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Nuclear Interactions GX2, GX1A and KB3 In fp-Shell Model

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Abstract. The energy levels of even-even isotopes of Titanium in the fp shell model GX2, GX1A, and KB3 interactions are estimated in this work. All possible nucleon combinations in the fp L-S shell(0f7/2, 1p3/2, 0f5/2, 1p1/2) are included in the model space using code OXBASH for the isotopes ^{42,44,46}Ti. Positive parity states and the values of total angular momentum are 0+, 1+, 2+, 3+, and 4+. Experimental results and ground and excited state energies are often in agreement.

keywords: Energy levels, GX2, GX1A, KB3 interaction, $^{24, 44, 46}$Ti, and shell model.

INTRODUCTION

The shell model is an essential part of nuclear theory and a vital theoretical tool for the microscopic description of nuclear structure. Each nucleon is created by the nucleons themselves and moves independently in an average field with a sizable spin-orbit term, according to the fundamental principles of the nuclear shell model. The nucleons then organise into groups of levels, or "shells," that are spaced widely apart from one another. This approximation states that the nucleus is composed of an inert core composed of shells packed with neutrons (closed shell) plus a specific quantity of exterior nucleons known as valence neutrons [1].

Using the effective interactions FE1, FPD6, and KB3G, the shell model in the fp area, experimental and theoretical energy levels of excitation energies and E2 transition probabilities compute in ^{46}Ti, ^{46}V, ^{48}V, ^{48}Cr, ^{50}Cr, ^{50}Mn nuclides and energy levels of ^{44}Ti, ^{46}V, ^{42}Sc nuclides [2]. The level schemes and transition rates B(E2;↑) of 48,56Ti isotopes were investigated using FPD6 and GXPF1 as effective interactions; the angular momentum (J) ranged from 0^+ to 10^+[3]. shell model computation with the GXPF1A interaction for ^{52}Fe in the whole fp space. The same angular momentum can have many energy levels [4]. The nuclear configurations in the fp L-S shell of the ^{42}Ca, ^{44}Ca, and ^{46}Ca are represented by the framework shell model. The effective interactions of FPD6, GXFP1, and BK3, as well as the residual interactions of Skyrme-Hartree Fock (Skx) and harmonic oscillator (HO), are used to compute energy levels and transition rates [5]. Calculated the binding energies and energy level low-lying excitation states and electric quadrupole transition rates in $^{24.44.46.48}$Ti isotopes using the GXFP1, FPD6, and KB3G effective interactions . All nucleon combinations in the L-S space are included in the model [6].

Reid's Potential (RP) and the Modified Surface Delta Interaction (MSDI) are used in a theoretical calculation of the spectrum level energy for ^{58}Ni, which is based on the shell model and quantum theory. comparison to the NZPSM, ESM, and experimental methods [7]. using jun45 and jj44b effective residual interactions to study binding energies for $^{59\text{-}68}$ Cu isotopes in the f5/2pg9/2space, as well as energy levels for positive and negative parity [8].

The nuclear shell model has been used to calculate the nuclear energy levels of even-even $^{42\text{-}56}$ Ca isotopes utilising interactions FPD6, GXPF1A, and KB3G.presumption that the inert core's nucleons remain inside it and do not travel outside of it. In the shell model computations, only valance nucleons outside of the core are taken into account [9]. The computed energy level scheme for even-even Si-isotopes with 2+ states that lie higher and lower. The computations were performed using the SDPFF shell model space and the SDPFK effective interaction [10].^{52}Ti isotope nuclear structure is studied utilising the effective interactions KB3, GXPF1, GXPF1A, and FPD6 [11].For the $^{44-46}$Ti, $^{45-47}$Ti, and $^{42-43}$ Ti isotopes the energy levels and reduced electric quadruple transition probability B(E2) in the F7shell were computed using the F7MBZ&F742 effective interactions[12-14]. Examine nuclear energy levels for isobars ^{44}Ca nuclei that were present outside of the closed core using the FPD6PN interaction to compute low levels of the fp-LS shell model [15]. In the ^{46}Cr nucleus, energy levels were also measured use FPD6, FPY, F742, F7MBZ, and KB3G interactions in the f7/2 model space[16]. In the ^{46}Sc nucleus, on the other hand, interactions with D3F7COSPN, F7MBZ, KB3G, and FPD6 were measured using 1d3/21f7/2 model space [17].

