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Calculation of Energy Level and B (E2) for $^{42-44}$Ca by using Shell Model Code OXBASH

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Abstract
In this work shell model are calculated in the f7-shell region for the nuclei ^{42}Ca, ^{43}Ca and ^{44}Ca by employing the effective interactions, f742pn and f7cdpn using the shell model code OXBASH for windows by applying spin-parity of valance nucleons. Found a good convergence of energy levels with the practical results are available and Found a good convergence of electrical transitions B (E2; ↓) with the practical results are available.
Keywords: Energy Levels, OXBASH Code and gamma transitions.

1. Introduction

The object of this work is to calculate the electrical transitions B (E2; ↓) and energy levels of $^{44-42}$ Ca isotopes by using OXBASH code for windows. This program is a set of codes for carrying out shell-model calculations with dimensions up to about 50,000 in the J-T scheme and about 2,000,000 in the M-scheme. Oxbash comes with a library of model spaces and interactions [1, 2]. The purpose of this study is to apply the shell model and use Modified Brown and Sherr (f7cdpn, f742pn) interaction for neutron and proton orbits in $^{42-44}$Ca energy levels and the B (E2) values. The nuclear shell model can predict various observables accurately and systematically. For light nuclei, there are several "standard" effective interactions such as the Cohen-Kurath [3] and the USD [4] interactions for the *p* and *sd* shells, respectively. On the other hand, in the next major shell, *i.e.*, in the f7-shell, there were also "standard" interactions such as f742pn and f7cdpn [5].The spectroscopy of nuclei, in the f7-shell region, has been well described within the shell model framework. Using several model spaces and two-body interactions, the most remarkable work of Brown and co-workers [6,7]. The starting point in all such shell-model calculations is the derivation of an effective interaction, Because of the quite importance of the f7-shell for variety of problems in nuclear structure, such as electron capture in supernova explosions. In this work we report the shell model calculations in the f7-shell region for the nuclei ^{42}Ca, ^{43}Ca and ^{44}Ca, to test the ability of the present effective interactions in reproducing the experiment in this mass region.

2. Shell Model Calculations

The calculations have been carried in the nuclear shell model f7 using the code OXBASH for windows [6]. The code uses an m-scheme Slater determinant Basis. With a projection technique wave functions with good angular momentum J and isospin T are constructed. The f7pn model space was comprised of (1f7/2) below the closed N = Z=20 shell. The two-body interaction matrix elements (TBMES) are from [8]. In addition we used the harmonic oscillator potential (HO, b), b<0. In this work presented the calculated results of states of the odd A and even A nuclei, number proton 20, with neutron numbers from 22 to 24. Energy levels and the B (E2) value .

2.1. Energy Levels Calculations

The objective of this study is calculate the nuclei lies in the f7-shell due to the importance of these in the recent applications in astrophysics. The calculations have been carried out using the code OXBASH for windows [9]. In the f7 model space which comprised of the 0f7/2 valence orbits outside the ^{40}Ca. Two of effective interactions were employed with f7 model space for the calculations of level spectra and transition probabilities, these effective in iterations are f742pn and f7cdpn [5]. We should mention here that ^{42}Ca have Isospin part $T = 1$, and ^{43}Ca have Isospin part $T = 0.5$, while ^{44}Ca have Isospin part $T = 2$.

Fig. 1 and Table.1, presents the comparison of the energy levels calculations respect to ground state with experimental excitation energies of ^{42}Ca with calculated values from f742pn and f7cdpn effective interactions. The effective interactions give good results in comparison with the experimental values.

Table 1.^{42}Ca energy levels calculations respect to ground state with different interactions.

