle$ terms are the energy for the inert core, the single particle energies (SPE) for the valence orbits and the two body matrix elements (TBME) of residual interaction amongst the valence particles, respectively. The shell model calculations are carried out in the full *pf* shell and inert ^{40}Ca is taken as the core. The *pf* model space includes $1p_{3/2}$, $1p_{1/2}$, $0f_{7/2}$ and $0f_{5/2}$ orbitals. In the present work, energy levels for ^{52,54,56}Ti isotopes have been calculated by using M-scheme representation with the thick-restart Lanczos method. Effective charges e_π = 1.5e and e_ν= 0.5e are used for protons and neutrons, respectively, for all the interactions. All these interactions predict the energy levels, B(E2) and B(M1) values by using g factors $g_p^s = 3.910$, $g_n^s = -2.677$, $g_p^l = 1.000$, $g_n^l = 0.000$. The calculated results are compared with the experimental data.

Results and Discussion

As an example, we have presented here the ground state nuclear structure properties of ^{52}Ti. All the three ^{52,54,56}Ti isotopes will be presented in the symposium.

In Fig. 1, experimental data for ^{52}Ti [13] are compared with the calculated energy levels using four different interactions. The experimentally observed energy spectra is reproduced well by the GXPF1A and GXPF1 interactions. The results of FPD6 and KB3 interactions are reasonable. Moreover, the present calculations predicted two new states with I= 3^+ and 1^+ in all the four interactions. The state I=2^+ calculated by all the four interactions gives good agreement with the experimental data. The experimentally observed I=2^+ state at 1.05MeV is reproduced by the GXPF1A interaction at 1.106 MeV. The absolute difference between the two values is 0.056 MeV. The calculated B(E2) values are shown in Table 1. In the present work, our predicted results for B(E2) values are close to the experimental data [5] in comparison with [6]. The B(E2) values for $2_1^+ \rightarrow 0_1^+$ and $4_1^+ \rightarrow 2_1^+$ transitions calculated by GXPF1 and GXPF1A are in good agreement with the experimental values [5] and B(E2) value for $6_1^+ \rightarrow 4_1^+$ is reasonably close to the experimental data. Table 2, shows the calculated B(M1) values. The calculated B(M1) values for ^{52}Ti with all the interactions give good agreement with the experimental data.

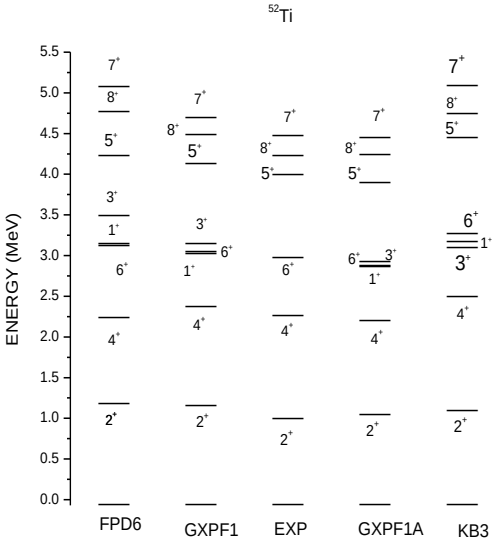

Fig. 1 Comparison of calculated energy levels for ^{52}Ti using the FPD6[11], GXPF1[8], GXPF1A [9] and KB3[10] interactions with the available experimental data [14].

Table 1: Comparison of calculated $B(E2; J_1^+ \rightarrow (J-2)_1^+)$ values using the effective interactions GXPF1[8], GXPF1A [9], KB3 [10], and FPD6 [11] with the available experimental data [5,6].

$B(E2; J_1^+ \rightarrow (J-2)_1^+)$ [e^{2}fm^4]				
I_1^+	2_1^+	4_1^+	6_1^+	8_1^+
Exp. [5]	86^{+5}_{-4}	109^{+16}_{-13}	100^{+7}_{-6}	8.8^{+1}_{-1}
Exp. [6]	108	142	134	109
GXPF1	85.8	113.8	86.6	47.1
GXPF1A	87.5	117.8	88	49.1
KB3	101.9	121.4	79.7	
FPD6	89.0	118.1	90.1	

Table 2: Comparison of calculated B(M1) values using the effective interactions GXPF1[8], GXPF1A [9], KB3[10], and FPD6 [11] with the available experimental data [14].

B(M1) (W.u.)		
	$2_2^+ \rightarrow 2_1^+$	$2_3^+ \rightarrow 2_1^+$
Exp.	0.31	0.056
GXPF1	0.46	0.05
GXPF1A	0.46	0.07
KB3	0.27	0.01
FPD6	0.46	0.00

Conclusions

The study of nuclear structure properties of neutron rich even-even Titanium nuclei has been carried out using KSHELL code. The overall calculated results for the energy levels, B(E2) and B(M1) values are in good agreement with the experimental data. The results are best reproduced by GXPF1 and GXPF1A interactions.

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