Journal of Radiation and Nuclear Applications
An International Journal

http://dx.doi.org/10.18576/jrna/020304

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

*Ali Khalaf Hasan and Rasool Mohammed Kareem**

Department of physics, Faculty of Education for Girls, University of Kufa, Najaf, Iraq.

Received: 10 Jun. 2017, Revised: 25 Aug.2017, Accepted: 29 Aug. 2017.
Published online: 1 Sep. 2017.

Abstract: In this paper, shell model is applied in the f7-shell region to calculate the energy levels and B(E2) for $^{42-44}$Ti and $^{42-44}$Sc nuclei by employing the effective interactions, f742pn and f7cdpn and using the shell model code OXBASH for windows by applying spin-parity of valance nucleons. It is found that there is good convergence of energy level sand B(E2) values with the standard practical value.
Keywords: Energy Levels, OXBASH Code and gamma transitions.

1 Introduction

The aim of this paper is study of the energy levels and electrical transitions B (E2; ↓) of $^{44-42}$Ti and $^{44-42}$Sc isotopes by using OXBASH code for windows. This program is a set of codes 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].Applied the shell model and use a Modified Brown and Sherr (f7cdpn, f742pn) interaction for neutron and proton orbits in $^{44-42}$Ti and $^{44-42}$Sc to calculate the energy levels and B (E2) values. Various observables can be predicted accurately and systematically in terms of the nuclear shell model. 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 are 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. The best example for using several model spaces and two-body interactions is that of Brown et al, which is the most remarkable work in this field [6,7]. The starting point in all such shell-model calculations is the derivation of an effective interaction owing to the fact that the f7-shell is the most important for a variety of problems in nuclear structure such as electron capture in supernova explosions. In this work, the shell model calculations are carried out in the f7-shell region for the isotopes $^{44-42}$Ti and $^{44-42}$Sc, 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 out 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, there are been constructed wave functions with good angular momentum J and isospin T. The f7pn model space is comprised of (1f7/2) below the closed N = Z=20 shell [8]. In addition, there have been used the harmonic oscillator potential (HO, b), b>0.In this work, one can find the calculated results of states of the odd A and even A nuclei, number of protons, i.e., 22 to the $^{44-42}$Ti, with neutron numbers from 20 to 22 and number of protons, 21 to the $^{44-42}$Sc, with neutron numbers from 21 to 23 energy levels and the B (E2) value.

2.1 Energy Levels Calculations

The calculations have been carried out using the code OXBASH for windows [9]. In the f7 model space comprised of the 0f7/2 valence orbits outside the ^{40}Ca. Two effective interactions have been employed with f7 model space for the calculations of level spectra and transition probabilities, these effective interactions are f742pn and f7cdpn [5]. It is worth mentioning that ^{42}Ti, ^{43}Ti and ^{44}Ti have Iso spin part (T = 1, 0.5 and 0) respectively, while ^{42}Sc,^{43}Sc and ^{44}Sc have Iso spin part (T = 0 , 0.5 and 1) respectively .The energy levels values for ^{42}Ti nucleus from f742pn and f7cdpn effective interactions are shown in table

*Corresponding author e-mail: rmk19861113@yahoo.com

1 and these effective interactions give good results in comparison with the experimental values.

Table1.shows a comparison of the energy levels values with respect to the ground state were calculated from f742pn and f7cdpn effective interactions with experimental excitation energies of ^{42}Ti

Exp. Res [10]		f742pn	f7cdpn	J^π
J^π	Energy elevels			
0^+	0.000	0.000	0.000	0_1^+
2^+	1.556	1.586	1.605	2_1^+
4^+	2.676	2.817	2.771	4_1^+
6^+	3.043	3.237	3.139	6_1^+

For ^{43}Ti nucleus, the energy levels values are shown in table 2. these values are agreement with the experimental values, and new energy levels have been reached.

