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Energy Levels Calculations of $^{36\text{-}37\text{-}38}$Ar Isotopes Using Shell Model Code OXBASH

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Abstract: Energy levels of three Argon isotopes with mass numbers 36, 37 and 38 are calculated. Calculations were carried out in the SD model space with 13 different potentials using the shell model code OXBASH by applying spin-parity of valance nucleons. OXBASH is a computing code for carrying out calculation of nuclear structure based on shell model. We compared calculated energy levels with experimental results and find the best energy and potential for each isotope.

Keywords: OXBASH Code, SD Model Space, Energy Levels, Argon Isotopes

1. Introduction

Obtaining the nuclear structure and energy levels of nuclei is one of the criteria to improve investigations of nuclei properties. Nuclear models have the property to help us to better understanding of nuclear structure which contains main physical properties of nuclei, and shell-model is one of the most prominent and successful nuclear models. This model can be compared with the electron shell model for atoms. As atomic behavior and properties can be described with valance electrons which exist out of a closed shell, similarly, valance nucleons (protons or neutrons) in a nucleus which are placed out of close shells (with magic numbers 2,8,20,28,50,82 and 126) play important roles in determining nuclear properties. Nuclei with magic numbers are very stable and have completely different properties comparing with their neighbors.

Existence of spatial levels is determined by Pauli Exclusion Principle. By knowing nuclear potentials for all nucleons in a nucleus, one can calculate energy levels.

Argon is a noble gas and with atomic number 18. This gas exists about 1% in the atmosphere of the earth. Argon also exists in electrical lamps, fluorescent lamps with the pressure of 400Pa, in photography industries and in warm and glowing lamps.

The object of this paper is to calculate the energies of Argon isotopes 36, 37 and 38 by using OXBASH code. This program is a set of commands for carrying out shell-model calculations with dimensions up to about 100,000 in the J-T scheme and about 2,000,000 in the M-scheme .We applied the 2005-8 version of this code which can be used on any Windows PC without the use of any other software.

2. Theory and Calculation

OXBASH is a powerful computer code to calculate the energy levels of light and medium nuclei. By using it, we can measure the energy levels of the nucleus and compare it with experimental data. One of the most important challenges in nuclear physics is to calculate and measure energy levels of medium and heavy nuclei by using shell model theory. As a result, it is important to check computer codes in this area. There are many codes written for this purpose such as: Nutshell, REDSTICK, ANTOINE, OXBASH, etc. In this paper we are using OXBASH code, a code which has been developed in this field for many years.

Experimental studies on the stability of some nuclei show that nuclei with protons or neutrons numbers (2, 8, 20, 50, 82, etc.) are more numerous and stable. In other words, the existence of these magic numbers suggests shell model structure in nuclear physics similar to atomic physics. In this paper, the energy levels of Na and Mg isotopes have been measured using the code OXBASH.The program includes a set of computational code which is based on the ability to measure the energy levels by forming ground state matrices with dimensions up to 2000000 and JT matrix with dimension

up to 100,000. The version of this code is 2005-8 which can be installed and used on any operating system without using any other additional software.

Space model SD

Considering the number of valence nucleons for sodium and magnesium isotopes, SD model space is the suitable model for these calculations. This model consists of $2s_{1/2}$ ،$1d_{3/2}$ ،$1d_{5/2}$ valence orbitals. Figure 1 shows the PF and SD model spaces according to shell model theory.

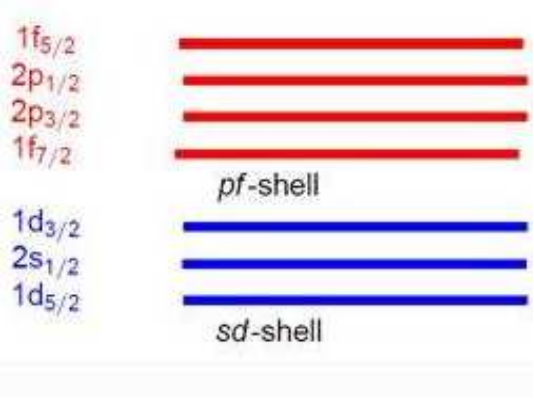

Figure 1. *PF and SD model spaces*

The basis of Hamiltonian in shell model calculations is normalized Green matrix. For SD model space in OXBASH code, 13 different interaction potentials to perform computations on different nuclei is included [4].