J^{π}	Experiment [10]	f742pn	f7cdpn	J^{π}
0^+	0.000	0.000	0.000	0_1^+
2^+	1.524	1.586	1.586	2_1^+
4^+	2.752	2.817	2.817	4_1^+
6^+	3.189	3.237	3.237	6_1^+

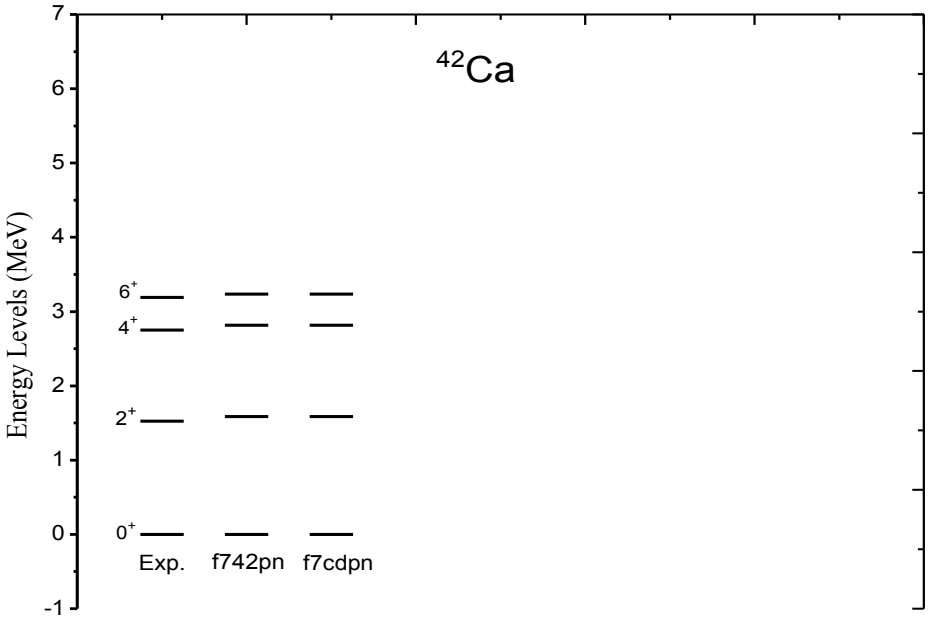

Fig 1. Comparison of the present theoretical work with the experimental excitation energies using f742pn and f7cdpn effective interactions.

Fig. 2 and Table.2, presents the comparison of the energy levels calculations respect to ground state with experimental excitation energies of ^{43}Ca with calculated values from f742pn and f7cdpn effective interactions. The effective interactions give results reasonably consistent with experimental data. Although the structure of odd-A nuclei is much more complicated than their even-even neighbors . On the other hand, there exist deviations between the calculated results and experimental data. In fig 2

Table 2.^{43}Ca energy levels calculations respect to ground state with different interactions.

J^{π}	Experiment [11]	F742pn	F7cdpn	J^{π}
$7/2^-$	0.000	0.000	0.000	$7/2_1^-$
$5/2^-$	0.372	0.327	0.327	$5/2_1^-$
$3/2^-$	0.593	1.379	1.379	$3/2_1^-$
$11/2^-$	1.677	1.807	1.807	$11/2_1^-$
$9/2^-$	2.093	2.102	2.102	$9/2_1^-$
$15/2^-$	2.754	3.144	3.144	$15/2_1^-$

