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Applying Nuclear Shell Model to Study Nuclear Structure for 18Ne by Using OXBASH Code

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ABSTRACT

In this study, the shell model used to calculate energy levels and reduced electric quadruple transition probability B(E2) for ^{18}Ne isotope using OXBASH code within the sd shell and using the KUOSD effective interaction. ^{18}Ne isotope contain two proton outside ^{16}O core in shell (0d5/2, 1s1/2, and 0d3/2) .The results of the energy levels and values of B(E2) were reasonably consistent with the experimental data available.

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Keywords:

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تطبيق أنموذج القشرة النووي لدراسة التركيب النووي لـ ^{18}Ne باستعمال كود أوكسباش

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الــخُــلاصــة

في هذه الدراسة تم حساب مستويات الطاقة واحتمالية الانتقال لرباعي القطب الكهربائي المختزلة B(E2) لنظير ^{18}Ne باستعمال كود OXBASH ضمن القشرة sd واستعمال التفاعل الفعال KUOSD حيث أن نظير ^{18}Ne يحتوي على بروتونين خارج القلب (^{16}O) في القشرة (d5/2, 1s1/2, and 0d3/2٠) .كانت قيم مستويات الطاقة واحتمالية الانتقال B(E2) تتفق بشكل معقول مع القيم العملية المتوفرة .

الكلمات المفتاحية:

كود اوكسباش
نظير ^{18}Ne ،
مستويات الطاقة
احتماليــة الانتقــال الكهربــائي المختزلة

1. INTRODUCTION

Access to the nuclear installation and nuclear power levels is one of the criteria to improve the investigations of the kernel characteristics. Nuclear models have the property to help researchers to have a better understanding of the nuclear structure that contains the main physical properties of the nucleus. Shell model is one of the most prominent and successful nuclear models[1]. One of the central challenges in nuclear physics understanding on the nuclear structure is choosing the correct effective interaction and model space that can lead to predicting a wide range of observation from the nuclear shell model systematically and correctly[2]. The nuclear shell model is one of the most powerful tools to give a quantitative interpretation of the empirical data. The two central ingredients of any calculation of the shell model are the N-N interaction and configuration space for valence particles. In principle, one can implement calculations of shell models with realistic N-N interaction in an indefinite configuration space or with effective renormalized interaction restricted configuration space[3]. The calculations of the shell model are made within a model space in which the nucleons are limited to a few orbits, when effective operators are used, taking into account the effect of the larger model space. This model offers a significant description of this issue [4]. Thus, the study of nuclei in the sd shell leads to a better understanding among the macroscopic (collective) description and the microscopic description of the core (shell model)[5]. In the current work, we focus a specific attention on the calculation of energy levels and the probability of transition within the shell model for ^{18}Ne isotope which has configurations of (0d5/2,1s1/2,0d3/2).

2-Theory:

Brown is the main person who involved in developing of the shell model code OXBASH. This code has been ported for different Unix operating systems, several shell-model codes have been developed recently such as m-scheme code ANTOINE and MSHELL and the J - scheme code NATHAN ,However, OXBASH remains one of the most versatile among existing codes. It has been extended to contain up to about 250 m-states and 30 j-states[6,7]. The word (OXBASH) stands for (The Oxford-Buenos-Aires-MSU Shell-Model Code) where it began in (Buenos-Aires) in 1976 ,It was developed in 2004 by B. Brown and a group of researchers in modality (OXBASH for Windows) at the University (Michigan State University)[8]. The basic requirements for the calculation of mixing shell model configuration are a group of single-particle energies (SPE) and matrix elements of the interaction of two bodies or a matrix of two bodies elements (TBME). These groups have newly been called effective interaction or (model space Hamiltonian).This Hamiltonian model space can be described in two ways: the first method is “realistic”, which is constructed for a given shell-model space from known data on the free nucleon-nucleon force, the second method is "empirical", which is based on one fashion or another on parameters whose values are determined by requiring agreement between measured level energies and shell-model eigenvalues [9].The allowable angular momentum states calculated from theorems[10]:

First theorem: allowable angular momentum values for two particles(neutron and proton)in the states j1 and j2 (j1≠ j2) is:

$$J = (j_1 + j_2), (j_1 + j_2 - 1), \dots\ |j_1 - j_2| \quad (1)$$

Second theorem: in the same single-particle orbit j(j half-integral)two neutrons or two protons can only couple their spins to even values:

$$J = 0,2,4, \dots, (2j - 1) \quad (2)$$

Three theorem: When nucleons are congruous to(neutrons and protons)in the same single orbit where n> 2, where n is the number of particles in the outside of the closed shell:

$$J_M = n\left[\frac{j-(n-1)}{2}\right] \quad (3)$$

The reduced electric transition probability can be defined by[11]:

$$B(\varpi L;\ J_i \rightarrow J_f) = \frac{\langle J_f \| O(\varpi L) \| J_i \rangle^2}{2J_i+1} \qquad (4)$$

Where (J_i and J_f) are the spin of the initial and final states, respectively and ($O(\varpi L)$ is the electric multipole operator.

