Why $^{24}Mg_{(g.s.)}$ has no $^{12}C_{(g.s.)} + ^{12}C_{(g.s.)}$ component.

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Theoretically the heavy cluster structure of $^{24}Mg_{(g.s.)}$ has been obtained in terms of $^{12}C_{(g.s.)}$+$^{12}C_{(g.s.)}$ and $^{16}O_{(g.s.)}$+$^{8}Be_{(g.s.)}$ configurations besides of course the α+$^{20}Ne_{(g.s.)}$ configuration. From the Constrained Hartree-Fock, involving Pauli principle and Molecular orbital approach M. Harvey [1] argued for the existence of $^{12}C_{(g.s.)}$ +^{12} $C_{(g.s.)}$ in the $^{24}Mg_{(}g.s.)$. M. Harvey constructed the ^{24}Mg configuration by adiabatically pushing together two $^{12}C_{(g.s.)}$ nuclei. Here the two $^{12}C_{(g.s.)}$ nuclei at large separations are assumed to have filled the $1s_{1/2}$ and $1p_{3/2}$ orbits, as given in Figs. 1 & 2, in a Cartesian representation and characterized by the oscillator quanta n_x, n_y and n_z in the spatial directions. The $^{12}C_{(g.s.)}$ nucleus is supposed to have an oblate intrinsic deformed state represented in the oscillator model by the filling of the $1s$-shell and 8-particles in the $1p$-shell. Each of the lowest Cartesian states in each potential well is occupied , as shown by 4-nucleons with $\pm 1/2$ spin and isospin projections. Although we have 3-dimensional wells it is really only the wave functions in the z-direction that are affected by the approaching nuclei in the z-direction; *i.e.* essentially we have a one dimensional problem. Now because of the greater number of particles the Pauli principle will demand occupancy of the 3-quantum shells. In Figs. 1 & 2 we show the schematic single particle picture of two merging $^{12}C_{(g.s.)}$ nuclei. In Fig.1 the axis of symmetry of the two $^{12}C_{(g.s.)}$ nuclei are perpendicular to the z-axis (i.e. the line joining the centres of mass of the approaching $^{12}C_{(g.s.)}$ nuclei). Here one reaches an excited state in ^{24}Mg.

In Fig.2 another situation is shown in which

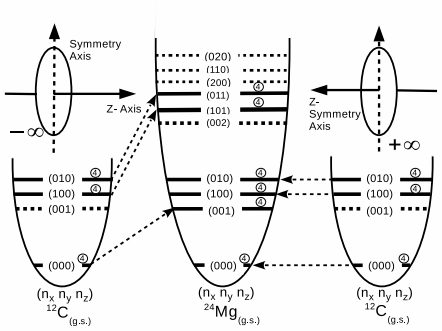

FIG. 1: Harvey diagram for two $^{12}C_{(g.s.)}$ nuclei with their planes parallel to each other and perpendicular to their line of approach will produce an excited ^{24}Mg.

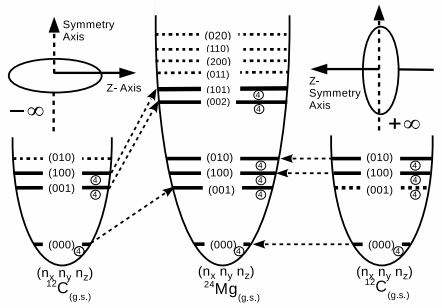

FIG. 2: Harvey diagram for two $^{12}C_{(g.s.)}$ nuclei with their planes perpendicular to each other and one plane parallel to the line of approach will produce a ground state ^{24}Mg

one of the $^{12}C_{(g.s.)}$ has its axis of symmetry perpendicular to the z-axis and the other has its axis of symmetry parallel to the z-axis. Again an adiabatic push in the z-direction brings the two $^{12}C_{(g.s.)}$ nuclei together in to the ground state configuration of ^{24}Mg. This indicates that there could be a significant component of $^{12}C_{(g.s.)}$- $^{12}C_{(g.s.)}$ state where their oblate planes are oriented perpendicular to each other. This Constrained Hartree-Fock

