Structure of $^{24}Mg_{(g.s.)}$ and the $^{12}C_{(g.s.)}$-$^{12}C_{(g.s.)}$ potential using oblate $^{12}C_{(g.s.)}$

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Introduction

Heavy nuclear molecular cluster structures of $^{24}Mg_{(g.s.)}$ has two main contenders from the Harvey prescription[1]: the $^{12}C_{(g.s.)}$ + $^{12}C_{(g.s.)}$ and the $^{16}O_{(g.s.)}$+ $^{8}Be_{(g.s.)}$ configurations. Harvey prescription predicted that only the perpendicular relative orientations of the two oblately deformed $^{12}C_{(g.s.)}$ nuclei can lead to the $^{24}Mg_{(g.s.)}$. This contradicts the experimental findings[2], of the non existence of $^{12}C_{(g.s.)}$ in the $^{24}Mg_{(g.s.)}$, from the ^{12}C-knockout reaction $^{24}Mg(^{12}C_{(g.s.)}, 2^{12}C_{(g.s.)})^{12}C_{(g.s.)}$ at $104MeV$ incident energy.

This discord between the heavy cluster knockout reaction results and the aforesaid heavy nuclear molecular prescription is being resolved here through a detailed study of the $^{12}C_{(g.s.)}$ + $^{12}C_{(g.s.)}$ Nuclear Interaction Potential with oblately deformed $^{12}C_{(g.s.)}$ structures in various orientations with respect to each other using a Monte Carlo Method. The nuclear interaction potential between deformed nuclei has not been attempted so far from the double folding model due to the required evaluation of a large number of 6-dimensional integrals.

Formalism

The repulsive Coulomb potential between two uniformly charged oblate $^{12}C_{(g.s.)}$ nuclei for three chosen configurations was already discussed in Ref.[3] .

For the nuclear interaction, the short range nature of the nucleon-nucleon (N-N) interaction requires at least some part of the volumes of the two deformed $^{12}C_{(g.s.)}$ nuclei to overlap. It was thus obtained by considering the interaction between the effective number of nucleons from each deformed $^{12}C_{(g.s.)}$ nucleus in the overlapping volume only. For the sake of simplicity the two $^{12}C_{(g.s.)}$ nuclei have been taken to be of uniform density with sharp surfaces and with proper deformation and size obtained from the electron scattering data. The effective number of nucleons n_1 from each of the two nuclei (separated by R), in the overlapping region is given by,

$$n_1 = \frac{\Delta V}{V_0} \times 12, \qquad (1)$$

where ΔV and V_0 are the volumes of the overlapping region of $^{12}C_{(g.s.)}$ + $^{12}C_{(g.s.)}$, in any particular configuration, and that of the whole $^{12}C_{(g.s.)}$ nucleus respectively.

For our Double Folding Model calculations we have used the N-N effective interaction of Bertsch *etal.*[4] given by:

$$v_{N-N}(r) = 7999\frac{e^{-4r}}{4r} - 2134\frac{e^{-2.5r}}{2.5r}, \qquad (2)$$

where v_{N-N} is in MeV and r is in fm.

Let v_{N-N}^{avg} be the average N-N interaction per pair between the two completely overlapping nuclei. This is obtained as the averaged N-N interaction from a random choice of a large number of points in a completely overlapping situation of the two nuclei. This v_{N-N}^{avg} is supposed to become smaller and smaller with increasing mass of the interacting nuclei.

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With the number of nucleons per unit volume represented by ρ, the number of nucleons n_1 in the overlapping volume, ΔV corresponding to one nucleus is $n_1 = \rho \times \Delta V$. There will be the same n_1 number of nucleons corresponding to the other nucleus. Thus, the number of pairs in the overlapping volume ΔV will be n_1^2, where for each pair one nucleon belongs to one nucleus and the other nucleon belongs to the other nucleus. The Nucleus-Nucleus interaction potential at given R for any given configuration will thus be given by,

$$V_N(R) = n_1^2 \times v_{N-N}^{avg} \quad (3)$$

Results and Discussion

The $^{12}C_{(g.s.)}$-$^{12}C_{(g.s.)}$ interaction results, $V_{^{12}C-^{12}C}(R)$ shown in Fig.1 for the two oblately deformed $^{12}C_{(g.s.)}$ nuclei indicate that Config. *no.*1 (oblate nuclei lying flat on a plane) has a longer range ($\sim$ 6.0 fm) and Config. *no.*2 (oblates standing on a plane) has the shortest range ($\sim$ 4.0 fm). However both have the same central depth ~ -350 MeV for R=0. These depths are similar to ~ -350 MeV depths obtained by Kondo *et al.* [5] for $^{16}O_{(g.s.)}$-$^{16}O_{(g.s.)}$ system. The nuclear potential for the perpendicular configuration has a central depth of $\sim$-250 MeV and range $\sim$ 5 fm. This lower value is because there is only partial overlap between the two ellipsoids even when their *c.m.*'s are coinciding at R=0.

These observations clearly indicate that the Harvey prescription does not satisfy the lowest nuclear potential energy $V_N(R)$ criterion for the $^{24}Mg_{(g.s.)}$. Thus our present results support the experimental findings[2] of the non-existence of $^{12}C_{(g.s.)}$ in the $^{24}Mg_{(g.s.)}$. They reject the Harvey prescription claim for the $^{12}C_{(g.s.)}$-$^{12}C_{(g.s.)}$ structure with perpendicular planes for the ground state of ^{24}Mg.

The present interaction potential calculations were performed using a novel Monte Carlo based method easily adaptable for any deformed shapes. The results show that the perpendicular orientation of the two oblately deformed $^{12}C_{(g.s.)}$ configuration, supported by the Harvey prescription, does not have the lowest potential energy value. Besides this $V_N(R)$ for the perpendicular orientations does not have enough well depth of $\sim$ 450 MeV required by Buck *et al.*[6] to have the 8-nodes in the relative wave function, $\phi_{^{12}C-^{12}C}(R)$ to reproduce the ground state properties of ^{24}Mg. We thus strongly support the experimental findings[2] that $^{12}C_{(g.s.)}$ + $^{12}C_{(g.s.)}$ nuclear molecular configuration does not have any significant contribution to the $^{24}Mg_{(g.s.)}$ structure.

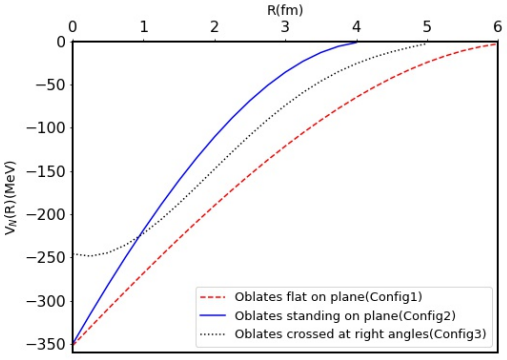

FIG. 1: Nuclear interaction potential, $V_N(R)$ between the two $^{12}C_{(g.s.)}$ nuclei for the three relative orientations of the planes of these two oblately deformed $^{12}C_{(g.s.)}$ nuclei with deformation, β_2=−0.4.

Acknowledgments

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References

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