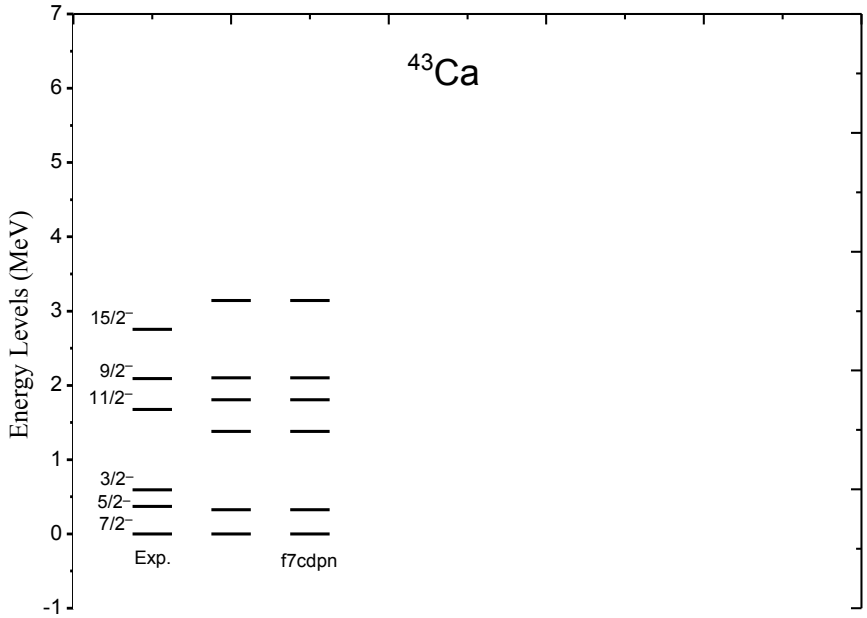

Fig 2. Comparison of the present theoretical work with the experimental excitation energies using f742pn and f7cdpn effective interactions.

Fig. 3 and Table.3, presents the comparison of the energy levels calculations respect to ground state with experimental excitation energies of ^{44}Ca with calculated values from f742pn and f7cdpn effective interactions. The effective interactions gives results reasonably consistent with experimental data, also improve the prediction of Ex (2) discrepancy by about 0.07 MeV. On the other hand, there exist deviations between the calculated results and experimental data. As shown in fig 3.

Table 3. ^{44}Ca energy levels calculations respect to ground state with different interactions.

J^{π}	Experiment [12]	F742pn	F7cdpn	J^{π}
0^+	0.000	0.000	0.000	0_1^+
2^+	1.157	1.586	1.586	2_1^+
4^+	2.283	2.589	2.589	4_1^+
4^+	3.044	2.817	2.817	4_2^+
6^+	3.284	3.237	3.237	6_1^+
(2)	3.676	3.607	3.607	2_2^+
5^-	3.922	3.927	3.927	5_1^+
8^+	5.089	5.372	5.372	8_1^+

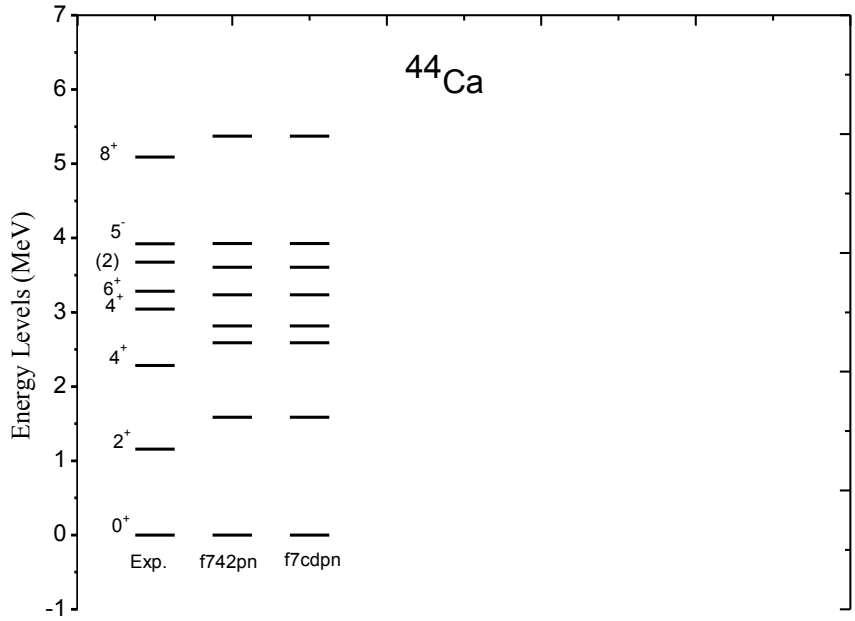

Fig 3. Comparison of the present theoretical work with the experimental excitation energies using f742pn and f7cdpn effective interactions.