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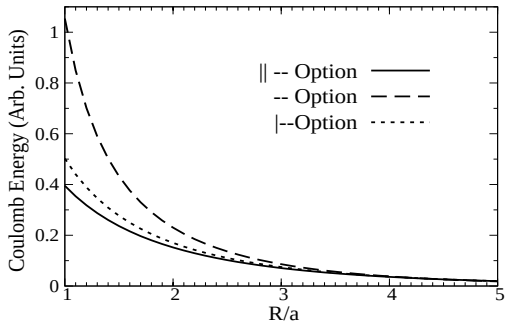

FIG. 3: Coulomb energy for the three options of configurations 1) to 3), i.e. parallel to each other, coins on a table and perpendicular planes as a function of R, the ratio of the separation of their centres and radii.

(CHF) model approach requires the system to be frozen at each stage of the separation of the fragments. In such a situation the Pauli Principle is allowed to have maximum effect.

Recently from the $^{24}Mg(^{12}C, 2^{12}C)^{12}C$ knockout reaction experiment [2] it has been concluded that there is almost no $^{12}C_{(g.s.)}$+$^{12}C_{(g.s.)}$ component in the ground state of ^{24}Mg.

Hence, in order to resolve this controversy, another aspect of the dynamics is to be looked into before jumping to any conclusion. Now when one looks at the situation described by the Harvey prescription then one has to realize that at large separations only the Coulomb field is operating between the two oblate $^{12}C_{(g.s.)}$ nuclei. Considering the $^{12}C_{(g.s.)}$ nuclei as plain circular discs[3] Out of the multitude of relative orientations there are 3-orientations which are extremes of the various possibilities. These are option-1) Discs are parallel to each other and perpendicular to the line of approach($\rightarrow|\ |\leftarrow$), option 2) Discs are parallel but side by side like two flat coins on a table ($\rightarrow - - \leftarrow$) approaching each other along line joining their centres and the option 3) when their planes are perpendicular to each other and approaching along line joining their centres($\rightarrow|\ -\leftarrow$).The Coulomb interaction energy vs. the separation of their centres of mass corresponding to the 3-options is schematically plotted in Fig.3. Here it is seen that the lowest Coulomb energy corresponds to the option 1) with ($\rightarrow|\ |\leftarrow$)parallel arrangement. The coins on the table arrangement option # 2 ($\rightarrow - - \leftarrow$) corresponds to the highest while the perpendicular planes option 3)($\rightarrow|\ -\leftarrow$) corresponds to somewhat intermediate Coulomb energy between the options 1) and 2).

Now it is obvious that energy wise there is a conflict because option 3) with perpendicular planes is the preferred choice at short separations between the two $^{12}C_{(g.s.)}$ nuclei according to the Harvey prescription. While Coulomb energy wise the Parallel arrangement option 1) is preferred at large distances. This therefore leads to an unstable situation unless there is a flip flop in orientations as the two $^{12}C_{(g.s.)}$'s move from small separations to larger separations. It has been shown by Simenel et al [4]that the change of orientation or flip flop can not be achieved fast enough. They showed that the maximum reorientation from large separations to almost touching distances is maximum 23^0 for (^{24}Mg+^{208}Pb) case while in our case of $^{12}C_{(g.s.)}$- $^{12}C_{(g.s.)}$ it turns out to be $\sim 12^0$ and depends neither on projectile nor on the relative energy but only on the deformation and the mass ratio which is just the inertia factor. Thus the reorientation effect can not reorient the two $^{12}C_{(g.s.)}$ nuclei in parallel configuration to the perpendicular configuration required for $^{24}Mg_{(g.s.)}$.

Looking into the three aspects i.e. the Pauli principle, the Coulomb energy and the reorientation effect one can conclude that a $^{24}Mg_{(g.s.)}$ can not be produced from the $^{12}C_{(g.s.)}$+$^{12}C_{(g.s.)}$ configuration.

References

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