ENERGY LEVEL SCHEMES

"The energy required to break up a given nucleus into its constituent parts of N neutrons and Z protons" is the definition of the binding energy E^b of the nucleus. The ground state of the nucleus has the highest binding energy value. The ground state of the nucleus has the highest binding energy value. The binding energy $E^b(n)$ of the nucleus in that state, measured with respect to the ground-state binding energy $E^b(0)$, yields the excitation energy $E_x(n)$ of the nth excited state. [18]:

$$E_x(n) = E^b(n) - E^b(0) \qquad \text{(i))}$$

From the preceding definition of binding energy, the different terms that contribute to the overall binding energy of such a nucleus can be expressed as follows:

$$E_\Gamma^b(core + \rho^2) = 2e_\rho + E_\Gamma^{(1)}(\rho^2) + E^b + E^b(core) \qquad \text{(ii))}$$

where e_ρ is the single particle energies. $E_\Gamma^{(1)}(\rho^2)$ is the binding energy contribution from the mutual nuclear interaction of the two outer-core particles. This term depends on the spin J and isospin T of the two particle system in addition to the orbit ρ. and E^b (core), which stands for the particles' binding energy in the core.
Consequently, when two active particles are present outside of a core, one has [18]:

$$H_{12}^{(1)} = V(1,2) \qquad \text{(iii))}$$

total Hamiltonian:

$$H = H_{core} + H_{s.p.}(1) + H_{s.p.}(2) + V(1,2) \qquad \text{(iv))}$$

The expected value gives the binding energy of the nucleus with two particles outside the core in the orbit ρ and connected to spin and isospin Γ:

$$E_\Gamma^b(A) = \left\langle \Phi_\Gamma^{(0)}(1,\dots,A) \middle| H \middle| \Phi_\Gamma^{(0)}(1,\dots,A) \right\rangle \qquad \text{(v))}$$

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

RESULTS AND DISCUSSION

The energy level scheme of ^{42,44,46}Ti in the fp-shell model space is based on interactions between the inert core ^{40}Ca and GX2, GX1A, and KB3 for $\mathbf{J_k^\pi}$ positive parties.

The isovector T=1 for ^{42}Ti, with positive parity, indicates the highest values chosen for excited states with energies less than 10.1 MeV in Figure 1. Consequently, the value of J=1,3 does not appear in the experimental calculations. Levels of energy are matched less than 5.7 MeV, with the experimental data. The energy levels exhibit a convergence starting at the 7.089 MeV energy level. Though they differ less from the KB3 reaction, the GX2 and GX1A reactions' results are in good accord.

In Fig. 2, the energy levels in ^{44}Ti , are shown to be in good agreement with the incremental data less than 3,2 MeV and to show convergence of energy levels from 2.304 MeV. We also notice that the three reactions' results, GX2, GX1A, and KB3, are in good agreement. The maximum value of energy levels selected is less than 9.2 MeV, the isovector T=0, positive parity states.

The energy levels in Figure 3 are calculated in ^{46}Ti, and their maximum values are less than 5.8 MeV, indicating positive parity states and the isovector T=1. The estimated data agrees with the values of energy levels less than 2.1 MeV, and value of J=3 do not present in experimental calculations. , however there appears to be a convergence from 2.698 MeV. Energy level values from the gx2 and gx1a interactions correlate better with empirical data from the kb3 interaction.