Table 2. Shows a comparison of the energy levels values with respect to the ground state were calculated from f742pn and f7cdpn effective interactions with experimental excitation energies of ^{43}Ti

Exp. Res [11]		f742pn	f7cdpn	J^π
J^π	Energy elevels			
$7/2^-$	0.000	0.000	0.000	$7/2_1^-$
(1/2,5/2)-	1.760	1.681	1.707	$9/2_1^-$
	2.438	2.336	2.345	$11/2_1^-$
	2.640	2.791	2.787	$7/2_2^-$
(15/2-)	2.951	2.889	2.911	$3/2_1^-$
	3.220	3.444	3.393	$5/2_1^-$
		3.503	3.472	$13/2_1^-$
		3.512	3.471	$15/2_1^-$
		3.638	3.556	$19/2_1^-$
		3.937	3.916	$5/2_2^-$
		4.103	4.037	$9/2_2^-$
		4.136	4.057	$7/2_3^-$
		4.291	4.209	$17/2_1^-$
		4.318	4.289	$1/2_1^-$
		4.391	4.341	$7/2_4^-$
		4.411	4.364	$11/2_2^-$
		4.464	4.439	$5/2_3^-$
		4.943	4.862	$13/2_2^-$
		5.515	5.480	$3/2_2^-$
		5.943	5.883	$11/2_3^-$
		6.238	6.181	$9/2_3^-$
		7.280	7.187	$15/2_2^-$

Table 3 shows a comparison of the calculations energy levels with respect to the ground state with experimental excitation energies of ^{44}Ti with f742pn and f7cdpn effective interactions. The effective interactions give results reasonably consistent with experimental data. The total angular momentum and parity are $(0_1^+, 2_1^+, 4_1^+, 6_1^+, 8_2^+, 6_6^+, 2_7^+, 4_{10}^+, 2_9^+)$respectively,confirmation of which is $(8^+, 4^+, 6^+, 10^+, 12^+, 2^+, 10^+, 4^+, 2^+, 6^+)$ respectively, as well as the confirmation of momentum only, which is $(6^-, 3^-, 3^-, 11^-)$ respectively

Table 3. Shows a comparison of the energy levels values with respect to the ground state were calculated from f742pn and f7cdpn effective interactions with experimental excitation energies of ^{44}Ti.

Exp. Res[12]		f742pn	f7cdpn	J^π
J^π	Energy elevels			
0^+	0.000	0.000	0.000	0_1^+
2^+	1.083	1.163	1.183	2_1^+
4^+	2.454	2.791	2.806	4_1^+
6^+	4.015	4.057	4.030	6_1^+
	4.792	4.956	4.989	2_2^+
		5.001	5.010	4_2^+
(6^-)	5.151	5.167	5.174	6_2^+
		5.231	5.255	2_3^+
(7^-)	5.67	5.610	5.587	6_3^+
		5.583	5.594	0_2^+
		5.662	5.677	1_1^+
3^-	5.421	5.788	5.806	3_1^+
5^-	5.305	5.868	5.875	5_1^+
		5.947	5.942	4_3^+
		5.995	5.995	3_2^+
		6.035	6.024	7_1^+
(8^+)	6.508	6.080	6.070	8_1^+
(8^+)	6.571	6.502	6.432	7_2^+
		6.506	6.464	5_2^+
(4^+)	6.959	6.707	6.713	4_4^+
(6^+)	6.848	6.878	6.855	6_4^+
		7.018	7.002	5_3^+
		7.289	7.272	5_4^+
8^+	7.458	7.345	7.321	8_2^+
(10^+)	7.671	7.380	7.341	10_1^+
		7.444	7.421	6_5^+
3^-	7.34	7.448	7.434	3_3^+
1^-	7.5	7.577	7.488	1_2^+
6+	7.670	7.551	7.529	6_6^+
	7.634	7.600	7.598	4_5^+

(12^+)	8.039	7.689	7.624	12_1^+
		7.806	7.772	2_4^+
		7.813	7.817	2_5^+
	8.067	7.979	7.941	9_1^+
$(1-,2^+)$	8.18	7.968	7.950	2_6^+
		8.143	8.120	4_6^+
		8.272	8.160	0_3^+
		8.234	8.187	8_3^+
		8.275	8.240	4_7^+
	8.318	8.325	8.298	8_4^+
$(2+,3^-)$	8.449	8.361	8.319	3_4^+
		8.369	8.330	7_3^+
		8.522	8.497	5_6^+
		8.528	8.524	6_7^+
		8.573	8.530	7_4^+
		8.616	8.556	9_2^+
(3^-)	8.534	8.688	8.652	3_5^+
		8.782	8.750	0_4^+
(10^+)	8.984	8.891	8.827	10_2^+
		8.920	8.888	7_5^+
		8.963	8.906	3_6^+
(4^+)	8.947	8.928	8.910	4_8^+
	9.03	9.094	9.043	6_8^+
2^+	9.227	9.265	9.220	2_7^+
5^-	9.4	9.305	9.232	5_7^+
	9.478	9.354	9.312	8_5^+
	9.632	9.639	9.601	3_7^+
	9.668	9.723	9.690	1_3^+
(11^-)	9.722	9.850	9.77	11_1^+
(2^+)	9.741	9.858	9.790	2_8^+
	9.895	9.863	9.816	5_8^+
	10.046	10.017	9.963	10_3^+
	10.046	10.041	10.002	6_9^+
	10.166	10.056	10.013	4_9^+
	10.52	10.666	10.595	9_3^+
	11.058	10.857	10.788	7_6^+
4^+	10.7	10.861	10.810	4_{10}^+
(6^+)	11.110	11.509	11.419	6_{10}^+
2^+	12.118	11.879	11.826	2_9^+
	12.2	12.200	12.137	5_9^+
	13	13.644	13.558	8_6^+

