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Nuclear Structure Study of ^{62}Ni, ^{62}Zn and ^{62}Cu Nuclei by using SDI and MSDI Interactions

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Abstract: ***The nuclear shell model calculations are employed to nuclear structure study of the nuclei ^{62}Ni, ^{62}Zn and ^{62}Cu in $fpg_{9/2}$ model space. The inert core ^{60}Ni is assumed, with two nucleons outside inert core are considered to describe the binding energy and excited states for both the positive and negative parities of the three nuclei . A computer code were written by Mathematica to perform the configuration mixing and pure shell model calculations by taking the surface delta interaction (SDI) and modified surface delta interaction (MSDI) as residual interactions. The binding energy calculations were in excellent agreement with experimental data. The predicated ground-state and low-lying states (energies, spins and parities) for the ^{62}Ni, ^{62}Zn and ^{62}Cu are compared with the recent available experimental data. Reasonable agreements were obtained by comparing our theoretical work with the experimental data***.

Keywords: Energy levels, Shell model, Binding energy

1. Introduction

Nuclear shell model is one of the most powerful tools for giving a quantitative interpretation to the experimental data. The two main ingredients of any shell model calculations are the N-N interaction and the configuration space for valence particles [1]. Owing to the progress in experiments on unstable nuclei, it has been recognized that the nuclear shell structure depends on *Z* or *N* as is often called shell evolution [2]. The appearance of shell gaps associated with magic nucleon numbers is one of the cornerstones of nuclear structure. The presence of magic gaps allows one, to determine the single-particle energies and the residual interaction among valence nucleons, providing essential input for nuclear models [3]-[4].

The interactions between nucleons depend on the orbitals they occupy and thus hitherto uninvestigated nuclei can contain important experimental information to adjust the effective interactions in the respective nuclear medium. As the number of valence nucleons increases, the residual proton-neutron interaction energy builds up. In some situations, the gain in binding energy of the proton-neutron interactions can be sufficiently large that the nucleus will deviate from its spherical shape and favors a deformed ground state. Because the residual proton-neutron interaction energy is normally largest when the number of active valence nucleons is maximal [4]. Strong proton-neutron residual interactions are present between the neutrons in the $vf_{5/2}$ and $vg_{9/2}$ orbitals and the protons in the $\pi f_{7/2}$ and $\pi f_{5/2}$ orbitals, which are not precisely known. Because the nuclear structure is sensitive to small differences in the interactions, it is important to deduce those interactions as accurate as possible from experiment. The $0g_{9/2}$ orbital has a high spin and a unique parity in the major lower-spin negative-parity *pf* shells between N = 20 and 50 facilitating the formation of isomerism. Therefore, corresponding configurations are easier to identify and they tend to have a pure character [4].

2. The Residual Interaction

Residual interaction is defined as the force that produces when nucleons collide with each other and this interaction is happen the perturbation in Hamiltonian operator that equal summing two particles potential and represent Hamiltonian operator to perturbation state from equation(1) [5]:

$$H = H_{\circ} + \sum_{i<j} V_{ij} \qquad (1)$$

V_{ij} is the residual two-body interaction , H_0 is represent Hamilton operator without perturbation. To calculate the spectrum of these nuclei we assume that the residual interaction V_{ij} is surface delta interaction (SDI). The SDI was introduced as a simple but yet successful method to calculate nuclear properties in the framework of the shell model. The interaction between two nucleons of zero range is assumed to be localized on the nuclear surface of the core [6]-[7]. We will use the surface δ-interaction (SDI) to theoretical description with only one parameter [6]. The interaction functions can be given in eq. (2)[5]:

$$V = -4\pi V_{\circ}\delta(\underline{r}_i - \underline{r}_j) \qquad (2)$$

The interaction can be written as [6]:

$$V_{12} = -A'_T \frac{\delta(r_1 - r_2)}{r_1 r_2} \times \delta(\cos\theta_1 - \cos\theta_2)\delta(\phi_1 - \phi_2) \qquad (3)$$

in spherical coordinates. The radial integral evaluated as

$$C_{\circ}(nl) = \frac{1}{4\pi}\int R^4_{nl}(r)\frac{1}{r^2}dr \qquad (4)$$

is assumed to be equal for all orbits *nl* with main quantum number n and orbital angular momentum l $\left(j = l \pm \frac{1}{2}\right)$. Here A_T denotes the product of strength factor and radial integral in eq.(5) [6]-[8].

