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Effective M3Y-P2 interaction of study nuclear energy levels for 48Ti in fp shell model

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Abstract: In the fp-shell area of the 48Ti isotope (Z=22, N=26), examine the nuclear excitation energies using the nuclear shell model. The energy levels, total angular momentum, and parity of the nucleons outside the locked core 40Ca are calculated using the OXBASH algorithm for GX2, GX1A, KB3, and effective M3Y-P2 interactions. mixing together two orbital configurations. There was a good agreement between the model space vectors and energy levels and experimental data, but the agreement decreased when the realistic M3YP-2 interaction was used. The core polarisability effect has been used to accommodate the rejected space: core and higher organization via the L-S shell with an effective M3Y-P2 interaction. A comparison of the theoretical and experimental results has been conducted.
Keywords: *Effective M3Y-P2 interaction,48Ti isotope, Excitation energies, OXBASH code, Shell model.*

1. Introduction

A fundamental theoretical tool for the detailed description of nuclear structure, the shell model is an essential part of nuclear theory. We have researched the even-even nuclear energy levels that occupy the whole fp-shell and exist outside of closed (^{40}Ca is considered an inert core). utilizing the FPD6, GXPF1, and KB3G interactions in conjunction with comparison with the Gogny-p2 interaction to ascertain the nuclear energy levels for ^{42}Ca [1]. Using jun45 and jj44b effective residual interactions, large-scale shell model calculations were carried out in the f5/2pg9/2 space to establish the level schemes and binding energies of 59-67Cu isotopes. The shell model accurately replicates the reported binding energies [2]. Only the valance nucleons that exit the core are taken into account in the shell model calculations, which presume that the nucleons in the inert core do not move outside of it. The nuclear shell model has been used to calculate the nuclear energy levels of even-even 42-56Ca isotopes using interactions FPD6, GXPF1A, and KB3G [3].

The computed energy level scheme for low and higher-lying 2+ states via SDPFK two-body effective interaction, as well as the nuclear structure of $^{28-40}$ Si isotopes. Given that it forecasts nuclear behavior and reveals new facets of nuclear structure that represent the primary obstacles to creating a generalized nuclear model, the study of the nuclear composition of neutron-rich nuclei has attracted significant attention on a global scale [4]. The fpd6pn interaction has been used to analyze nuclear energy levels in inside shell model calculations for the isobars ^{44}Ca nuclei, which occupied low levels fp-LS shell (1f7/2,1f5/2,2p3/2,2p1/2). We also looked into the C4 form factors for elastic electron scattering for nucleons outside of the closed core. The inert core is now included in the residual interaction M3Y for the form factors [5]. identified the energy levels for the $^{42-43}$Ti isotopes in the F7shell, F7MBZ, and F742 effective contacts and reduced the electric quadruple transition probability B(E2). The model space includes all nucleon combinations in the f 7/2 orbits [6], the same effective interaction for the $^{42-43}$Ti and $^{44-46}$ Ti isotopes [7, 8], while energy levels for ^{52}Ti are based on the FPD6, GXPF1, GXPF1A, and KB3 interactions [9]. Within shell model calculations, nuclear energy levels in ^{46}Sc with moderate fp-LS shell occupancy have been determined. FPD6, KB3G, and FPY are the interactions, and they use the fp shell and d3f7cospn for the 1d3/21f7/2 model space [10].

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Investigating the nuclear shell model for Po isotopes with A = 200 to 210 using the KHH7B interaction in the model space surrounding doubly-magic 208Pb with Z = 58-114 and N = 100-164. We permit valence neutrons to occupy the orbitals 1f5/2, 2p3/2, 2p1/2, and 0i13/2, and two valence protons beyond Z = 82 to occupy the orbitals 0h9/2, 1f7/2, and 0i13/2[11]. Additionally, for $^{204-213}$Bi isotopes, KHH7B and KHM3Y effective interactions are used [12]. Additionally, interactions KHHE, KHH7B, and KHM3Y have been exploited by the shell model configurations to analyze the well-known isomeric states for the $^{204-206}$Tl, $^{204-210}$Tl, and ^{208}Tl isotopes, respectively [13].