3-Shell model calculation:

The calculations were performed by using OXBASH code[8]. The goal of the present study is to calculate energy levels and reduced electric quadruple transition probability B(E2) by using harmonic oscillator potential (HO, b), b<0 for ^{18}Ne isotope. This isotope was previously thought theoretically [12,13]. The calculations were performed in the space model (0d5/2, 1s1/2, and 0d3/2) above the N = 8 and Z = 8 closed shells for neutrons and protons within sd space with interaction KUOSD.

3.1 Energy levels of ^{18}Ne nucleus:

Depending on the shell model, the ground state of ^{18}Ne nucleus is a closed ^{16}O core, with $J^{\pi} = 0^+$ and T=1, the excited states consist of the configuration of the nucleons in the sd-shell. In the current work we use KUOSD interaction and single-particle energies (SPEs) are {1d5/2=-4.150,2s1/2=-3.280and 1d3/2=0.930} respectively. Comparison between theoretical results and available experimental results were conducted[14] For Neon isotopes using KUOSD interaction is shown in the table1, From this table, we noted KUOSD Hamiltonians agree reasonably well with experimental data.

The angular momentum and parity are identical to the ground state of level 0^+ when compared with the available experimental data.

The agreement is good for the states $(0_2^+, 2_1^+, 2_2^+, 4_1^+)$as compared with the experimental data.

The experimental energy value (5.090) MeV was confirmed for angular momentum (3_1^+) with positive parity.

In our calculations, we expect the angular momentum and parity to experimental energies (7.713,8.086,8.500,9.201) MeV is $(4_2^+, 2_3^+, 1_1^+, 3_2^+)$ when compared with our theoretical values.

Based on current calculations, we found four values of energies (10.077, 10.221,14.385, 14.420) MeV corresponding to angular momentum $(1_2^+, 2_4^+, 0_3^+, 2_5^+)$ were higher than the experimental values available until now.

Table1: Comparison of the experimental excitation energies[14] and excitation energies predictions for ^{18}Ne nucleus by using KUOSD interactions

J^+ (OXBASH)	Energy (OXBASH) KUOSD(MeV)	Energy (exp.) (MeV)	J(exp.)
0_1	0	0.0	0^+
2_1	1.744	1.887	2^+
4_1	3.381	3.376	4^+
2_2	3.995	3.616	2^+
0_2	4.027	3.576	0^+
3_1	4.943	5.090	$(2^+,3^-)$
4_2	7.793	7.713	-----
2_3	8.416	8.086	-----
1_1	8.849	8.500	-----
3_2	9.116	9.201	-----
1_2	10.077		
2_4	10.221		
0_3	14.385		
2_5	14.420		

3.2 Reduced electric quadruple transition probability B(E2) Calculation:

The reduced electric quadruple transition probability B(E2) were predicted for ^{18}Ne within the nuclear shell model using KUOSD interactions with the harmonic oscillator potential (HO, b) b < 0. The comparison between experimental B (E2) and theoretical shows a feature for KUOSD calculations for many levels, the primary polarization effect was included by selecting the effective charge for proton and neutrons (en = ep = 0.350), respectively. Table 2 shows a comparison between theoretical values and experimental values available[14]. From the table below, new electrical transitions B (E2) were expected in our results through the use of the KUOSD interaction of the ^{18}Ne isotope, B (E2) gives reasonably consistent agreement in comparison with the experimental data.

Table 2: Comparison of the B(E2) results for ^{18}Ne nucleus with the experimental data[14].

$J_i^+ \to J_j^+$	B(E2) ours. Results (e^2 fm^4) e_n=0.350 , e_p=0.350	B(E2) Exp. Results (e^2fm^4)
$2_1 \to 0_1$	42.2	49.597
$2_2 \to 0_1$	0.7967	1.849
$4_1 \to 2_1$	37.00	24.938
$2_2 \to 2_1$	26.73	
$0_2 \to 2_1$	26.12	14.010
$3_1 \to 2_1$	0.9782	
$4_2 \to 2_1$	4.564	
$1_1 \to 2_1$	3.140	
$3_2 \to 2_1$	0.1624	
$1_2 \to 2_1$	0.8514	
$2_2 \to 4_1$	3.857	
$3_1 \to 4_1$	28.03	
$4_2 \to 4_1$	8.889	
$3_2 \to 4_1$	0.4425	
$0_2 \to 2_2$	98.78	
$3_1 \to 2_2$	8.767	
$4_2 \to 2_2$	5.346	
$1_1 \to 2_2$	1.397	
$3_2 \to 2_2$	7.345	
$1_2 \to 2_2$	2.199	
$4_2 \to 3_1$	16.84	
$1_1 \to 3_1$	13.54	
$3_2 \to 3_1$	10.29	
$1_2 \to 3_1$	3.113	
$3_2 \to 4_2$	0.2270	
$3_2 \to 1_1$	15.44	
$1_2 \to 1_1$	25.51	
$1_2 \to 3_2$	18.54	

4. Conclusions

The calculations have been made by using the OXBASH code. The calculations of energy levels and reduced probabilities of the $B(E2)$ transitions for ^{18}Ne were carried out within the sd shell using effective interaction KUOSD. The study demonstrated that the interaction files are consistent with the available experimental data . We conclude that the shell model configuration mixing is very successful in this model space. In our calculations, new energy levels were predicted and we confirmed the angular momentum only for the value of the experimental energy(5.090)MeV which was not confirmed experimentally before .

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