$$A_T = A'_T C_{\circ}(nl) \qquad (5)$$

For two body outside core the matrix elements of the SDI can be written in *j-j* coupling as [5]-[8]-[9].

$$\langle j_1 j_2 | V_{12} | j_3 j_4 \rangle_{JT} = (-1)^{n_1+n_2+n3+n4} \frac{A_T}{2(2I+1)}$$
$$\left\{ \frac{(2j_1+1)(2j_2+1)(2j_3+1)(2j_4+1)}{(1+\delta_{12})(1+\delta_{34})} \right\}$$
$$\left\{ (-1)^{j_2+j_3+l_2+l_4} \right.$$
$$\langle j_1 \tfrac{1}{2} j_2 -\tfrac{1}{2} | I0 \rangle \langle j_3 \tfrac{1}{2} j_4 -\tfrac{1}{2} | I0 \rangle [1-(-1)^{l_1+l_2+I+T}]$$
$$- \langle j_1 \tfrac{1}{2} j_2 \tfrac{1}{2} | I1 \rangle \langle j_3 \tfrac{1}{2} j_4 \tfrac{1}{2} | I1 \rangle [1+(-1)^T] \left. \right\} \quad (6)$$

Consider two groups of energy levels of one nucleus, one group with T = 0 and the other with T =1 Let S_{12}(exp) be the experimental value of the energy spacing between the lowest state with T = 0 and the lowest state with T = 1, and let S_{12}(cal.) be the theoretical value of this spacing as reproduced with the SDI. Let us denote the difference between the experimental and calculated values by $\Delta_{T=0,T=1} = S_{12}(\text{exp}) - S_{12}(\text{cal.})$ [8,9]. Analysis shows that the deviations $\Delta_{T=0,T=1}$ can be compensated for by adding a T-dependent term to the SDI defined in eq.(7) [8]-[9].

$$V^{MSDI}(1,2) = -4\pi A'_T \delta(r(1)-r(2))\delta(r(1)-R_\circ) + B'(\tau(1).\tau(2)) + C' \quad (7)$$

In analogy with derivation of eq.(7) one obtains the expectation values:

$$\langle \tau(1).\tau(2) \rangle_T = 2T(T+1) - 3$$

Thus the contribution of the additional terms:

$$\langle B(\tau(1).\tau(2)) + C \rangle = \begin{cases} -3B + C & \text{for T=0} \\ B + C & \text{for T=1} \end{cases}$$

Where B and C denote the products of B' and C' with the radial integral $C_\circ(nl)$ .the resulting modified surface delta interaction (MSDI) is thus given by [8]:

$$\langle j_1 j_2 | V_{12} | j_3 j_4 \rangle_{IT} = (-1)^{n_1+n_2+n3+n4} \frac{A_T}{2(2I+1)}$$
$$\left\{ \frac{(2j_1+1)(2j_2+1)(2j_3+1)(2j_4+1)}{(1+\delta_{12})(1+\delta_{34})} \right\}$$
$$\left\{ (-1)^{j_2+j_3+l_2+l_4} \right.$$
$$\langle j_1 \tfrac{1}{2} j_2 -\tfrac{1}{2} | I0 \rangle \langle j_3 \tfrac{1}{2} j_4 -\tfrac{1}{2} | I0 \rangle [1-(-1)^{l_1+l_2+I+T}]$$
$$- \langle j_1 \tfrac{1}{2} j_2 \tfrac{1}{2} | I1 \rangle \langle j_3 \tfrac{1}{2} j_4 \tfrac{1}{2} | I1 \rangle [1+(-1)^T] \left. \right\}$$
$$+ ([2T(T+1)-3]B + C)\delta_{12}\delta_{34} \quad (8)$$

Where $\langle j_1 \tfrac{1}{2} j_2 -\tfrac{1}{2} | JM \rangle$ are Clebsch- Gordan coefficients and $j_1 j_2 j_3 j_4$ are the spin states of particles .J and T are indicat to the spin and isospin of two particle state. Where A_T,B,C are strength parameters of (SDI and MSDI).