2. M3Y Effective Interaction

The form that is frequently used by is provided for the M3Y effective interaction $veff\ (r)$ [14]:

$$\nu_{\mathrm{eff}}(\mathrm{r}) = 7999\frac{\mathrm{e}^{-4\mathrm{r}}}{4\mathrm{r}} - 2134\frac{\mathrm{e}^{-2.5\mathrm{r}}}{2.5\mathrm{r}} \quad (1)$$

The spin and isospin distinct components of the effective N-N potential's core component are shown in equation (1); it does not contain the goals of the One Pion Exchange Potential. Relativistic Mean Field Lagrangian's and meson fields serve as the basis for the as follows:

$$\nu_{\mathrm{eff}}(\mathrm{r}) = \frac{\mathrm{g}_{\mathrm{w}}^2}{4\pi}\mathrm{B}_{\mathrm{w}}\frac{\mathrm{e}^{-\mathrm{m_w r}}}{\mathrm{r}} - \frac{\mathrm{g}_{\sigma}^2}{4\pi}\mathrm{A}_{\sigma}\frac{\mathrm{e}^{-\mathrm{m_\sigma r}}}{\mathrm{r}} \quad (2)$$

Equation (2) may be associated with the phenomenological M3Y effective N-N potential of Equation (1).Equation (2) shows that the masses and correlation constants of the ω and σ mesons are $m\sigma$, $m\sigma$, $g\sigma$, and $g\sigma$, respectively.

The parameters $\mathrm{B_w} = \left(1 + \frac{1}{2}\left(\frac{\mathrm{m_w}}{\mathrm{M}}\right)^2\right)$ And $\mathrm{A}_\sigma = \left(1 - \frac{1}{4}\left(\frac{\mathrm{m}_\sigma}{\mathrm{M}}\right)^2\right)$ are dependent on relativistic corrections $\left(\frac{\mathrm{m_i}}{\mathrm{M}}\right)^2$; $i = (\omega, \sigma)$, That allows the field energies mi to approach the nucleon mass M[14].

3. Binding Energies and Excitation Energies

"The energy required to break up a given nucleus into its constituent parts of N neutrons and Z protons" is the definition of the nucleus' binding energy E^b.In its ground state, the nucleus has the highest binding energy value. For the nth excited state, the excitation energy E_x (n) is obtained by measuring the binding energy E^b (n) of the nucleus in that state in relation to the ground-state binding energy E^b (0) [15]:

$$\mathrm{E_x(n)} = \mathrm{E^b(n)} - \mathrm{E^b(0)} \quad (3)$$

According to the definition of binding energy provided above, the different terms that contribute to the overall binding energy of such a nucleus can be expressed as:

$$\mathrm{E}_\Gamma^{\mathrm{b}}(\mathrm{core} + \rho^2) = 2\mathrm{e}_\rho + \mathrm{E}_\Gamma^{(1)}(\rho^2) + \mathrm{E^b(core)} \quad (4)$$

where e_ρ is the single particle energies? The binding energy contribution of the two outer-core particles' mutual nuclear interaction is $\mathrm{E}_\Gamma^{(1)}(\rho^2)$. E^b (core) is the binding energy of the particles in the core, and this term depends on the orbit ρ as well as the spin J and isospin T of the two-particle system. Consequently, when there are two active particles outside of a core, one has [15]:

$$\mathrm{H}_{12}^{(1)} = \mathrm{V}(1,2) \quad (5)$$

total Hamiltonian:

$$\mathrm{H} = \mathrm{H_{core}} + \mathrm{H_{s.p.}}(1) + \mathrm{H_{s.p.}}(2) + \mathrm{V}(1,2) \quad (6)$$

Spin and isospin Γ are linked to two particles in orbit ρ outside the core, the nucleus's binding energy is determined by the expectation value:

$$\mathrm{E}_\Gamma^{\mathrm{b}}(\mathrm{A}) = \left\langle \Phi_\Gamma^{(0)}(1,\dots,\mathrm{A}) \middle| \mathrm{H} \middle| \Phi_\Gamma^{(0)}(1,\dots,\mathrm{A}) \right\rangle \quad (7)$$

The whole nucleus's total Hamiltonian in the state $\Phi_\Gamma^{(0)}\ (1, \dots, A)$.

