Introduction of our theoretical framework

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INTRODUCTION

We investigate the structural changes of the $^{18-28}$O isotopes, both even and odd isotopes, by examining the energies of their low-lying states. This is done by developing our own shell model program and comparing the energies it generates to the NushellX@MSU program [1]. We use ^{16}O as a closed core, leaving 8 protons and 8 neutron at the sp-shell $(0s_{1/2}, 0p_{3/2}, 0p_{1/2})$. More neutrons are then excited in the sd-shell $(0d_{5/2}, 1s_{1/2}, 0d_{3/2})$, which serves as our model space. The Hamiltonian (1), which incorporates the pair breaking interaction (3), is used. The two-body matrix elements (TBME) of Eq. (3) **(define them as in [2])** uses those of the USDB interaction [2] (given there in Tables I and II, in J-scheme, for $T = 1, 0$ respectively) where the single particle energies (SPE) $(1s_{1/2}, 0d_{3/2}, 0d_{5/2})$ are $(-3.2079, 2.1117, -3.9257)$. We work in M-scheme, where the SPE are ordered as given in Table I. Using the single particle states (SPS) we construct the appropriate slater determinants, $|\psi\rangle$, according to number of particles which we place in the sd-shell.

TABLE I. Single particle energies of the sd-shell in the M-scheme basis with their corresponding quantum numbers (N, ℓ, J, M_j).

index	N	ℓ	J	M_j	SPE
1	1	0	1	$-1/2$	-3.20790
2	1	0	1	$+1/2$	-3.20790
3	0	2	3	$-3/2$	2.11170
4	0	2	3	$-1/2$	2.11170
5	0	2	3	$+1/2$	2.11170
6	0	2	3	$+3/2$	2.11170
7	0	2	5	$-5/2$	-3.92570
8	0	2	5	$-3/2$	-3.92570
9	0	2	5	$-1/2$	-3.92570
10	0	2	5	$+1/2$	-3.92570
11	0	2	5	$+3/2$	-3.92570
12	0	2	5	$+5/2$	-3.92570

MY TOC

Background

1. The $1s0d$-shell model space.

2. Description for the Oxygen isotopes.

3. Pairing Hamiltonian and pair breaking Hamiltonian (We use second quantization. Is this only in m-scheme?).

$$\hat{H} = \hat{H}_0 + \hat{V} \tag{1}$$

$$\hat{H}_0 = \xi \sum_{p,\sigma} (p-1) \hat{a}^\dagger_{p\sigma} \hat{a}_{p\sigma}, \tag{2}$$

$$\hat{V} = \sum_{p \le q} \langle p|V|q\rangle \, \hat{P}^+_p \hat{P}^-_q, \tag{3}$$

$$\hat{P}^+_p = \sum_{\sigma_p, \ge 0} \hat{a}^\dagger_{p,\sigma_p} \hat{a}^\dagger_{p,-\sigma_p}, \qquad \hat{P}^-_p = \sum_{\sigma_p, \ge 0} \hat{a}_{p,-\sigma_p} \hat{a}_{p,\sigma_p}. \tag{4}$$

4. Many-body Schrodinger eq.

Introduction of our theoretical framework

1. Description for the Oxygen isotopes - the physical phenomenon we investigate.

2. Describe the sd-shell which serves as our model space.

3. Many-body Schrodinger eq.

4. The Hamiltonian we are using.

5. sps. coupling to M_{tot}

6. matrix elements in m-scheme.

   (a) Translate Eq. (19) in [2] to M-scheme?

   (b) The USD Hamiltonian is defined by 63 sd-shell two-body matrix elements (TBME) and three single-particle energies (SPE) given in Table I of [1]. This is converted to the M-scheme and was given to us by Morten in the sdshellint.dat file. To this we added the refinement of Eq. (19) in [2].

7. Slater determinants.

8. The different NushellX interactions:

(a) USD (the original, by Winldenthal)

(b) USDB.

(c) USDA.

(d) CCEI (Gustav's).

(e)

[1] B. A. Brown and W. Rae, Nucl. Data Sheets **120**, 115 (2014).
[2] B. A. Brown and W. A. Richter, Phys. Rev. C **74**, 034315 (2006).