# Calculation for ground and resonance states in neutron-rich exotic $^{32}Ne$ nucleus

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## Introduction

Neutron-rich nuclei like $^{6-10}$He, $^{11}$Li, $^{19-22}$C are drawing much attention of physicists with the rapid development in radioactive ion beam facilities (RIB). Production and detection of highly neutron-rich nuclei like $^{31}$Ne and $^{37}$Mg have been reported recently [1] [2] [3]. In the present communication we concentrate on the theoretical structrure of recently produced $^{32}$Ne [4]. Here we will explore the ground state as well as resonance states in the framework of few-body model.

We assume a three-body model of $^{32}$Ne as a structureless core $^{30}$Ne surrounded by two valence neutrons (n). We first solve for the ground state of the three-body system using standard GPT [5] nn potential and standard SBB [6] core-n potential using hyperspherical coordinates. Parameters of the core-n potential chosen subject to the criteria that $^{31}$Ne subsystem is just unbound. The ground state wave function then used to construct a one parameter family of isospectral potential. The parameter is adjusted to develop a deep well followed by a positive barrier facilitating the trapping of particles(s) within the deep-well and sharp barrier at energy E ( > 0). Probability of trapping of the particle within the well-barrier combination is computed for different positive energies which shows a peak at resonance energy. After locating the resonance energy we used WKB approximation to calculate the width of resonance.

## Method

In hyperspherical harmonics expansion formalism we label the relatively heavier nuclear core $^{30}Ne$ as particle "i" and two valence nucleons as particles "j" and "k" respectively to define the Jacobi cordinates as:

$$\left.\begin{array}{rcl} \vec{x_i} &=& a_i(\vec{r_j}-\vec{r_k}) \\ \vec{y_i} &=& \frac{1}{a_i}\left(\vec{r_i}-\frac{m_j\vec{r_j}+m_k\vec{r_k}}{m_j+m_k}\right) \\ \vec{R} &=& \frac{(m_i\vec{r_i}+m_j\vec{r_j}+m_k\vec{r_k})}{M} \end{array}\right\} \quad (1)$$

where $a_i$ is const.; $m_i, \vec{r_i}$ are the mass and position of the $i^{th}$ particle and $M = m_i + m_j + m_k, \vec{R}$ is the centre of mass (CM) of the system. We then introduce the hyperradius $\rho = \sqrt{x_i^2 + y_i^2}$, an invariant under three dimensional rotations and permutations of particle indices together with the five angular variables $\Omega_i \rightarrow \{\phi_i, \theta_{x_i}, \phi_{x_i}, \theta_{y_i}, \phi_{y_i}\}$ constitute hyperspherical coordinates of the system. It is to be noted that hyperangles $\Omega_i$ depend on the choice of the particular partition $i$. In terms of hyperspherical variables $(\rho, \Omega_i)$ the three-body Schrödinger equation becomes

$$\left[-\frac{\hbar^2}{2\mu}\left\{\frac{1}{\rho^5}\frac{\partial}{\partial\rho}(\rho^5\frac{\partial}{\partial\rho}) - \frac{\hat{\mathcal{K}}^2(\Omega_i)}{\rho^2}\right\}\right]\Psi(\rho,\Omega_i) + [V(\rho,\Omega_i) - E]\Psi(\rho,\Omega_i) = 0 \quad (2)$$

where $V(\rho, \Omega_i)$ is the total interaction potential and $\hat{\mathcal{K}}^2(\Omega_i)$ is the square of hyper angular momentum operator an analogue of orbital angular momentum operator in three-dimension.

## Tables and Figures

## Results and Discussions

As it is difficult to achieve fully converged solution for small-sized computer which restricts the expansion basis to some small finite value as well as the computation becomes time consuming, search of an effective alternative method becomes inevitable. Here we used

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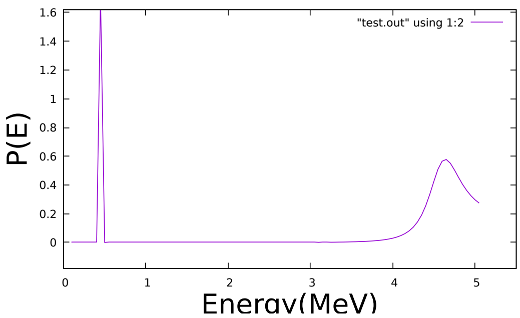
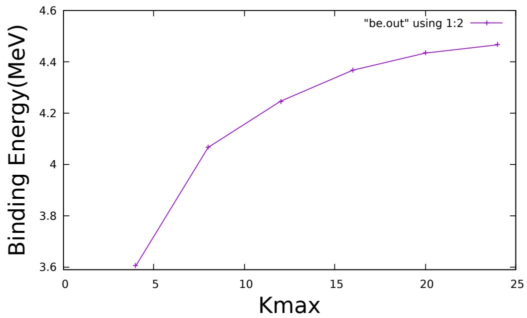
TABLE I: **Calculated 2n-separation energy ($S_{2n}$), contribution of $l_x = 0^{th}$ partial wave in the probability density and energy respectively for different $K_{max}$ in the ground state of $^{32}Ne$.**

| $K_{max}$ | $S_{2n}(=-E)(MeV)$ | $P_{lx=0}$ | $E_{lx=0}(MeV)$ |
|---|---|---|---|
| 4 | 3.6040 | 0.9400 | -3.3697 |
| 8 | 4.0662 | 0.9317 | -3.7785 |
| 12 | 4.2460 | 0.9340 | -3.9557 |
| 16 | 4.3673 | 0.9359 | -4.0832 |
| 20 | 4.4338 | 0.9371 | -4.1523 |
| 24 | 4.4660 | 0.9378 | -4.1844 |




(a) Represention of Resonance states of $^{32}Ne$.




(b) Binding Energy vs Kmax graph of $^{32}Ne$

a novel technique to study resonance states of weakly bound nuclei by contructing one parameter family of supersymmetric isospectral partner potential of the original potential using the ground state wavefunction. Results are presented in Tables I, II and III. It can be seen from Table II that the depth of the potential well increases and simultaneously the height of barrier also increases as the parameter $\delta$ approaches zero. It can also be noted

TABLE II: **Parameters of the isospectral potential as the parameter $\delta$ decreases from $+\infty$ (original potential $v(\rho)$) towards 0+.**

| $\delta$ | Potential well | | Potential Barrier | |
|---|---|---|---|---|
| | $V_w$(MeV) | $r_w$(fm) | $V_b$(MeV) | $r_b$(fm) |
| 1000000 | -11.369 | 3.046 | 4.058 | 0.100 |
| 100 | -11.451 | 3.042 | 4.060 | 0.099 |
| 1 | -17.958 | 2.782 | 4.618 | 7.079 |
| 0.1 | -43.433 | 2.278 | 11.502 | 3.890 |
| 0.01 | -97.893 | 1.778 | 38.121 | 2.783 |
| 0.001 | -157.518 | 1.362 | 86.332 | 2.133 |
| 0.0001 | -276.083 | 0.982 | 144.129 | 1.700 |
| 0.00001 | -486.800 | 0.711 | 245.533 | 1.196 |

TABLE III: **Comparison calculated results with other works found in the literature for $^{32}$Ne.**

| State | Observables | Present work | Others work |
|---|---|---|---|
| $0^+$ | E (MeV) | -4.4660 | -1.9700[7] |
| $0^+_1$ | $E_R$ (MeV) | 0.45 | – |

that the width of the well as well as that of the barrier become narrower with decreasing $\delta$ and the minimum of the well shifts towards the origin producing a dramatic effect.

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