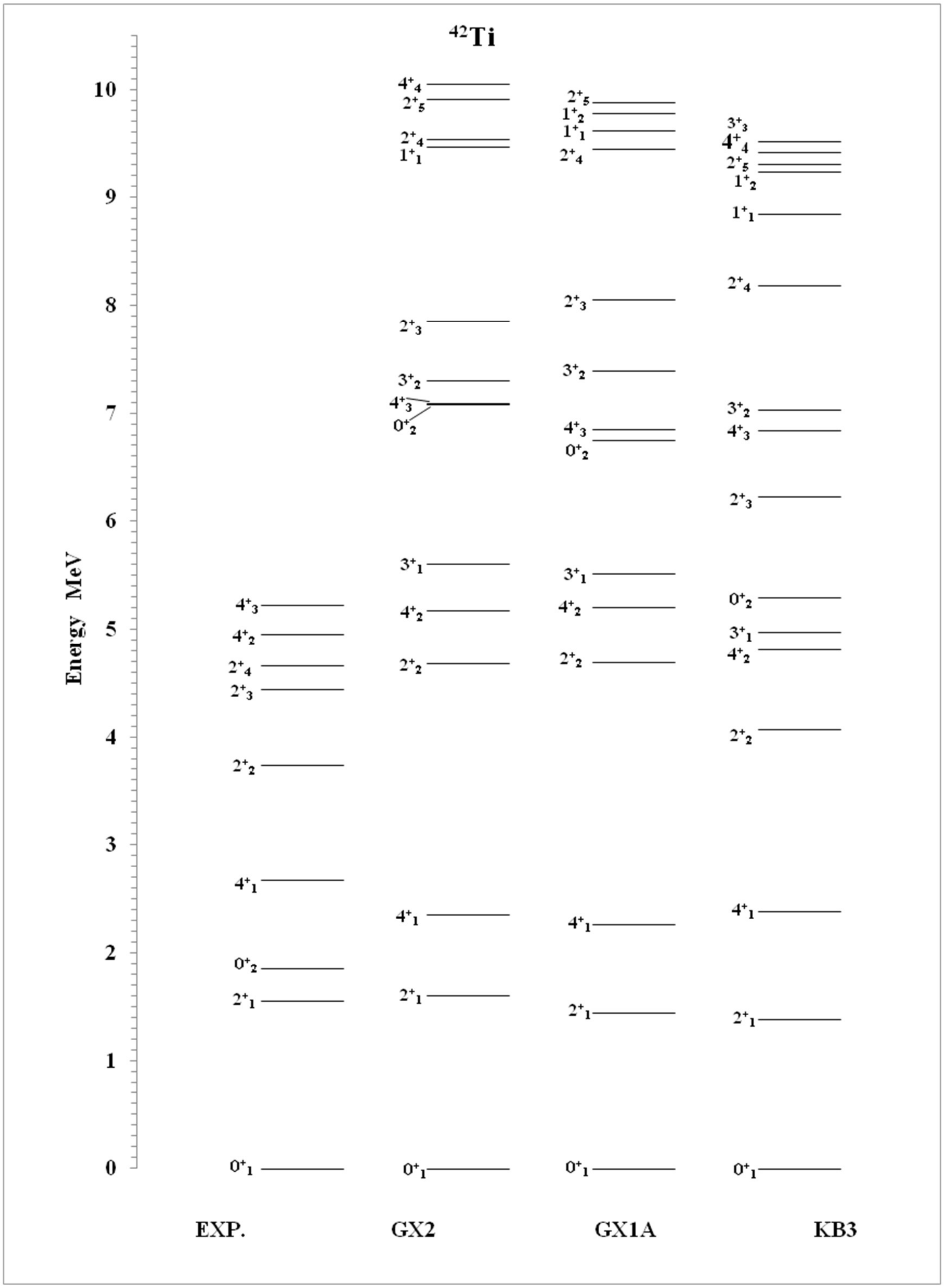

Figure 1**.** energy levels of ^{42}Ti by using GX2, GX1A and KB3 interactions with experimental data.

