

Shell Model Calculations For Even-Even ^{42,44,46}Ca Nuclei

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Abstract

The energy levels and transition rates calculations of *fp* shell nuclei ⁴²Ca, ⁴⁴Ca and ⁴⁶Ca is studied in the framework shell model nuclear of configuration $1f_{7/2}, 2p_{3/2}, 1f_{5/2}$ and $2p_{1/2}$. By using FPD6, GXFP1 and BK3 effective interaction and Skyrme-Hartree Fock (Skx) and harmonic oscillator (HO) as residual interactions for calculate transition rates. A good agreement at comparison between our results and the experimental data.

1. Introduction

The isotopes of calcium lying between doubly magic ⁴⁰Ca and ⁴⁸Ca provide a unique laboratory for examining the foundation of *fp* shell model calculations. Available spectroscopic information on odd mass Ca isotopes, mean charge radii, excitation energies, $B(E2 : 0_1^+ \rightarrow 2_1^+)$ values and electric quadruple moments of the 2_{1+} states in even mass Ca nuclei have all indicated that ⁴⁰Ca was not a good closed shell nucleus. Already in 1967 it had been postulated that a breakdown of the $Z = 20$ shell closure, caused by the promotion of *sd* shell protons into the *fp* shell, was responsible for the observed spectroscopic properties [1].

The Ca isotopes have been the subjects of much experimental and theoretical interest. This is in large part due to the fact that ⁴⁰Ca and ⁴⁸Ca, which occupy the ends of the stable isotope series for this element, are both doubly magic nuclei within shell model theory. For this reason, knowledge concerning the structure of the ground- and excited-state charge distributions of these two isotopes is of particular value in elucidating the general systematic of nuclei in this region[2].

Nuclei with valence nucleons in the *fp* shell have been intensively studied and discussed in recent years following the striking progress in the development and refinement of large-scale shell model calculations [3].

In the present work, the level schemes and transition probabilities are studied for ⁴²Ca, ⁴⁴Ca and ⁴⁶Ca. The core is taken ⁴⁰Ca for nuclei in the *fp* shell, by generating the wave functions of a given level schemes and transition probabilities in known nuclei by adopting code Oxbash [4] and FPD6, GXFP1 and KB3 interactions.

2. Shell Model Calculations

The importance of including the whole *fp* shell in the description of the structure of these nuclei at an increasing number of valence nucleons [3]. The rates transition calculations was performed using Skx [5] and HO[6] as effective residual interactions with FPD6[7] for ^{42,44,46}Ca and using code Oxbash[4].

The core ⁴⁰Ca is taken for this nuclei and model space *fp* with effective interactions FPD6 [7], GXFP1 [8] and KB3 [9] to calculate the energy levels.

3. Results and discussion

In Fig.1. we present the theoretical level schemes for ⁴²Ca employing FPD6, GXFP1 and KB3 are compared with the experimental data. The prediction of $Ex(2_1^+)$ in the interaction *gx1fp* is better than FPD6 and KB3, while the FPD6 in high spin states is given a good agreement with experimental data.

The predicted spectrum of ⁴⁴Ca presented in Fig.2. shows, the first excitation (2_1^+) state in KB3 is very close for experimental data than *fpd6* and *gx1* and still *fpd6* is in better agreement in describing the high spin states, the *fpd6* predicts level sequens $J = 4_2, 6_1, 5_1, 8_1$ are in acceptable agrees, while GXFP1 and KB3 predicts $J = 4_2, 6_1, 8_1, 5_1$.

The experimental energy levels for ⁴⁶Ca are comparing with theoretical work as in Fig.3. We found that the calculated results in acceptable agreement with experiment data, but shell model calculations with effective interaction GXFP1 in this nucleus are in good agreement with the experimental data from FPD6 and KB3.

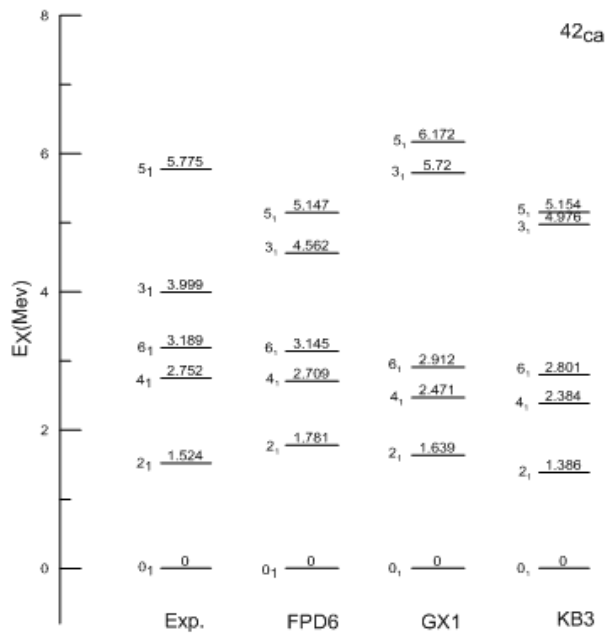


Fig.(1) The Comparison between Theoretical value and Experimental data [10]