3. Shell Model Calculations

Large scale shell model calculations have been performed for neutron rich nickel, copper and zinc nuclei in the mass region A=62, A computer code were written by Mathematica to perform the shell model calculations by taking SDI and MSDI as residual interactions to calculate two body matrix elements (TBME). In the present work , besides ground states, low –lying excitation states and the binding energies have been carried out. In the model space $0f_{5/2}$, $1p_{1/2}$, $0g_{9/2}$ the neutron single particle energies (-7.8201,-7.5372,-5.6971)MeV and in the model space $1p_{3/2}$ $0f_{5/2}$, $1p_{1/2}$, $0g_{9/2}$ the proton single particle energies (-4.8005,-3.8305,-2.7205,-2.0805)MeV were taken. The configurations mixing and pure shell model respected to ^{60}Ni inert core were performed.

3.1 The Binding Energy

Binding energies are important to nuclear astrophysicists when determining *Q*-values of proton capture reactions and beta decays [10]. To compare our shell model results with the experimental binding energies relative to binding energies of core. we use following formula [10]:

$$B = B(\text{core}) - < H >$$

In Tables 1 and 2, We see that the experimental binding energies are excellent agreement with our theoretical calculations in both interaction SDI and MSDI. By determined the parameters in the shell model calculations of binding energies for these nuclei were fitted with experimental data.

Table 1: The experimental and calculated binding energy for ^{62}Ni, ^{62}Zn and ^{62}Cu in SDI interaction.(SMCM).

Z	*N*	*Nucleus*	*B(Exp.)MeV* [11]-[12]	*B(Cal.)MeV* SDI	|δE|
28	34	^{62}Ni	-545.262	-545.261	0.001
30	32	^{62}Zn	-538.1226	-538.1224	0.0002
29	33	^{62}Cu	-540.5314	-540.5318	0.0004

Table 2: The experimental and calculated binding energy for ^{62}Ni, ^{62}Zn and ^{62}Cu in MSDI interaction.(SMCM).

Z	N	Nucleus	*B(Exp.)MeV* [11]-[12]	*B(Cal.)MeV* MSDI	|δE|
28	34	^{62}Ni	-545.262	-545.2618	0.0002
30	32	^{62}Zn	-538.1226	-538.1226	0
29	33	^{62}Cu	-540.5314	-540.5303	0.0011

3.2. The Energy Levels

3.2.1. Nickel Nucleus ^{62}Ni

In Table 3. Shows configuration mixing of two neutron in $f_{5/2}$,$p_{1/2}$ and $g_{9/2}$ valance space. We see the configuration mixing is increased low-lying states in this space, but without $g_{9/2}$ orbit, energy levels are decreasing the possible contribution, and taken positive parity only.

The comparison between experimental and calculated ground-state and low-lying energies are shown in Table.4. for the positive and negative parities, T=1 spectra. We see that rotational energy levels (2^+,4^+,6^+,8^+) in ground band of theory results in good agreement of MSDI interaction with experimental data from SDI interaction. The excitation levels for negative parity are very close of experimental data in both SDI and MSDI. The spin and parity of high energy levels experimentally (4.648, 5.041)MeV were uncertain but the same levels are predicted by 7^-,4^-. As well as the some data have been predicted in configuration

mixing. Have been concord low lying states in Table.5. For calculated results in SDI and MSDI interactions with data. From the comparison between the configuration mixing and pure, we found configuration mixing is better.