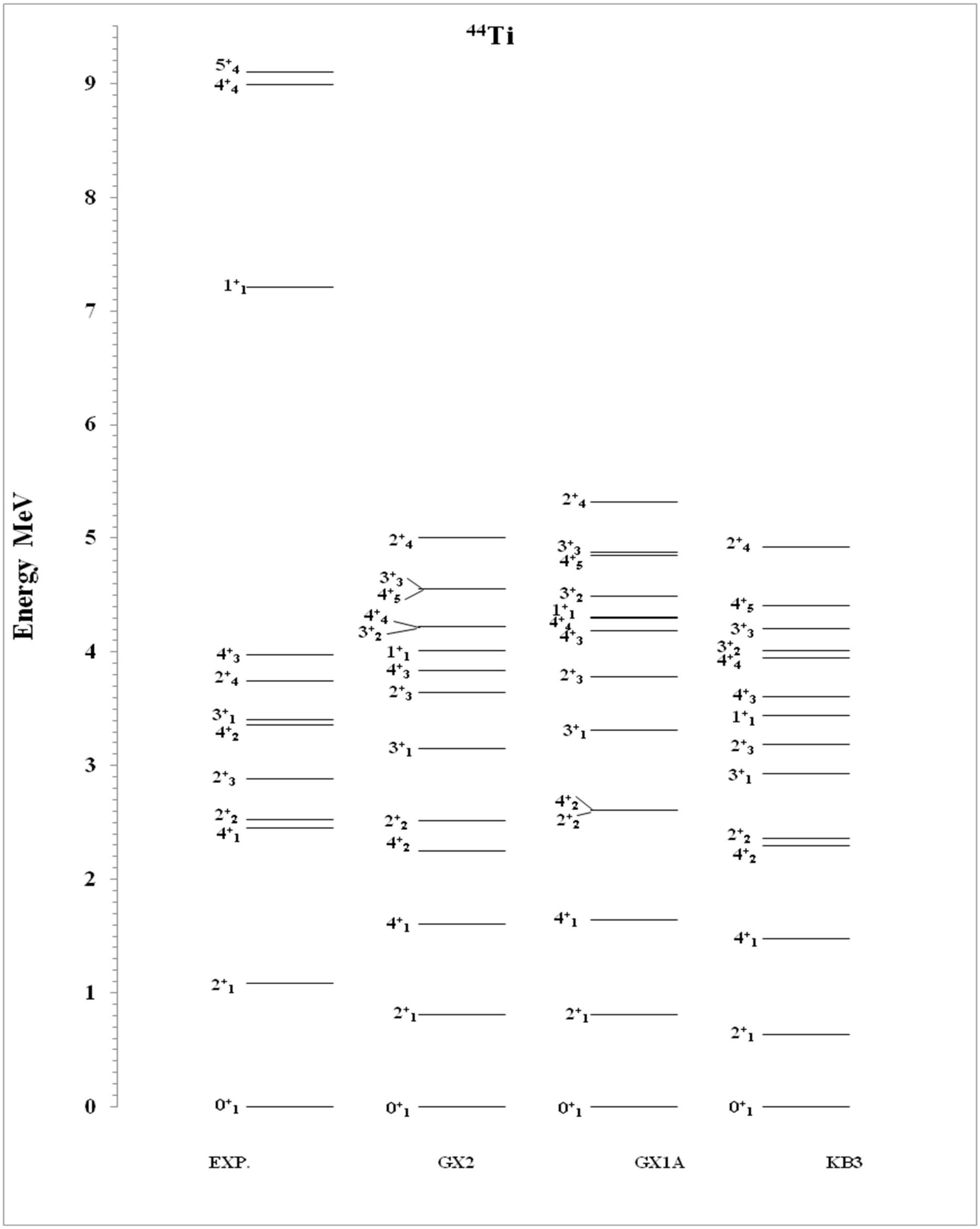

Figure 2. energy levels of ^{44}Ti by using GX2, GX1A and KB3 interactions with experimental data.