But for ^{42}Sc nucleus, table 4 shows a comparison of the energy levels calculations with respect to the ground state from f742pn and f7cdpn effective interactions, with experimental excitation energies. The effective interactions give results reasonably consistent with experimental data. The total angular momentum and parity are $(0_1^+, 1_1^+, 3_1^+, 2_1^+, 4_1^+)$ respectively, confirmation of which is (5^+), as well as confirmation of momentum only, which is (7, 6) respectively.

Table 4. shows a comparison of the energy levels values with respect to the ground state were calculated from f742pn and f7cdpn effective interactions with experimental excitation energies of ^{42}Sc

Exp. Res[10]		f742pn	f7cdpn	J^π
J^π	Energy elevels			
0^+	0.000	0.000	0.000	0_1^+
1^+	0.611	0.611	0.685	1_1^+
$(7)^+$	0.616	0.618	0.692	7_1^+
3^+	1.490	1.491	1.565	3_1^+
(5^+)	1.510	1.511	1.585	5_1^+
2^+	1.586	1.586	1.647	2_1^+
4^+	2.815	2.817	2.877	4_1^+
$(6)^+$	3.242	3.237	3.295	6_1^+

The energy levels values for ^{43}Sc nucleus from f742pn and f7cdpn effective interactions are shown in table 5 and these effective interactions results reasonably consistent with experimental data. The total angular momentum and parity are ($7/2_1^-$, $5/2_1^-, 5/2_2^-, 7/2_4^-, 3/2_2^+$) respectively, confirmation of which is ($17/2^-$) respectively , as well as confirmation of momentum only, which is (9/2 , 11/2 , 7/2 , 3/2 , 13/2 , 19/2 , 7/2 , 9/2 , 17/2 , 11/2 , 5/2 , 15/2) respectively.

Table 5. Shows a comparison of the energy levels values with respect to the ground state were calculated from f742pn and f7cdpn effective interactions with experimental excitation energies of ^{43}Sc

Exp. Res [11]		f742pn	f7cdpn	J^π
J^π	Energy elevels			
$7/2^-$	0.000	0.000	0.000	$7/2_1^-$
$(5/2,9/2)^-$	1.882	1.681	1.700	$9/2_1^-$
$(11/2)^-$	2.635	2.336	2.355	$11/2_1^-$
5/2,7/2,9/2)(	2.811	2.791	2.806	$7/2_2^-$
$(1/2,3/2,5/2)^+$	2.86	2.889	2.908	$3/2_1^-$
$5/2^-$	3.463	3.444	3.462	$5/2_1^-$
$(\leq 13/2)^+$	3.480	3.503	3.522	$13/2_1^-$
$(5/2^-_,7/2^-_,9/2^-_,)$	3.631	3.512	3.531	$15/2_1^-$
$(5/2T019/2)^-$	3.7	3.638	3.656	$19/2_1^-$
5/2-,7/2-	3.939	3.937	3.956	$5/2_2^-$

$(3/2TO17/2)^+$	4.132	4.136	4.103	$7/2_3^-$
(9/2,11/2,13/2)-	4.158	4.103	4.122	$9/2_2^-$
$(17/2^-)$	4.36	4.291	4.309	$17/2_1^-$
	4.343	4.318	4.337	$1/2_1^-$
$5/2^-, 7/2^-$	4.383	4.391	4.409	$7/2_4^-$
$(11/2^+, 13/2^-)$	4.555	4.411	4.429	$11/2_2^-$
(5/2:9/2)	4.455	4.464	4.461	$5/2_3^-$
	4.927	4.943	4.96	$13/2_2^-$
$1/2^-, 3/2^-$	5.502	5.515	5.514	$3/2_2^-$
	5.977	5.943	5.939	$11/2_3^-$
	6.242	6.238	6.234	$9/2_3^-$
5/2,17/2,19/2)(1	7.273	7.280	7.275	$15/2_2^-$