Table 3: The possible 2-neutron configurations of ^{62}Ni in (SMCM)

J	*CONFIGURATIONS*	*J*	*CONFIGURATIONS*
0	$(f_{5/2})^2$, $(p_{1/2})^2$, $(g_{9/2})^2$	5	$f_{5/2}\, g_{9/2}$, $p_{1/2}\, g_{9/2}$
2	$(f_{5/2})^2$, $f_{5/2}\, p_{1/2}$, $f_{5/2}\, g_{9/2}$, $(g_{9/2})^2$	6	$f_{5/2}\, g_{9/2}$, $(g_{9/2})^2$
3	$f_{5/2}\, p_{1/2}$, $f_{5/2}\, g_{9/2}$	7	$f_{5/2}\, g_{9/2}$
4	$(f_{5/2})^2$, $f_{5/2}\, g_{9/2}$, $p_{1/2}\, g_{9/2}$, $(g_{9/2})^2$	8	$(g_{9/2})^2$

Table 4: Comparison of theoretical calculations with experimental data from Ref.s. [13-]-[14] for nickel nucleus (The parameters of SDI A=0.478, MSDI A=0.51, B=0.502,C=0)

Cal.Rse.(Mixing)			*Exp.Rse.*	
J^π	*E(MeV) SDI*	*E(MeV) MSDI*	J^π	*E(MeV)*
0^+	0	0	0^+	0
2^+	1.92	1.944	2^+	1.172
4^+	2.63	3.009	4^+	3.176
2^+	2.898	3.156	2^+	3.157
3^+	3.059	3.058	3^+	3.058
0^+	3.212	3.253	0^+	2.89
7^-	4.196	4.149	(7^-)	4.648
5^-	4.344	4.299	5^-	4.86
3^-	4.775	4.766	3^-	4.655
2^-	4.899	4.899	---	4.835
6^-	4.899	4.898	6^-	4.86
4^-	4.899	4.899	---	4.949
5^-	5.035	5.034	(5^-)	5.041
4^-	5.182	5.182	(4^-)	5.041
0^+	5.626	6.804	0^+	5.447
2^+	6.559	7.181	2^+	6.354
4^+	6.731	7.326	---	7.08
6^+	6.844	7.333	6^+	7.62
8^+	6.925	7.421	8^+	7.17

Note: the dotted line is indicated to unexpected experimental value

Table 5: Comparison of theoretical calculations with experimental data for nickel nucleus.

Cal.Rse.(Pure)			*Exp.Rse.*	
J^π	*E(MeV) SDI*	*E(MeV) MSDI*	J^π	*E(MeV)*
0^+	0	0	0^+	0
2^+	1.107	1.18	2^+	1.172
4^+	1.298	1.384	4^+	2.336
0^+	1.522	1.586	0^+	2.048
0^+	3.29	3.226	0^+	3.524
2^+	5.101	5.158	(2^+)	5.148
4^+	5.379	5.455	4^+	5.355
6^+	5.502	5.586	6^+	5.53
8^+	5.584	5.673	-8	5.806

The experimental data are taken from Ref.s.[13]-[14].

3.2.2. Zink Nucleus ^{62}Zn

The possible 2-proton configurations of even-even nucleus outside close shell Z=28 shows in Table.6. The model space was taken space $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$ *and* $0g_{9/2}$. In order to apple configuration mixing between the orbits, the proton contribution is increased, this may be due to the effect that the $0g_{9/2}$ orbit.

The low-lying energy levels have been calculated and compared with the recent experimental data are shown in Table.7. T=1 spectra, Ground state spin is correctly predicted but the first 2^+ state is upper in energy and other yrast levels are slightly higher in energy in comparison to the experimental value. Some energy levels have been predicated by spins and parities. In Table.8. where the configuration pure is used, we found the first 2^+,4^+states and the second 0^+ state are slightly lower in energy in comparison to the experimental value. And also the level (9^-) has been predicated by level 6^+, because the two value for their very close. We obtain in our calculations in SDI and MSDI interactions are almost identical.

Table 6: The possible 2-proton configurations of ^{62}Zn in (SMCM).