4. Results and Discussion

The maximal energy value for ^{48}Ti in Fig. 1 is less than 4.8 MeV, indicating positive parity states for the isovector T=2. The energy values show strong agreement at less than 1.5 MeV, and energy levels appear to be convergent from 2.102 MeV; nevertheless, as energy values climbed, so did the differences between the calculated and experimental data values. So, the GX2 and GX1A interactions closer of available experimental data.

Figure 2 shows the energy states. Two are on J=0, four by J=2, two through J=3, and five with J=4 when compared to the results of the M3Y-P2 interaction**,** when you compare the data from the experiments (at $J = 0^+_0, 2^+_2, 4^+_2$) with the same state of GX2, GX1A, KB3, and M3YP2 interactions. You can see conformity in the ground state at $J = 0^+_0$, in all interactions. The deviations are Δ=0.044,0.294,0.319,0.407 at $J = 2^+_2$ and Δ= 0.799,0.65,1.107,0.305 for $J = 4^+_2$, respectively. It can be concluded that the M3Y-P2 interaction performs the less when compared to the experimental information, with some energy levels located outside the scheme range and beneath the ground states (specifically in the M3Y-p2 interaction). So from the result M3Y-P2 interaction less matching of the others compare with exp. data.

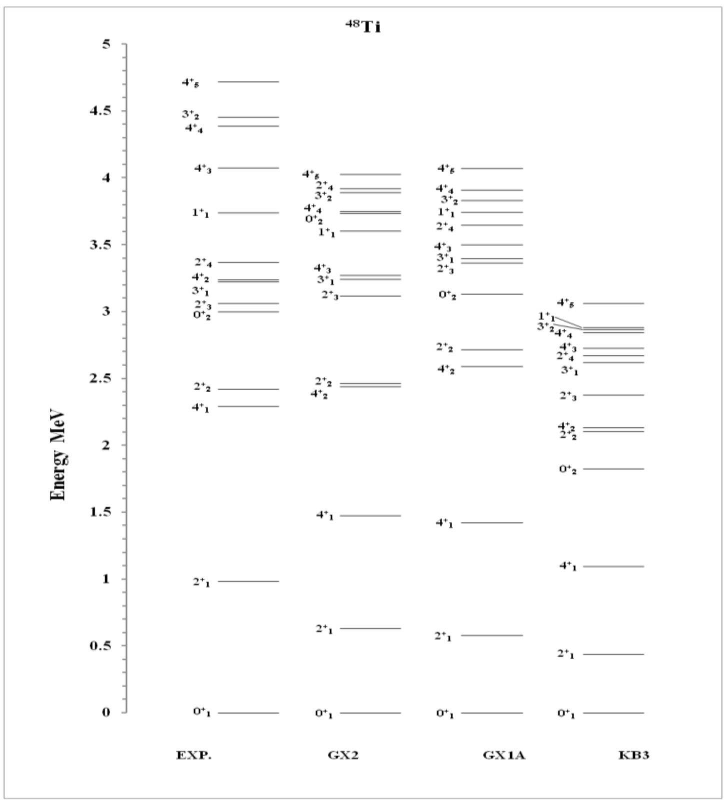

Figure 1.
Energy levels of ^{48}Ti by using GX2, GX1A and KB3 interactions with experimental data.