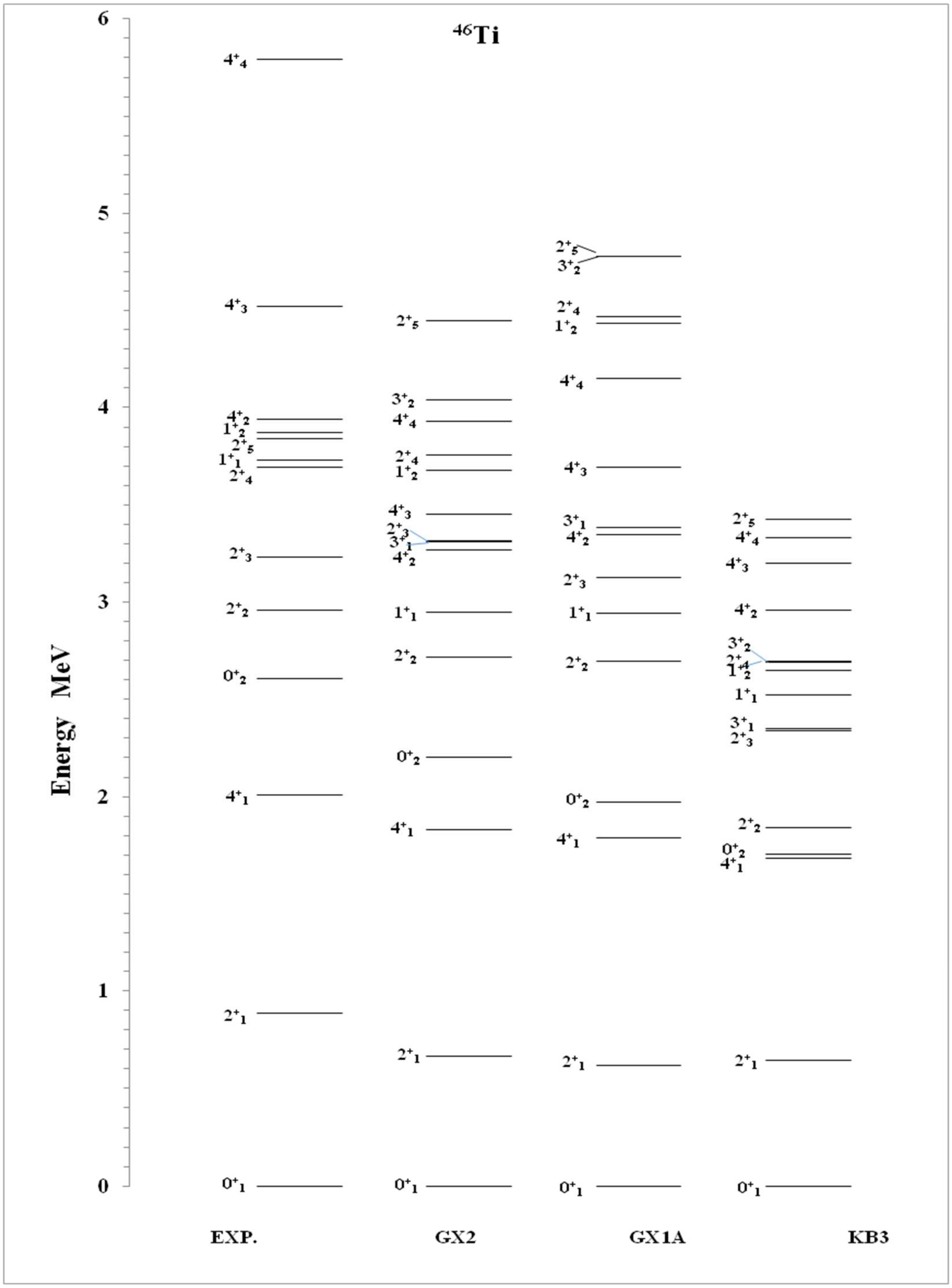

Figure 3. energy levels of ^{46}Ti by using GX2, GX1A and KB3 interactions with experimental data.

CONCLUSIONS

- The shell model is a computational advancement that involves the incorporation of particles in a whole shell, whereby they occupy an inert core and make the other particles active to replicate nuclear properties.
- The GX2, GX1A, and KB3 interactions accord with the experimental findings; however, the agreement is stronger between the GX2 and GX1A interactions.
- As the energy value rises, the energy levels converge and become more intense.
- Since agreement also found for some odd values, J= 1+ and 3+, the agreement in the total angular momentum is not limited to the even values J=0+, 2+, and 4+.

References

1. Honma, M., Otsuka, T., Brown, B. A., & Mizusaki, T. (2002). Effective interaction for pf-shell nuclei. *Physical Review C*, *65*(6), 1-5.. https://doi.org/10.1103/PhysRevC.65.061301

2. Hasegawa, M., Kaneko, K., & Tazaki, S. (2000). Application of the extended P+ QQ force model to N≈ Z fp shell nuclei. *Nuclear Physics A*, *674*(3-4), 1-34. https://doi.org/10.1016/S0375-9474(00)00171-8

3. Majeed, F. A., & Auda, A. A. (2006). Full fp-shell study of even-even $^{48-56}$Ti isotopes. *Brazilian Journal of physics*, *36*, 229-231. https://doi.org/10.1590/S0103-97332006000200016

4. Puddu, G. (2009). A shell model calculation for ^{52}Fe in the full fp space. *Acta Physica Polonica B*, *40*(6), 1685- 1694.