J	*CONFIGURATIONS*	*J*	*CONFIGURATIONS*
0	$(p_{3/2})^2$, $(f_{5/2})^2$, $(p_{1/2})^2$, $(g_{9/2})^2$	5	$p_{3/2}\, g_{9/2}$, $f_{5/2}\, g_{9/2}$,$p_{1/2}\, g_{9/2}$
1	$p_{3/2}\, f_{5/2}$, $p_{3/2}\, p_{1/2}$	6	$p_{3/2}\, g_{9/2}$, $f_{5/2}\, g_{9/2}$, $(g_{9/2})^2$
2	$(p_{3/2})^2$, $p_{3/2}\, f_{5/2}$, $p_{3/2}\, p_{1/2}$, $(f_{5/2})^2$, $f_{5/2}\, p_{1/2}$, $f_{5/2}\, g_{9/2}$, $(g_{9/2})^2$	7	$f_{5/2}\, g_{9/2}$
3	$p_{3/2}\, f_{5/2}$, $p_{3/2}\, g_{9/2}$, $f_{5/2}\, p_{1/2}$, $f_{5/2}\, g_{9/2}$	8	$(g_{9/2})^2$
4	$p_{3/2}\, f_{5/2}$, $p_{3/2}\, g_{9/2}$, $(f_{5/2})^2$, $f_{5/2}\, g_{9/2}$, $p_{1/2}\, g_{9/2}$, $(g_{9/2})^2$		

Table 7: Comparison of theoretical calculations with experimental data from Ref.s. [13]-[14] for zink nucleus (The parameters of SDI A=0.3453, MSDI A= B=0.3967, C=0).

Cal.Rse.(Mixing)			*Exp.Rse.*	
J^π	*E(MeV) SDI*	*E(MeV) MSDI*	J^π	*E(MeV)*
0^+	0	0	0^+	0
2^+	1.392	1.623	2^+	0.953
4^+	2.201	2.13	4^+	2.186
2^+	2.417	2.38	2^+	2.803
3^+	2.646	2.646	3^+	2.384
1^+	2.646	2.646	(1^+)	3.18
0^+	2.721	2.659	0^+	2.341
2^+	3.149	3.13	2^+	3.06
4^-	3.545	3.853	(4^+)	3.73
2^+	3.687	3.882	2^+	3.83
3^-	3.701	3.594	(3^-)	3.73
1^+	3.756	3.756	(1^+)	3.96
5^-	4.154	4.045	$(5)^-$	4.043
6^-	4.187	4.396	---	4.535
2^+	4.471	4.522	(2^+)	4.33
4^+	4.396	4.396	(4^+)	4.38
3^+	4.726	4.726	---	4.535
7^-	4.859	4.783	(7^-)	4.904
5^-	5.119	5.154	(6^-)	5.131
3^-	5.314	5.31	(3^-)	4.86
2^-	5.366	5.366	---	5.47
6^-	5.366	5.366	(6^-)	5.131
4^-	5.366	5.366	(4^+)	5.37
0^+	5.389	5.349	0^+	5.34
5^-	6.251	6.218	---	6.4
0^+	6.338	7.462	---	7.4

4^-	6.476	6.476	---	6.4
2^+	6.821	7.351	---	7.2
4^+	6.923	7.373	---	7.2
6^+	6.988	7.365	---	7.4
8^+	7.046	7.432	(8^+)	7.54

Note: the dotted line is indicated to unexpected experimental value

Table 8: Comparison of theoretical calculations with experimental data for zink nucleus.
The experimental data are taken from Ref.s. [13]-[14].

Cal.Rse.(Pure)			*Exp.Rse.*	
J^π	*E(MeV)* SDI	*E(MeV)* MSDI	J^π	*E(MeV)*
0^+	0	0	0^+	0
2^+	0.551	0.634	2^+	0.953
0^+	1.595	1.543	0^+	2.341
2^+	2.394	2.461	2^+	2.803
4^+	2.532	2.62	4^+	2.743
0^+	4.404	4.25	0^+	4.008
0^+	4.505	4.556	(0^+)	4.62
2^+	5.712	5.752	---	5.7
4^+	5.913	5.983	---	5.7
6^+	6.002	6.085	(9^-)	6.081
8^+	6.061	6.153	(8^+)	6.3

Note: the dotted line is indicated to unexpected experimental value

3.2.3 Copper Nucleus ^{62}Cu

In Table.9. The possible 1-proton -1 neutron configurations in odd-odd nucleus outside close shell (Z=28, N=32). The model space $1p_{3/2}$ $0f_{5/2}$, $1p_{1/2}$ and $0g_{9/2}$ for proton and $0f_{5/2}$, $1p_{1/2}$ and $0g_{9/2}$ for neutron is used. We notice that the probability taken $0g_{9/2}$ orbit to valence space is increased the energy levels. The mixed orbits for proton-neutron in this nucleus much more from the identity nucleons. one sees the mixed configuration in odd-odd nucleus very complex from pure.