The first normalized G matrix was introduced in 1960 which its results were in good agreement with experimental data for A = 18 to A = 38 nuclei [9, 10], however, with increasing nucleon numbers, solving this matrix was very difficult [11]. In 1976 for the bottom layer of SD model space, the Hamiltonian CWH [7, 8] was introduced and in 1984 the potential W was introduced for the entire layer SD [12].

OXBASH code is a computer program that is described with a set of model spaces and interactions to apply in shell model calculations with high dimensions.

In order to use this code one should specify the model space and interaction. In other words after choosing appropriate model space which is chosen considering valance nucleons, this code constructs a set of possible ground states and then makes JT matrix based on linear combination of ground states which give suitable T and J values. Finally by choosing the desirable interaction potential it constructs the Hamiltonian of the problem and carries out the calculations and as a default gives 10 lowest energies.

The applied model space illustrates the orbitals which are considered in calculations using main shells in shell-model theory.

Considering the number of valance nucleons of Argon isotopes 36, 37 and 38, the suitable space for related calculations of these nuclei is SD space. The SD model space includes the $1s_{1/2,}$ $1d_{5/2}$ and $1d_{3/2}$ orbitals and 13 different interaction potentials which are considered in this model space are: SDBA, KUOSD, KUOSDM, BKUOSD, PW, CW, W, CWH, KUOSDH, SDM, W, HBUSD, HBUMSD and SU3SD.

The shell model configuration of Argon isotope 36 with Z=18 ,N=18 is ($1s_{1/2}$ $1p_{3/2}$ $1d_{5/2}$ $2s_{1/2}$), Argon 37 with Z=18, N=19 is ($1s_{1/2}$ $1p_{3/2}$ $1d_{5/2}$ $2s_{1/2}$ $1d_{3/2}$) and Argon 38 with Z=18, N=20 is ($1s_{1/2}$ $1p_{3/2}$ $1d_{5/2}$ $2s_{1/2}$ $1d_{3/2}$). The number of valance nucleons, Isospin and range of angular momenta for these three isotopes are n=20, 21 and 22, T=0, 0.5 and 1 and J=0- 8, 1/2-13/2 and 0-4 respectively, and parity is even for all of them.

The basis of the Hamiltonian in shell model calculations is the suitable normalized Green matrix for the problem [4, 5]. In this paper calculations carried out for all 13 potentials separately for 3 Argonne isotopes 36, 37 and 38.

The first normalized G matrix for SD space model has been suggested in 1960 and its results were in good agreement with experimental spectrum for A=18 to A=38 [1, 2, 3] but in case of temperature increase it fails [6]. CWH Hamiltonian was suggested for the lower part of SD layer in 1976 [7, 8] and the W potential introduced for total SD layer in 1984 [6].

Table 1 show results obtained by executing OXBASH code in SD space model for 6 suitable interacting potentials for ^{36}Ar and figure 2 show its related curves. Comparing these results shows that the W potential has the best compatibility with experimental data.

Table1. *Comparison of resulted energy levels for ^{36}Ar by applying 6 interacting suitable potentials in SD space model $1d_{3/2}$ $1d_{5/2}$ $2s_{1/2}$ with experimental data.*

J	Experimental	PW	CW	SDM	W	HBUSD	HBUMSD
Ground state	-230.409	-229.696	-232.567	-231.447	-230.514	-230.488	-231.117
0	4.3291	7.28	7.268	5.859	4.702	4.735	4.383
1	7.1789	7.099	6.798	6.619	6.668	8.841	8.325
2	4.44	4.755	5.329	5.4	4.41	4.43	4.171
3	7.14	9.173	9.592	8.616	7.248	6.972	6.626
4	6.356	7.171	6.545	7.96	6.357	6.189	5.946
5		13.789	12.789	10.68	11.284	10.736	11.042
6	9.186	13.484	11.112	8.634	9.696	9.471	9.819
7		28.66	22.818	19.94	20.204	20.001	20.875
8	19.5	23.359	17.591	18.521	15.136	15.376	16.352