For ^{44}Sc nucleus the energy levels calculations from f742pn and f7cdpn effective interactions are shown in table 6 . The effective interactions give results reasonably consistent with experimental data. The total angular momentum and parity are $(2_1^+, 6_1^+, 1_1^+, 3_1^+, 7_1^+)$ respectively, confirmation of which is $(5^+, 5^+, 4^+, 3^+, 5^+, 3^+, 5^+, 4^+, 4^+)$ respectively, as well as confirmation of momentum only is (5, 3, 1, 4, 2) respectively

Table 6. Shows a comparison of the energy levels values with respect to the ground state were calculated from f742pn and f7cdpn effective interactions with experimental excitation energies of ^{44}Sc

Exp .Res[12]		F742pn	F7cdpn	J^π
J^π	Energy elevels			
2^+	0.000	0.000	0.000	2_1^+
6^+	0.271	0.379	0.382	6_1^+
1^+	0.667	0.431	0.456	1_1^+
4^-	0.631	0.716	0.712	4_1^+
3^+	0.762	0.764	0.789	3_1^+
7^+	0.968	1.271	1.294	7_1^+
5^-	1.197	1.275	1.299	5_1^+
$(2TO5)^+$	1.957	2.058	2.081	5_2^+
6^-	2.210	2.213	2.228	6_2^+
$(2TO5)^+$	2.291	2.217	2.241	3_2^+
$(1TO6)^-$	2.333	2.346	2.369	1_2^+
$(2TO5)^+$	2.424	2.369	2.393	4_2^+
$(1TO6)^-$	2.524	2.575	2.594	2_2^+
	3.035	3.041	2.990	0_1^+
+	3.162	3.094	3.117	8_1^+
	3.178	3.130	3.154	3_3^+
(2^+TO5^+)	3.285	3.291	3.315	5_3^+
	3.323	3.297	3.321	6_3^+
	3.439	3.342	3.365	7_2^+
	3.483	3.385	3.408	9_1^+
+	3.72	3.689	3.713	7_3^+
(2^+TO5^+)	3.626	3.697	3.718	4_3^+
(2^+TO5^+)	3.851	3.732	3.755	3_4^+
	4.053	4.034	4.057	2_3^+
(2^+TO5^+)	4.087	4.074	4.097	5_4^+
+	4.144	4.123	4.146	8_2^+
(2^+TO5^+)	4.533	4.408	4.431	3_5^+
	4.56	4.492	4.516	1_3^+
	4.595	4.627	4.607	2_4^+
	4.622	4.619	4.641	11_1^+
(2^+TO5^+)	4.697	4.632	4.655	$5\ _5^+$
10	4.949	4.786	4.809	10_1^+
	4.762	4.810	4.832	6_4^+
(2^+TO5^+)	4.820	4.825	4.848	4_4^+
	5.500	5.435	5.457	9_2^+
(0^+TO7^+)	5.526	5.630	5.625	4_5^+
	5.608	5.626	5.649	7_4^+
	5.716	5.858	5.838	4_6^+
		6.278	6.257	6_5^+
		6.648	6.643	2_5^+
		6.969	6.963	5_6^+
		8.413	8.405	8_3^+

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 by using the harmonic oscillator potential (HO, b), where b > 0 for each in-band transition by assuming pure *E*2 transition. Core polarization effects have been included by choosing the effective charges for proton e_π= 1.7*e* and for neutron e_ν= 0.350*e*. Table 7 is about ^{42}Ti, which is calculated by using f742pn and f7cdpn effective interaction. In general, all of the calculated results are reasonably consistent with available experimental data.

Table 7. presents the *B* (*E*2) values in the ground-state band of ^{42}Ti. Their units are e^2 fm^4.This work is assumed pure *E*2 transition limit.

$J_i^\pi \rightarrow J_f^\pi$	Exp [10]	F7cdpn	F742pn
$2_1^+ \rightarrow 0_1^+$	138.75 ± 4	138	138
$4_1^+ \rightarrow 2_1^+$	----------	137.7	137.7
$6_1^+ \rightarrow 4_1^+$	27.58± 21	62.72	62.72

The effective charges are taken from both proton and neutron (1.3e). For the calculations of the transition probability in Table 8, about ^{43}Ti, f742pn and f7cdpn effective Interactions are used. In general, the calculated results are reasonably consistent with available experimental data.