For T=0 spectra, the positive and negative parity of the calculated energy levels and experimental results of low-lying states presented in Table.10. Ground state is predict in our calculations at 1^+, the yrast levels of first 2^+,4^+ states and second 1^+ state respectively are slightly higher energies of the experimental data. There is uncertainty in the spin and parity of some high energy levels experimentally. Have been uncertainty the experimental values (5.785, 5.841) MeV by 5^+, 8^+ in Table.10. But in configuration pure is presented in Table.11. we found first 5^+ state didn't specify its a value approach in experimental data. Our calculations in both SDI and MSDI interactions predict correct the spins and parities for mostly experimental energy levels, because increasing in mixed orbits and also more values from experimental data in this nucleus weren't predicated. In the present calculations we found some excitation energies identical in pure configurations of SDI and MSDI, this shows that the configuration mixture is best. One sees the comparison between the calculated results and experimental data in good agreement, this is due for the interactions utilized are the realistic effective interactions.

Table 9: The possible 1-proton -1 neutron configurations of ^{62}Cu in (SMCM).

J	*CONFIGURATIONS*
0	$(f_{5/2})^2$, $(p_{1/2})^2$, $(g_{9/2})^2$
1	$p_{3/2}\ f_{5/2}$, $p_{3/2}\ p_{1/2}$, $(f_{5/2})^2$, $(p_{1/2})^2$, $(g_{9/2})^2$
2	$p_{3/2}\ f_{5/2}$, $p_{3/2}\ p_{1/2}$, $(f_{5/2})^2$, $f_{5/2}\ p_{1/2}$, $f_{5/2}\ g_{9/2}$, $p_{1/2}\ f_{5/2}$, $g_{9/2}\ f_{5/2}$, $(g_{9/2})^2$
3	$p_{3/2}\ f_{5/2}$, $p_{3/2}\ g_{9/2}$, $(f_{5/2})^2$, $f_{5/2}\ p_{1/2}$, $f_{5/2}\ g_{9/2}$, $p_{1/2}\ f_{5/2}$, $g_{9/2}\ f_{5/2}$, $(g_{9/2})^2$
4	$p_{3/2}\ f_{5/2}$, $p_{3/2}\ g_{9/2}$, $(f_{5/2})^2$, $f_{5/2}\ g_{9/2}$, $p_{1/2}\ g_{9/2}$, $g_{9/2}\ f_{5/2}$, $g_{9/2}\ p_{1/2}$,$(g_{9/2})^2$
5	$p_{3/2}\ g_{9/2}$, $(f_{5/2})^2$, $f_{5/2}\ g_{9/2}$, $p_{1/2}\ g_{9/2}$, $g_{9/2}\ f_{5/2}$, $g_{9/2}\ p_{1/2}$,$(g_{9/2})^2$
6	$p_{3/2}\ g_{9/2}$, $f_{5/2}\ g_{9/2}$, $(g_{9/2})^2$, $g_{9/2}\ f_{5/2}$, $(g_{9/2})^2$
7	$f_{5/2}\ g_{9/2}$, $g_{9/2}\ f_{5/2}$, $(g_{9/2})^2$
8	$(g_{9/2})^2$
9	$(g_{9/2})^2$

Table 10: Comparison of theoretical calculations with experimental data from Ref.s. [13,14] for copper nucleus (The parameters of SDI A=0.2295, MSDI A= B=0.1785, C=0)

