Ab initio no core shell model results for *sd* shell nuclei

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Introduction

The no core shell model (NCSM) is a method to solve the fully A-body problem for a system of non-relativistic particles that interact by realistic two or two plus three nucleon interactions. In the NCSM, all the nucleons are considered as active, there is no inert core like in naive shell model calculations. Hence, the "no core" in the name of the approach. Realistic two nucleon interactions mean the *NN* potential that fit nucleon nucleon phase shifts with high precision upto a certain energy, typically upto 350 MeV[1].

The NCSM uses a variety of realistic interactions such as Argonne potential, Bonn potential based on meson exchange, effective field theory guided by QCD. The *NN* potentials, such as Argonne V18(AV18)[2], CD-Bonn 2000[3], inside non local outside Yukawa (INOY)[4], generate strong short range correlations that can not be accommodated in many nucleon harmonic oscillator (HO) bases accessible at present computers. In order to account for these short range correlations and to speed up convergence with basis enlargement, we need a renormalization procedure to soften these potentials. There are two such renormalization procedures named Okubu-Lee-Suzuki(OLS)[5] and Similarity Renormalization Group(SRG)[6]. In the present work, we have done calculations using OLS procedure for large but finite, harmonic oscillator model spaces.

No Core shell model formalism

The starting Hamiltonian of NCSM is

$$H_A = T_{rel} + V = \frac{1}{A}\sum_{i<j}^{A}\frac{(\vec{p}_i - \vec{p}_j)^2}{2m} + \sum_{i<j}^{A} V_{NN,ij} + \sum_{i<j<k}^{A} V_{NNN,ijk}, \quad (1)$$

where m is the nucleon mass, $V_{NN,,ij}$ is the *NN* interaction, and $V_{NNN,ijk}$ is the three-nucleon interaction. In the present work we have used two body *NN* potential INOY. We add the center-of-mass HO Hamiltonian in Eqn. (1). This treatment leads to HO frequency and N_{max} dependency to converge the final results. We have now two variational parameters in the final Hamiltonian; first one is the harmonic oscillator frequency $\hbar\Omega$ and the second one is N_{max}, where N_{max} is the parameter that measures the maximal allowed HO excitation energy above the unperturbed ground state.

Results and Conclusions

In this work, we have done the calculations using INOY *NN* potential for oxygen chain ^{18,20,22}O. The benefit of using INOY *NN* potential is that we can achieve the convergence of the final results much faster than any other *NN* potential. We show the dependence of ground state energy with HO frequency and N_{max}, in Fig.1. We choose the region in which the ground state energy is less dependent on HO frequency. This treatment finally results in getting the optimized frequency for obtaining the convergence. We find that the range of HO frequency from 18-22 MeV is suitable for oxygen isotopes. We show in Fig.2 the energy spectra for ^{20}O with $\hbar\Omega$=18 MeV and the results are compared with experimental values. We have done the calculations upto N_{max}=4 due to our computational limitations of handling large dimensions. We are trying

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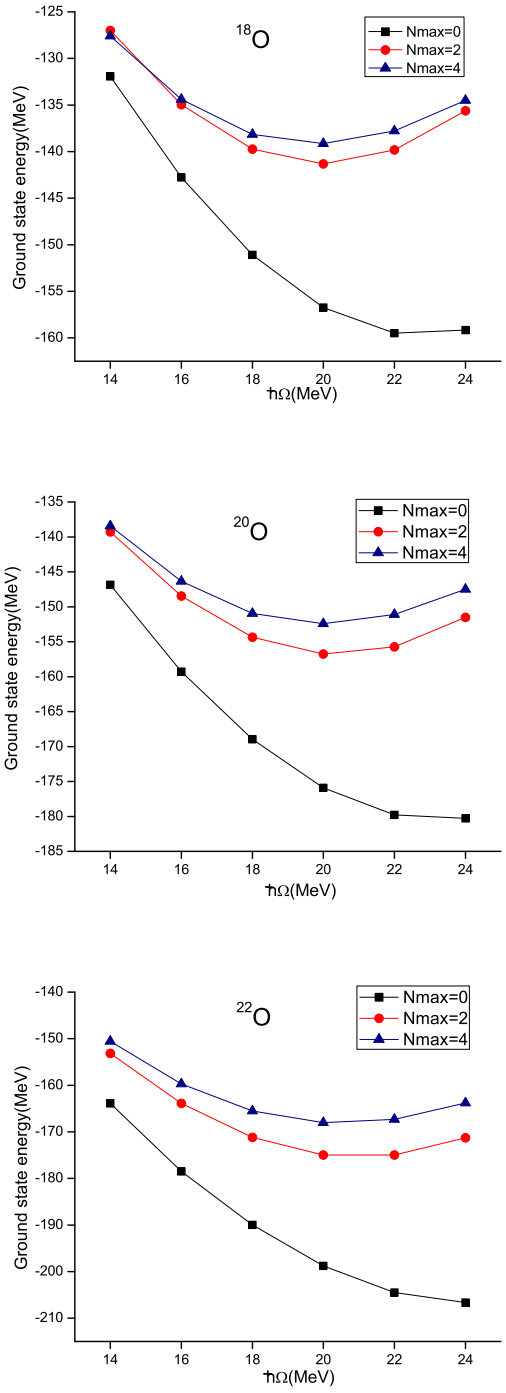

FIG. 1: Harmonic oscillator frequency dependence of ground state energy for ^{18}O, ^{20}O and ^{22}O with different N_{max}.

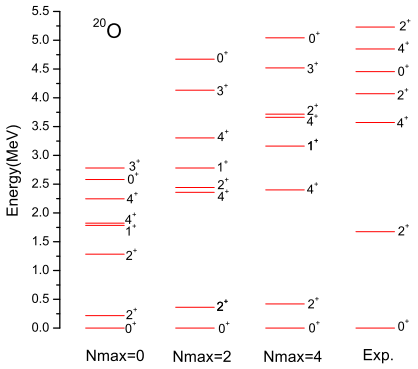

FIG. 2: Calculated and experimental excitation energies of ^{20}O with $\hbar\Omega$=18MeV and increasing basis space size.

to perform calculations for higher values of N_{max}. As we increase the N_{max} from 0 to 4, the calculated results with N_{max}=4 best fit the experimental data among these calculations. The agreement of the calculated results may improve for the higher N_{max} values. The calculations for fluorine chain are also in progress.

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