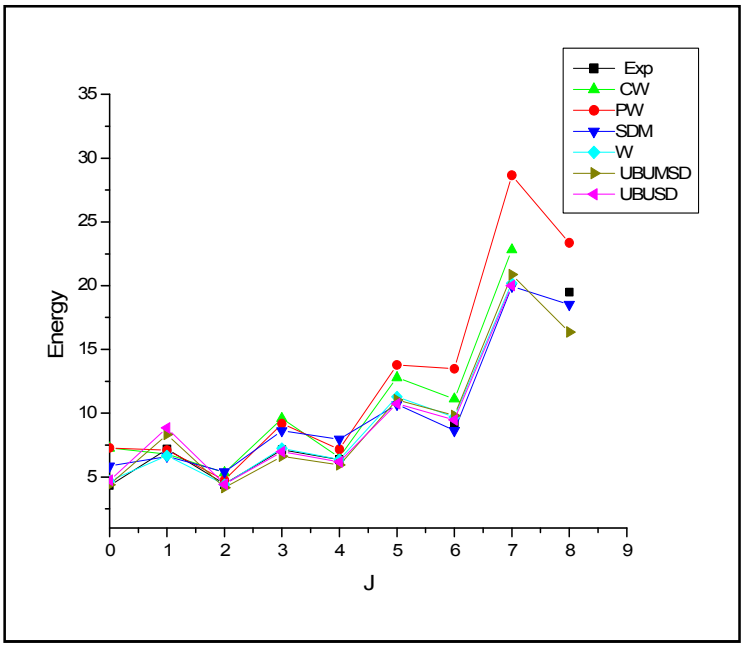

Figure2. *Resulted curves for energy levels of ^{36}Ar by applying 6 interacting suitable potentials in SD space model $1d_{3/2}$ $1d_{5/2}$ $2s_{1/2}$ and comparing with experimental data.*

By executing this code in SD space for ^{37}Ar we obtained energy levels and by comparing these results to experimental data we found that SDM, SDBA and BKUOS interacting potentials lead to best results which among them SDM has nearest results to experimental data. In this calculation, ground state energy referred to J=3/2 is also considered.

Results have been shown in table 2 and figure 3.

Table2. *Comparison of resulted energy levels for ^{37}Ar by applying BKUOSD, SDBA, SDM interaction potentials with experimental data*

J	E(Brown)*	E(exp)	E(SDM)	E(SDBA)	E(BKUOSD)
gs(1.5)	-239.196	-239.197	-238.007	289.633	-316.953
0.5	1.586	1.41			
3.5	2.128	2.217	2.216	2.122	2.014
2.5		2.796			
2.5		3.171	3.553	3.17	3.088
1.5		3.602	3.634	3.742	3.766
0.5		4.509	4.196	4.679	4.04
3.5		4.624	4.311	4.437	4.788

* in [3]

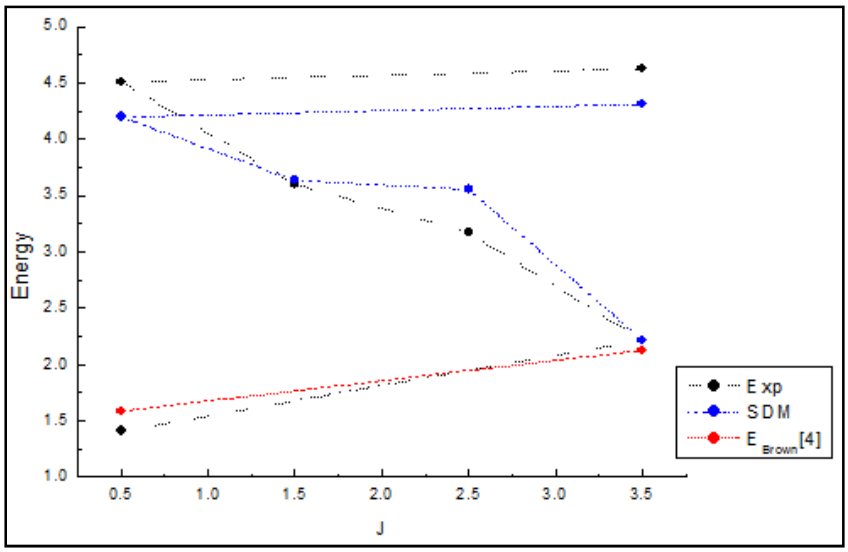

Figure3. *Resulted curve for energy levels of ^{37}Ar by applying BKUOSD, SDBA, SDM interaction potentials and comparing with experimental data.*

Finally the resulted data for ^{38}Ar has been shown in table 3 and figure 4, which by comparing them it can be concluded that the best fit with experimental data is related to SDM potential.