Table 8.presents the B (E2) values in the ground-state band of ^{43}Ti. Their units are e^2 fm^4.This work is assumed pure E2 transition limit.

$J_i^\pi \to J_f^\pi$	Exp [11]	F7cdpn	F742pn
$5/2_1^- \to 1/2_1^-$	----------	32.56	32.31
$7/2_1^- \to 3/2_1^-$	----------	20.91	20.43
$9/2_1^- \to 5/2_1^-$	----------	0.05065	0.01946
$11/2_1^- \to 7/2_1^-$	----------	64.34	63.98
$13/2_1^- \to 9/2_1^-$	----------	73.62	73.58
$15/2_1^- \to 11/2_1^-$	----------	95.42	95.75
$17/2_1^- \to 13/2_1^-$	----------	45.94	45.71
$19/2_1^- \to 15/2_1^-$	51 ± 3	51.24	51.32

In Table 9, about of ^{44}Ti, the effective charges for proton and neutron are taken to be (0.95e and 1.1e) respectively; for the calculations of the transition forces, f742pn and f7cdpn effective Interactions are used. In general, the calculated results are reasonably consistent with available experimental data.

Table 9.presents the B (E2) values in the ground-state band of ^{44}Ti. Their units are e^2 fm^4.This work is assumed pure E2 transition limit.

$J_i^\pi \to J_f^\pi$	Exp [12]	F7cdpn	F742pn
$2_1^+ \to 0_1^+$	119.94 ± 4	126.2	126.4
$4_1^+ \to 2_1^+$	276.81 ± 5	159.8	160.5
$6_1^+ \to 4_1^+$	156.86 ± 24	68.02	69.97
$8_1^+ \to 6_1^+$	----------	70.03	72.52
$10_1^+ \to 8_1^+$	----------	80.07	80.97
$12_1^+ \to 10_1^+$	----------	43.6	43.81
$3_1^+ \to 1_1^+$	----------	1.292	1.755
$5_1^+ \to 3_1^+$	----------	32.5	30.99
$7_1^+ \to 5_1^+$	----------	23.56	23.85
$9_1^+ \to 7_1^+$	----------	27.89	29.22
$11_1^+ \to 9_1^+$	----------	1.901	2.572

Moreover, f742pn and f7cdpn effective Interactions have been used for the calculation of the transition probability in table 10 of ^{42}Sc. The effective charges are taken from both proton and neutron (1.4e) . In general, the calculated results are reasonably consistent with available experimental data.

table 10 shows The effective charges for proton e_π= 1.4*e* and for neutron e_ν= 1.35*e* have been chosen for table 11, about ^{43}Sc, for the calculation of the transition probability, using f742pn and f7cdpn effective interactions. In general, all of the calculated results are reasonably consistent with available experimental data.

Table10.presents the B (E2) values in the ground-state band of ^{42}Sc. Their units are e^2 fm^4.This work is assumed pure E2 transition limit.

$J_i^\pi \to J_f^\pi$	Exp [10]	F7cdpn	F742pn
$2_1^+ \to 0_1^+$	69.38 ± 3	68.33	68.33
$4_1^+ \to 2_1^+$	----------	68.17	68.17
$6_1^+ \to 4_1^+$	----------	31.06	31.06
$3_1^+ \to 1_1^+$	34.69 ± 7	76.7	76.7
$5_1^+ \to 3_1^+$	----------	51.27	51.27
$7_1^+ \to 5_1^+$	----------	12.26	12.26

Table11. Presents the B (E2) values in the ground-state band of ^{43}Sc. Their units are e^2 fm^4.This work is assumed pure E2 transition limit.

$J_i^\pi \to J_f^\pi$	Exp [11]	F7cdpn	F742pn
$5/2_1^- \to 1/2_1^-$	----------	25.17	25.16
$7/2_1^- \to 3/2_1^-$	----------	15.21	15.08
$9/2_1^- \to 5/2_1^-$	----------	1.95	1.947
$11/2_1^- \to 7/2_1^-$	137.8 ± 24	32.86	32.69
$13/2_1^- \to 9/2_1^-$	----------	36.22	36.22
$15/2_1^- \to 11/2_1^-$	48.32 ± 7	48.92	48.93
$17/2_1^- \to 13/2_1^-$	----------	19.55	19.54
$19/2_1^- \to 15/2_1^-$	23.89 ± 2	26.22	26.23

For the calculations of the transition probability in table 12 of ^{44}Sc, the effective charges are taken for proton and neutron (0.9e , 0.8e) respectively, using f742pn and f7cdpn effective Interaction. In general, the calculated results are reasonably consistent with available experimental data.