Cal.Rse.(Mixing)			*Exp.Rse.*	
J^π	*E(MeV)* SDI	*E(MeV)* MSDI	J^π	*E(MeV)*
1^+	0	0	1^+	0
2^+	0.446	0.616	2^+	0.287
4^+	0.738	0.811	4^+	0.548
1^+	0.815	0.587	1^+	0.39
0^+	1.009	1.21	+	1.221
1^+	1.179	1.318	(1^+)	1.285
2^+	1.242	1.25	2^+	1.023
3^+	1.404	0.776	3^+	0.674
3^-	1.486	1.206	3	1.373
5^-	1.706	1.156	---	1.416
2^+	1.771	1.428	2^+	1.43
4^-	2.036	1.428	---	1.581
2^+	2.036	2.21	2^+	2.176
3^+	2.138	1.993	+	1.993
2^+	2.19	2.252	2^+	2.176
4^+	2.213	2.533	4^+	2.36
6^-	2.469	2.639	(6^-)	2.295
3^+	2.577	2.753	3^+	2.835
3^+	2.92	2.94	+	2.993
5^+	2.938	3.053	(5^+)	3.15
2^-	3.03	3.047	---	3.42
7^-	3.159	3.32	(7^-)	3.029
0^+	3.228	3.033	+	2.993
1^+	3.272	3.095	1^+	2.835
5^-	3.276	3.375	---	3.42
4^-	3.394	3.44	---	3.42
3^-	3.554	3.583	---	3.55
6^-	3.7	3.715	(6^-)	3.191
4^-	3.888	3.896	---	3.67
5^-	3.922	3.932	---	3.675
2^-	3.988	3.993	---	4.104
7^-	4.015	4.02	---	4.104
3^-	4.039	4.048	---	4.104
6^-	4.092	4.101	---	4.104
4^-	4.115	4.118	---	4.104
5^-	4.118	4.119	---	4.104
4^-	5.051	5.076	---	5
0^+	5.068	5.529	---	5
5^-	5.127	5.146	---	5
1^+	5.432	5.252	---	5
9^+	5.492	5.049	---	5
3^+	5.672	5.288	---	5

7^+	5.68	5.196	---	5
5^+	5.702	5.3	$(2)^+$	5.785
8^+	5.909	5.372	(12^-)	5.841
6^+	5.909	5.373	---	6.008
2^+	5.909	5.446	2^+	5.72
4^+	5.909	5.446	---	6.008

Note: the dotted line is indicated to unexpected experimental value

Table 11: Comparison of theoretical calculations with experimental data for copper nucleus.
The experimental data are taken from Ref.s.[13]-[14].

Cal.Rse.(Pure)			*Exp.Rse.*	
J^π	*E(MeV) SDI*	*E(MeV) MSDI*	J^π	*E(MeV)*
1^+	0	0	1^+	0
5^+	0.045	0.035		
3^+	0.163	0.127	3^+	0.426
$2^+,0^+,4^+$	0.372	0.29	2^+	0.243
			4^+	0.39
1^+	1.536	1.504	1^+	1.525
0^+	1.766	1.683	(0^+)	1.678
1^+	3.655	3.704	(1^+)	3.008
9^+	3.83	3.84	(9^-)	3.979
3^+	3.989	3.964	---	3.675
7^+	4.017	3.985	---	4.104
5^+	4.037	4.001	---	4.104
$0^+,4^+,6^+,8^+$	4.246	4.163	$(0)^+$	4.628
			---	4.596

Note: the dotted line is indicated to unexpected experimental value

4. Conclusions

Large-scale shell model calculations were performed using model space taken *1p3/2 0f5/2, 1p1/2 and 0g9/2* for proton and *0f5/2, 1p1/2 and 0g9/2* for neutron. The SDI and MSDI interactions were employed. The present study demonstrated the binding energy of the ground state and low excited energy levels with positive and negative parities for ^{62}Ni, ^{62}Zn, ^{62}Cu. Good agreements were obtained by comparing these calculations with the recently available experimental data for binding energy with energy levels. The theoretical results of these nuclei are computed in surface delta interaction and modified surface delta interaction; we found are in good agreement with each other and with the practical values. We concluded this due to the realistic SDI and MSDI strengths are enhance energy levels. Also the shell model configuration mixing and pure in this region by the two interactions is very successful.

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