Study of Nitrogen Isotopes with No Core Shell Model

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Introduction

The No Core Shell Model (NCSM) is an *ab initio* approach in which we calculate the nuclear properties from the first principle [1]. Now a days, there are several other approaches available which can be used for *ab initio* calculations [2–4]. In NCSM approach we need a very huge computational facility. For p shell nuclei, the energy spectrum is well described and the other observables are also calculated within the framework of no core shell model in Ref. [5]. Recently, NCSM with perturbative approach is used to study lighter sd shell nuclei [6]. There are few experimental data available in the case of nitrogen isotopes, so, the NCSM study of nitrogen isotopes will be very useful to plan for the new experiments.

Formalism

The starting Hamiltonian in the NCSM is given as:

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

Where, m is the nucleon mass, $V_{NN,ij}$ is the NN interaction which have nuclear as well as Coulomb part. Here, we work with the large and finite harmonic oscillator (HO) basis in our model. In the present work we have used the effective INOY NN interaction [7] which have the effect of NNN interaction in terms of nonlocality present in it. This interaction is not soft interaction so it generates short range correlations and we face the problem with the convergence, so, we need a renormalization scheme called similarity transformation to soften the interaction. In the present work, we have used Okubu-Lee-Suzuki(OLS) [8] similarity transformation. In the NCSM calculations, there are two parameters: the basis truncation parameter N_{max} and HO frequency $\hbar\Omega$.

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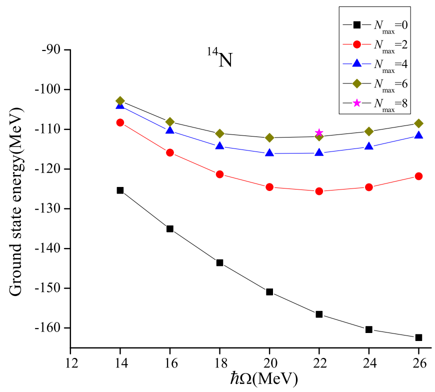

FIG. 1: Ground state energy curve using INOY NN interaction corresponding to different frequency and N_{max}.

TABLE I: The dimensions of the Nitrogen isotopes with increasing N_{max}.

N_{max}	^{14}N	^{16}N	^{18}N
0	5	8	1×10^2
1	2×10^2	3.9×10^2	4.5×10^3
2	4.1×10^3	9×10^3	8.9×10^4
3	5.3×10^4	1.2×10^5	1.1×10^6
4	4.8×10^5	1.2×10^6	1×10^7
7	1.1×10^8	4×10^8	3.3×10^9
6	2.1×10^7	6.8×10^7	5.6×10^8
8	5.4×10^8	2×10^9	1.7×10^{10}

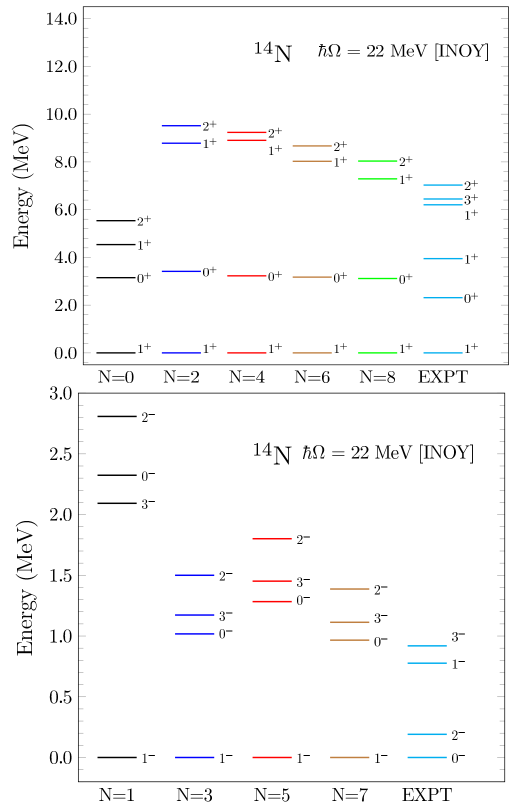

FIG. 2: Calculated and experimental energy spectra of ^{14}N for positive and negative parity states with $\hbar\Omega$ = 22 MeV.

Results and Discussions

We have done NCSM calculations for nitrogen chain. But, in the present paper, we show only the energy spectra of ^{14}N. More details will be presented during meeting. The m-scheme dimension of the matrices for nitrogen isotopes are given in the table I. At present, we have reached up to N_{max}=8 in the case of ^{14}N for positive parity states and N_{max}=7 for the negative parity states. In the case of ^{18}N for negative parity states we have reached up to N_{max}=4. In the Fig. 1, we show the variation of g.s. energy with the frequencies and increasing model space sizes. For the largest model space size we choose the region where the g.s. energy becomes less dependent on $\hbar\Omega$ values. In the present calculations, the region is 20-22 MeV. Thus, we have taken $\hbar\Omega$= 22 MeV to calculate further the energy spectrum. In the Fig. 2, we show the energy spectra for ^{14}N for positive and negative parity states ('N' corresponds to N_{max}). It is clear that INOY interaction gives the correct g.s. 1^+. The 0^+ state is reaching towards the experimental state as increasing model space size. The 1_2^+ state is very high in energy. The 2^+ state is decreasing and reaching towards the experimental data as model size increases. There is a large energy difference between calculated and experimental value for 0^- state. Although, this 0^- state is also not the first negative parity state in the work of Yuan and his co-authors [9] in which they have done the shell model study with monopole based universal interaction.

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