2.2. Reduced Electric Quadrupole Transition Probability B(E2) Calculations

The transition rates represent a sensitive test for the most modern effective interactions that have been developed to describe f7-shell nuclei. The transition probability calculated in this work performed using the harmonic oscillator potential (HO, b), where b < 0 for each in-band transition by assuming pure *E*2 transition. Core polarization effect were included by choosing the effective charges for proton $e\pi$ = 0.7*e* and for neutron ev = 0.5*e*. in Table 1 for ^{42}Ca ,using f742pn and f7cdpn effective interaction. In general, all of the calculated results are reasonably consistent with available experimental data.

The *B*(*E*2) values in the ground-state band of ^{42}Ca. Their units are e^2 fm^4.This work is assumed pure *E*2 transition limit

$J_i^{\pi} \rightarrow J_f^{\pi}$	Experiment [10]	f7cdpn	f742pn
$2_1^+ \rightarrow 0_1^+$	83.77 ± 24	61.33	61.33
$4_1^+ \rightarrow 2_1^+$	66.77 ± 11	61.19	61.19
$6_1^+ \rightarrow 4_1^+$	6.63 ± 15	27.88	27.88

The effective charges are taken for proton $e\pi$ = 0.7*e* and for neutron ev = 0.5*e*. for the calculations of the transition probability of ^{43}Ca , using f742pn and f7cdpn effective Interaction. In general, all of the calculated results are reasonably consistent with available experimental data.

The $B(E2)$ values in the ground-state band of ^{43}Ca. Their units are e^2 fm^4.This work is assumed pure $E2$ transition limit

$J_i^\pi \rightarrow J_f^\pi$	Experiment [11]	f7cdpn	f742pn
$5/2_1^- \rightarrow 3/2_1^-$	----------	9.899	9.899
$7/2_1^- \rightarrow 5/2_1^-$	----------	43.31	43.31
$9/2_1^- \rightarrow 7/2_1^-$	9.843 ± 4	9.749	9.749
$11/2_1^- \rightarrow 9/2_1^-$	----------	16.7	16.7
$7/2_1^- \rightarrow 3/2_1^-$	----------	10.12	10.12
$9/2_1^- \rightarrow 5/2_1^-$	----------	9.139	9.139
$11/2_1^- \rightarrow 7/2_1^-$	50.11 ± 10	26.25	26.25
$15/2_1^- \rightarrow 11/2_1^-$	16.64 ± 8	20.65	20.65

The effective charges for proton and neutron are taken to be 0.5e and 0.4e respectively, for the calculations of the transition strengths of ^{44}Ca, using f742pn and f7cdpn effective Interaction. In general, all of the calculated results are reasonably consistent with available experimental data.

The $B(E2)$ values in the ground-state band of ^{44}Ca. Their units are e^2 fm^4.This work is assumed pure $E2$ transition limit

$J_i^\pi \rightarrow J_f^\pi$	Experiment [12]	f7cdpn	f742pn
$2_1^+ \rightarrow 0_1^+$	100.6 ± 6	99.29	99.29
$4_1^+ \rightarrow 2_1^+$	166.08 ± 7	109.8	109.8
$6_1^+ \rightarrow 4_2^+$	41.5 ± 4	91.65	91.65
$8_1^+ \rightarrow 6_1^+$	----------	70.92	70.92

3- Conclusions

The present study demonstrated that interaction files used in this research gave consistent results well in the calculation of the energy levels and the transition probability B (E2) when compared with modern process values. In f7-space shell model calculations were performed using the code OXBASH for windows to reproduce the level spectra and transition probability B(E2) for the nuclei ^{42}Ca, ^{43}Ca and ^{44}Ca,good agreements were obtained by comparing these calculations with the recently available experimental data to level spectra and transition probabilities using f742pn and f7cdpn effective interactions both.

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