5. Hussain, F. M., & Khudhur, M. (2013). Shell Model Calculations For Even-Even $^{42, 44, 46}$ Ca Nuclei. *Journal of Information Engineering and Applications, 3*(10) 46- 49.

6. Majeed, F., Hussain, F. M., & Khudhur, M. (2014). Shell Model Calculations of Some Titanium Isotopes. *journal of kerbala university*, *10*(1), 162-169.

7. Hadi, J. M., Jarallah, N. T., Ebrahiem, S. A., & Rabee, R. F. (2017). Theoretical Calculation of The Binding And Excitation Energies For $^{58}_{28}Ni_{30}$Using Shell Model And Perturbation Theory. *Ibn AL-Haitham Journal For Pure and Applied Science*, *26*(3), 225-235.

8. Majeed, F. A., Tawfeek, H. M., & Obaid, S. M. (2018). Large basis shell model calculations of some nuclei around doubly-magic ^{56}Ni. *International Journal of Nuclear Energy Science and Technology*, *12*(4), 370-380. http://dx.doi.org/10.1504/IJNEST.2018.10018246

9. Akkoyun, S., Ayhan, Y., & Bayram, T. (2020). Nuclear Shell Model Calculations for Ca Isotopes. *Bitlis Eren Üniversitesi Fen Bilimleri Dergisi*, *9*(3), 1-6. https://doi.org/10.1103/PhysRevC.101.041301

10. Alzubadi, A. A. (2021). Study of the Nuclear Structure of some Neutron Rich Si Isotopes Using Shell Model with Skyrme Interaction. *Iraqi Journal of Physics*, *19*(48), 89-106. https://doi.org/10.30723/ijp.v19i48.634

11. Sadiq, S.; Devi, R .**(2022)**.Study of nuclear structure properties of some neutron-rich titanium nuclei. *Proceedings of the DAE Symp. on Nucl. Phys*., 66 ,302-303.

12. Hasan, A. K., & Chyad, H. K. (2023). Nuclear Structure of $^{44-46}$Ti isotopes using shell model by OXBASH code. *Journal of Survey in Fisheries Sciences*, *10*(3S), 4062-4073.
https://doi.org/10.17762/sfs.v10i3S.1406

13. Hasan, A. K., & Chyad, H. K. (2023). Study of nuclear structure of ^{45,,47} Ti isotopes by using oxbash code. *Open Access Repository*, *9*(2), 78-90.
https://doi.org/10.17605/OSF.IO/DPB3M

14. Hasan, A. K. (2023). Study of Nuclear Structure of $^{42-43}$Ti isotopes by using F7MBZ & F742 interactions. *Journal of Kufa-Physics*, *15*(01), 31-36.
https://doi.org/10.31257/2018/JKP/2023/v15.i01.10921

15. Hassan, M. K., & Majeed, F. Z. (2023). Nuclear Energy Levels in ^{44}Ca using FPD6pn Interaction. *East European Journal of Physics*, (1), 69-74.
https://doi.org/10.26565/2312-4334-2023-1-07

16. Kadhim, H. A., & Majeed, F. Z. (2023). Nuclear Energy Levels Scheme of ^{46}Cr Using FPD6, FPY, and KB3G Interactions. *East European Journal of Physics*, (3), 187-191.
https://doi.org/10.26565/2312-4334-2023-3-15

17. Kadhim, H. A., & Majeed, F. Z. (2024). Nuclear Energy Levels Scheme of ^{46}Sc by Using FPD6 and KB3G Interaction. *Ibn AL-Haitham Journal For Pure and Applied Sciences*, *37*(3), 147-156.
https://orcid.org/0000-0001-6527-3913

18. Brussaard, P. J., & Glaudemans, P. W. M. (1977). Shell-model Applications in Nuclear Spectroscopy. *North-Holland Publishing Company, Amsterdam* **1977**.