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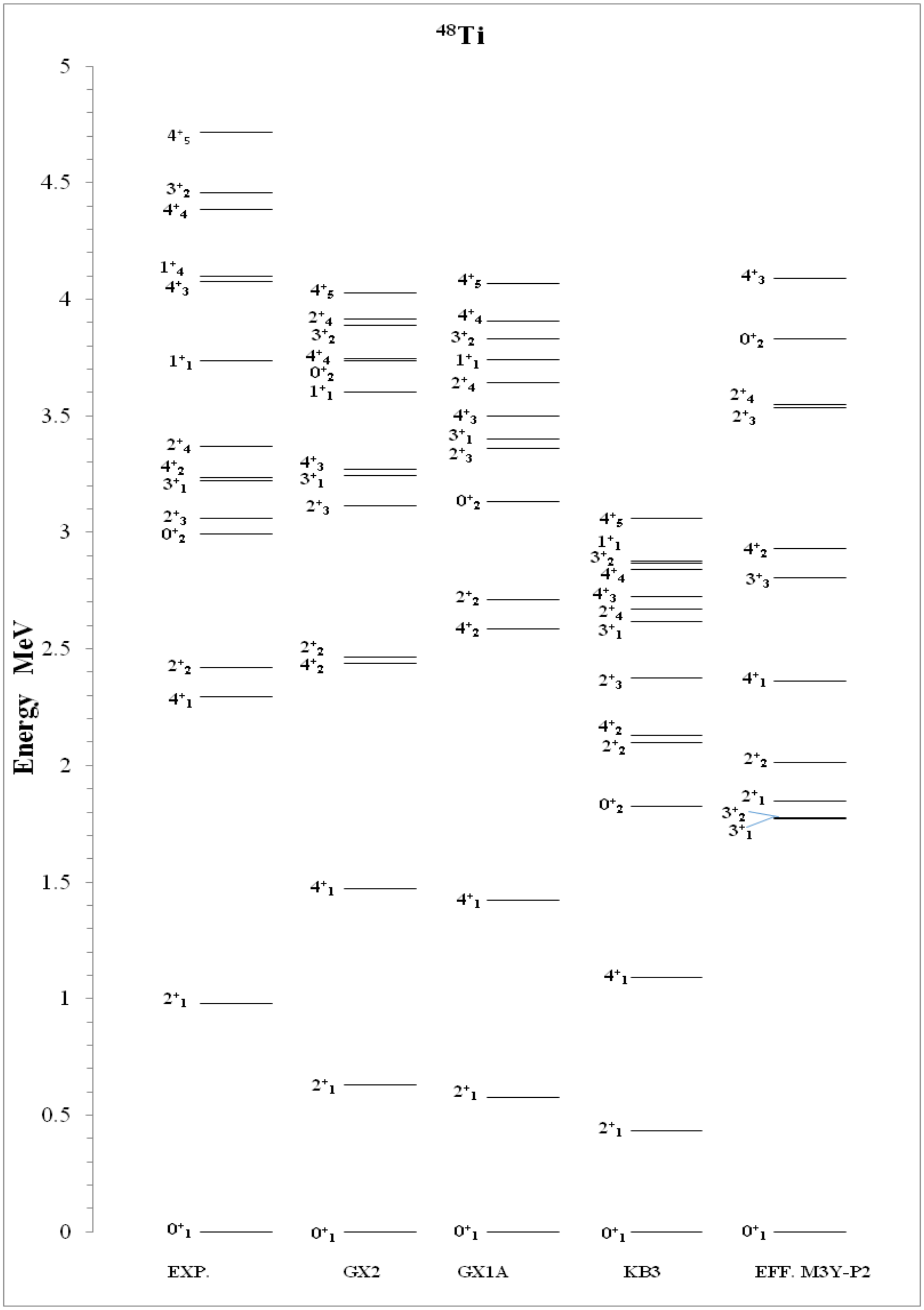

Figure 2.
The energy levels of ^{48}Ti by using GX2, GX1A, KB3 and Effective M3Y-p2 interactions with experimental data.

5. Conclusions

For the low-lying states in particular, the realistic effective M3Y-P2 interaction is highly helpful in reproducing energy levels in ^{48}Ti.

- By including particles in the complete shell and making them inhabit the inert core while making the others active to recreate nuclear characteristics, the shell model improves calculations.
- According to the fitting interactions (GX2, GX1A, and KB3), energy levels are fairly consistent.
- Compared to the outcomes of the other interactions (GX2, GX1A, and KB3), the energy levels determined by the realistic (effective M3Y-P2) interaction are less consistent with experimental evidence.

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