Table 12. presents the B (E2) values in the ground-state band of ^{44}Sc. Their units are e^2 fm^4.This work is assumed pure E2 transition limit.

$J_i^\pi \to J_f^z$	Exp [12]	F7cdpn	F742pn
$2_1^+ \to 0_1^+$	----------	3.135	3.205
$4_1^+ \to 2_1^+$	34.6 ± 23	34.78	35
$6_1^+ \to 4_1^+$	----------	12.42	12.34
$8_1^+ \to 6_1^+$	----------	11.76	11.62
$10_1^+ \to 8_1^+$	----------	4.51	14.51
$3_1^+ \to 1_1^+$	----------	33.9	33.9
$5_1^+ \to 3_1^+$	----------	36.72	36.74
$7_1^+ \to 5_1^+$	----------	11.71	11.72
$9_1^+ \to 7_1^+$	23.07 ± 5	16.94	16.94
$11_1^+ \to 9_1^+$	20.66 ± 8	13.29	13.29

3 Conclusions

The present study demonstrates that interaction files used in this research give 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 $^{44-42}$Sc and $^{44-42}$Ti. Good agreements were obtained by comparing these calculations with the recently available experimental data about level spectra and transition probabilities using both f742pn and f7cdpn effective interactions.

References:

[1] B. A. Brown, C. R. Bronk and P. E. Hodgson, "Systematics of nuclear RMS charge radii." , Nuclear Physics., 10(12) , 1683 ,1984.

[2] B. A. Brown, S. E. Massen and J. I. Escudero, "PE llodgson, G. Madurga and J. Vinas." , J. Phys.,G 9, 423,1983.

[3] S. Cohen and D. Kurath, "Effective interactions for the 1p shell.", Nuclear Physics., 73(1), 1-24 , 1965.

[4] B. Alex. Brownand B. H. Wildenthal , "Status of the nuclear shell model.", Annual Review of Nuclear and Particle Science., 38(1), 29-66 ,1988.

[5] A. B. Brown and R. Sherr "Charge-dependent two body interactions deduced from displacement energies in the 1f7/2shell", Nucl . Phy.,A 322(1), 61-91 ,1979.

[6] A. Gade, D. Bazin, C. A. Bertulani, B. A. Brwon, C. A. Church, D. C. Dinca, J. Enders, T. P. Glasmacher, G. Hansen, Z. Hu, K. W. Kemper, W. F. Muller, H. Olliver, B. C. Perry, L. A. Riley, B. T. Roeder, B. M. Sherrill, J. R. Terry, J. A. Tostevin and K. L. Yurkewics, Phys. Rev., C71, 051301(R),2005.

[7] S. J. Freeman, R. V. F. Janssens, B. A. Brown, M. P. Carpenter, S. M. Fischer, N. J. Hammond, M. Honma, C. J. Lister, T. L. Khoo, G. Mkherjee, D. Seweryaniak, J. F. Smith, B. J. Varley, M. whitehead and S. Zhu., Phys. Rev., 764, 142-147 ,2005.

[8] L. Rydström, J. Blomqvist, R. J. Liotta and C. Pomar, Structure of proton-deficient nuclei near 208Pb. Nuclear Physics A, 512(2), 217-240 ,1990.

[9] B. A. Brown, A. Etchegoyen , N. S. Godwin, W. D. M. Rae, W. A. Richter, W. E. Ormand, E. K. Warburton, J. S. Winfield, L. Zhao and C. H. Zimmerman, MSU-NSCL report number.,1289 ,2004 .

[10] B. Singh and J. A. Cameron, " Nuclear Data Sheets for A = 42 ", Nuclear Data Sheets.,92(1),1-146 ,2001.

[11] J. A. Cameron and B.Singh, " Nuclear Data Sheets for A = 43 ",Nuclear Data Sheets., 92, 783-892 ,2001.

[12] J.Chen,B. Singh and J. A.Cameron, " Nuclear Data Sheets for A = 44 " Nuclear Data Sheets., 112(9), 2357-2495 ,2011.