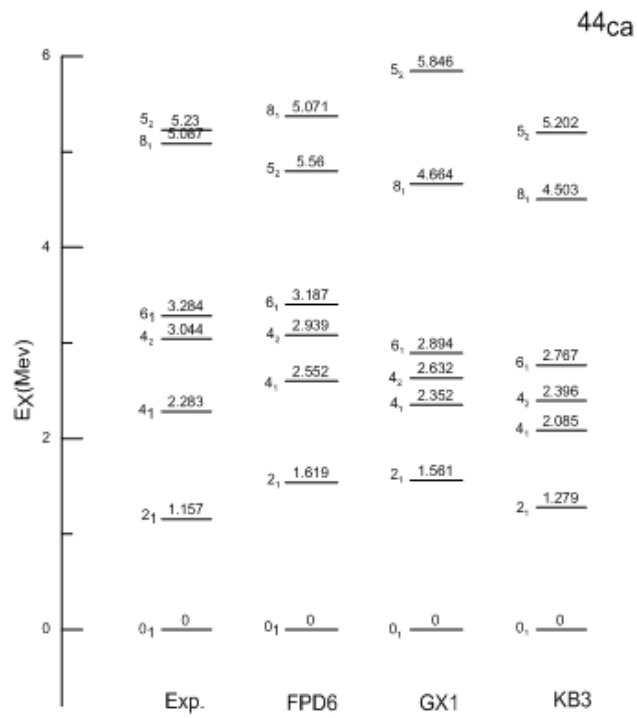


Fig.(2) The Comparison between Theoretical value and Experimental data [11]

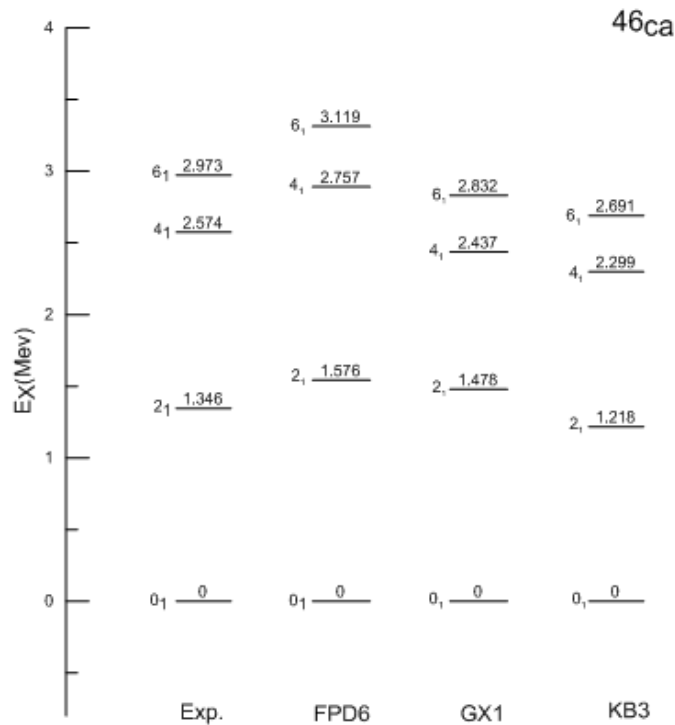


Fig.(3) The Comparison between Theoretical value and Experimental data [12]

In table .1. The electromagnetic transition probability $B(E2; 0_1^+ \rightarrow 2_1^+)$ values calculated for *fp* model space and FPD6 with Skyrme- Hartree- Fock and harmonic-oscillator potentials as residual interactions. From the table we can see that our calculations in Skx is in excellent agreement with experimental data for ⁴²Ca , and BE2 for ⁴⁴Ca is agreement with experimental data in ho that is better than sk20. The calculated $B(E2)$ value is found in ⁴⁶Ca with the use of Skx and HO is far from the measured value as appear in table, This is due to the use of different effective charge.

TABLE1: Theoretical values of the reduced transition probabilities $B(E2)$ in units of $e^2 fm^4$ and in comparison with experimental values.

Nucleus	$J_f^\pi T_f$	Exp.[13]	Sk20	HO.
⁴² Ca	2 ₁ ⁺ 1	420(30)	421.3	499.7
⁴⁴ Ca	2 ₁ ⁺ 2	470(20)	4285	5027
⁴⁶ Ca	2 ₁ ⁺ 3	182(13)	385.9	450.2

4- Conclusions

Shell model calculations were performed using the model space *fp* by taking ⁴⁰Ca as core for ⁴²Ca, ⁴⁴Ca and ⁴⁶Ca. The results of shell model calculations in agreement with experimental data.

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