Table3. *Comparison of resulted energy levels for ^{38}Ar with experimental data.*

J	E(B)	EXP	SDM	HBUMSD	CW	CWH
0	6.182	7.06	7.166	4.68	7.41	6.58
1	5.555	5.974	5.227	5.55	5.82	5.39
2	4.489	5.974	5.1	4.28	4.89	4.52
3	10.166	6.824	5.084	3.98	5.25	4.54
4	8.521	7.233	6.221	5.89	6.47	6.42

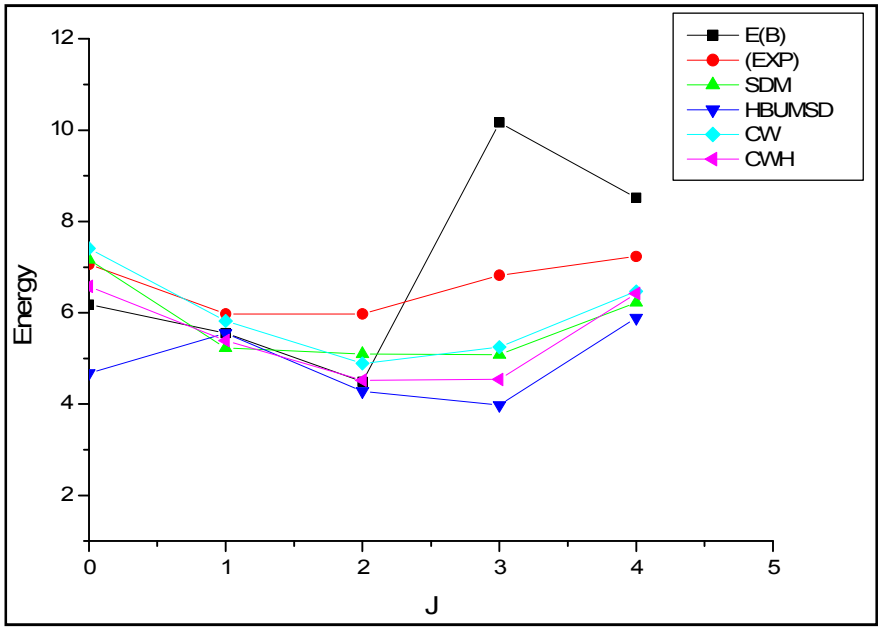

Figure4. *Resulted curve for energy levels of ^{38}Ar and comparing with experimental data.*

3. Conclusions

We have compared calculated results for energy levels which are obtained by running OXBASH code for 13 different interacting potentials in SD space model for three Argonne isotopes 36, 37 and 38 and comparing them with experimental data. Comparing results for ground state energies of ^{36}Ar for 6 interactions has been chosen and their results listed in table and figure 2. As it shows, the results for W interaction overall are in good agreement with experimental data meanwhile in some cases comparison between levels shows good fit for some interactions.

For isotopes ^{37}Ar and ^{38}Ar as we can see in tables 2 and 3 and figures 3 and 4 the best fit refers to SDM interacting potential.

References

[1] T.T.S. Kuo and G.E. Brown, Nucl. Phys. 85, 40 (1966)

[2] T.T.S. Kuo, Nucl. Phys. A103, 71 (1967)

[3] B.H. Wildenthal, E.C. Halbert, J.B.McGrory and T.T.S. Kuo, Phys. Rev. C 4,1266 (1971).

[4] Oxbash for Windows, 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.

[5] The Nuclear Shell Model Towards the Drip Lines, B. A. Brown, Progress in Particle and Nuclear Physics 47, 517 (2001)

[6] B. H. Wildenthal, Prog. Part. Nucl. Phys. 11, 5 (1984).

[7] W. Chung, Pd. D. thesis, Michigan State University (1976).

[8] B.H. Wildenthal in Elementary Modes of Excitation in Nuclei, Proceedings of the International School of Physics Enrico Fermi, course 69, edited by A. Bohr and R.A. Broglia (North-Holland,1977), p. 383; B.H. Wildenthal and W. Chung in Mesons in Nuclei, edited by M. Rho and D.H. Wilkinson, (North-Holland, 1979), p. 723

[9] K.-H Speidel *et al,* phys let B 6591001, 2008.

[10] K.-H Speidel *et al,* phys Rev C 78, 017304, 2008.

[11] B.H.Wildenthal, Prog. Part. Nucl. Phys. 11,5, 1984.

[12] A.E. Stuchnery et al Phys Rev C 74,054307, 2006.