Non-existence of $^{12}C_{(g,s)}+^{12}C_{(g,s)}$ configuration in $^{24}Mg_{(g,s)}$ due to mismatch of $^{12}C_{(g,s)}$ deformed configurations at the surface

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1. Introduction

In the last few decades, heavy cluster structure prescriptions have been proposed [1] to describe the ground state as well as the excited states of light– medium mass nuclei. The key feature of these theoretical heavy cluster models is that the nucleus is described in terms of two sub-nuclei. ^{24}Mg is described as a cluster of $^{12}C_{(g,s)}+^{12}C_{(g,s)}$ and ^{16}O + ^{8}Be structures apart from the alpha cluster with ^{20}Ne. Harvey [2] proposed that ^{24}Mg ground state is a cluster of two oblate deformed $^{12}C_{(g.s)}$ nuclei only if their planes are perpendicular to each other. Microscopic alpha cluster model calculations [3,4] using $\alpha - \alpha$ interactions concluded that both $^{12}C_{(g,s)}+^{12}C_{(g,s)}$ and $^{16}O_{(g.s)}$ +$^{8}Be_{(g.s)}$ show up only in the excited states of ^{24}Mg nucleus. The heavy cluster structure of the ground state of ^{24}Mg has been probed experimentally by Joshi et al. [5] using the heavy cluster knockout reaction ^{24}Mg (^{12}C, 2^{12}C)^{12}C in the quasifree scattering kinematic domain and it was concluded that there was a negligible $^{12}C_{(g.s)}$ +$^{12}C_{(g.s)}$ clustering in $^{24}Mg_{(g.s)}$.

The present work represents our calculations for the repulsive Coulomb potential energy between the two deformed $^{12}C_{(g,s)}$ nuclei: i) as a function of separation between center of masses for a fixed quadrupole deformation factor-R(fm), ii) as a function of the relative angle between the symmetry axes of the nuclei with oblate surfaces in contact- θ(Degrees) and iii) as a function of the quadrupole deformation parameter with the oblate surfaces in contact for three different configurations namely: 1) Nuclei flat on the plane, 2) Nuclei parallel to each other but perpendicular to the plane 3) Nuclei perpendicular to each other (as per Harvey's prescription).

2. Formalism

The repulsive Columbic energy between two uniformly charged oblate $^{12}C_{(g,s)}$ nuclei in Cartesian coordinates as a function of separation between center of masses (R) is

$$V(R) = \frac{\rho^2}{4\pi\epsilon_0}\iint \frac{dV_1 dV_2}{\sqrt{(x_1-x_2)^2+(y_1-y_2-R)^2+(z_1-z_2)^2}}$$

where (x_1, y_1, z_1) and (x_2, y_2, z_2) denote the coordinates of Oblate1 and Oblate2 respectively and R is distance between the center of masses of the two $^{12}C_{(g,s)}$ nuclei.

Intercepts of the two oblate $^{12}C_{(g,s)}$ nuclei were calculated for a deformation parameter $\beta_2 = -0.45$ [6] using $R(\theta, \varphi) = R_{av}[1 + \beta_2 Y_{20}(\theta, \varphi)]$ and are summarized in Table 1. Intercepts 'a' and 'b' denote semi-major and semi minor axes of the oblate $^{12}C_{(g,s)}$ nuclei. The above integral was transformed into Oblate spheroidal coordinate system (μ, ν, φ) in order to exploit the Oblate spheroid symmetry of $^{12}C_{(g.s)}$. The new limits for six-dimensional numerical integration were obtained using transformation equations and the transformed integrand was evaluated using Quasi-Monte Carlo method. The potential energy as a function of R(fm), θ(Degrees) and β_2 is plotted in Figures1, 2 and 3 respectively.

Table 1: Parameters used in the calculations

β_2	a (fm)	b (fm)	μ
-0.45	3.1339	1.9642	0 to 0.7314

3. Results and discussion

The discrepancy between the Harvey 's proposed theory and the experimental results can be resolved by finding the orientation of the clustering sub nuclei with minimum repulsive potential energy. If Harvey's prescription were true, then the sub nuclei cluster in the perpendicular configuration to form $^{24}Mg_{(g.s)}$, However, the results of our calculations shown in the Figure (1) clearly indicate that configuration 3, corresponding to Harvey's prescription, does not have minimum potential energy, but configuration 2 with oblates parallel to each other has minimum potential energy. Also, Figure (2) confirms that among all the possible relative orientations of oblates with respect to their symmetry axes, Harvey's prescription does not have minimum potential energy. Figure (3) confirms that Harvey's prescription is not the minimum energy configuration for increasing deformation of the clusters. From these results, we conclude that Harvey's perpendicular configuration of clusters is not the minimum energy configuration in $^{24}Mg_{(g,s)}$

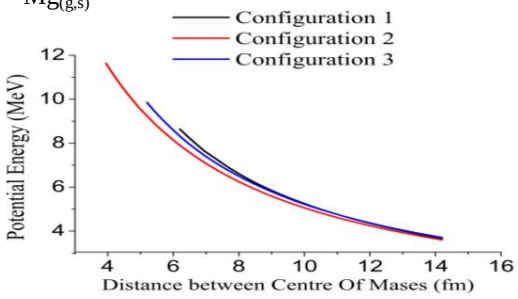

Figure 1:Potential energy as a function of separation between centre of masses.

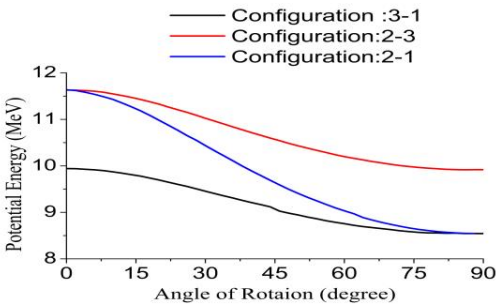

Figure 2: Potential energy as a function of angle between symmetry axes.

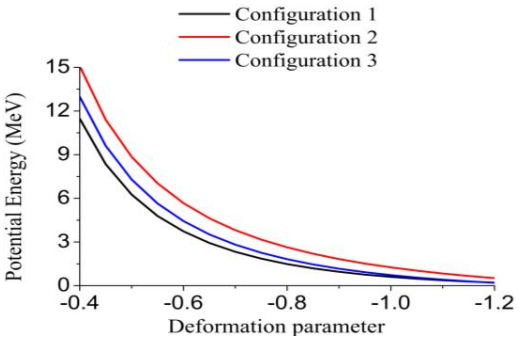

Figure 3: Potential energy as a function of deformation parameter.

Moreover, if Harvey's prescription was true, then the two $^{12}C_{(g.s)}$ nuclei with their planes perpendicular to each other move perpetually with respect to each other from smaller to larger separations. This perpetual flipping of planes at the ^{24}Mg surface leads to the mismatch of the internal and external wave functions at the surface resulting in negligible $^{12}C_{(g.s)}$ + $^{12}C_{(g.s)}$ clustering in $^{24}Mg_{(g.s)}$.

4. Conclusion:

Hence, our theoretical calculations support the experimental findings [5] that $^{12}C_{(g,s)}$ +$^{12}C_{(g,s)}$ configuration does not exist in the $^{24}Mg_{(g,s)}$ due to the two deformed configurations having different orientations in the inside and outside regions. The two $^{12}C_{(g.s)}$ nuclei in perpetual motion from inside to outside and flipping the orientation at the surface results in the mismatch of the two different configurations at some boundary. So, $^{16}O_{(g.s)}$ +$^{8}Be_{(g.s)}$ heavy cluster is the preferred configuration in this scenario.

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