# Ground-state properties of nuclei generated with a soft-core Gaussian form of NN potential

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## Introduction

In classical microscopic approaches for heavy-ion collisions such as *Classical Molecular Dynamics* [1], *Classical Rigid-Body Dynamics* [2,3] or microscopic *Static Barrier Penetration Model* [4] the initial conditions require specification of positions of all the nucleons in the given collision partners. These ground-state (g.s.) configurations of colliding nuclei are obtained by a potential energy minimization procedure "STATIC" [1] with a given form of the phenomenological two-body potential between nucleons. A soft-core Gaussian form of NN potential given by

$$V_{ij}(r_{ij}) = -V_0\left(1-\frac{C}{r_{ij}}\right)\exp\left(-\frac{r_{ij}^2}{r_0^2}\right)$$

has been used along with the usual Coulomb interaction in heavy-ion fusion studies [1-5].

The parameters of the potential are chosen to reproduce the g.s. properties of the colliding nuclei such as binding energy (BE), root-mean-square radius ($R_{rms}$) and quadrupole deformation parameter ($ß_2$). A potential parameter set P4 ($V_0$=1155 MeV, C=2.07 fm and $r_0$=1.2 fm) has been used to generate g.s. configurations of some of the nuclei like $^{24}$Mg, $^{208}$Pb etc. [5]. The calculated g.s. properties of a large number of stable nuclei across the periodic table with the potential P4 using the variational potential energy minimization procedure "STATIC" are presented here.

## Calculational Details

The nuclei in g.s. are obtained by the procedure "STATIC" by generating a random distribution of all the nucleon positions in a sphere of given radius and then cyclically minimizing the total potential energy of the nucleon configurations with respect to small displacements of the individual nucleon coordinates. Total BE is the total potential energy and $R_{rms}$ is calculated from all the nucleon positions. The deformation parameter ($ß_2$) is calculated from the expression [5]

$$b_2 = \sqrt{\frac{16p}{5}}\left(1-\frac{R(90)}{R_0}\right)$$

However, for A = 5, a number of static isomeric configurations exist. Therefore, a large number of randomly generated different initial configurations are required to be considered.

## Results and Discussion

Fig. 1 and fig. 2 shows such isomeric configurations generated in the case of $^{24}$Mg, as an example. Fig.1 shows BE and $R_{rms}$ of each of about 1000 such generated configurations for $^{24}$Mg as a point on the two-dimension plot. Similarly fig. 2 shows BE versus $ß_2$ of each of such configurations for $^{24}$Mg.

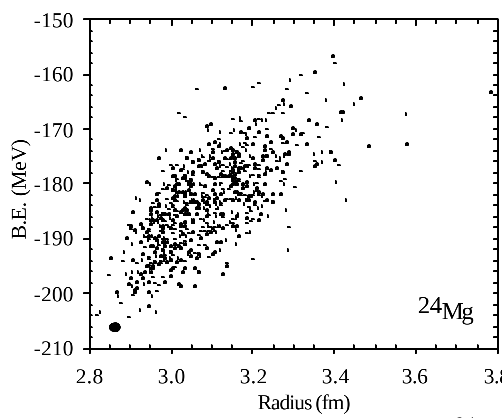


**Fig. 1:** Calculated BE and rms radius for $^{24}$Mg.

While in ref [2-3] the configurations corresponding to nearly the experimental g.s. properties are chosen, in the present study we choose the configurations corresponding to the maximum BE of all the generated configurations for the given nucleus. Such a configuration for $^{24}$Mg is shown in fig.1 and fig.2 by bigger points.

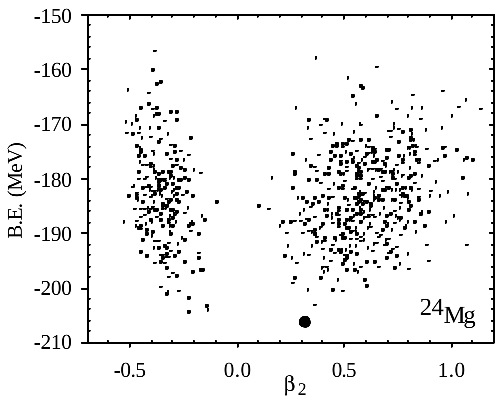


**Fig.2:** Calculated BE and $ß_2$ for $^{24}$Mg.

Ground-state BE per nucleon (BE/A) for various nuclei so generated are shown in fig. 3 and compared with the corresponding experiment values [6]. The essential features of the experimental curve are reproduced by the calculated values. However, for heavier nuclei the calculated values are slightly overestimated as seen in the inset of fig. 3.

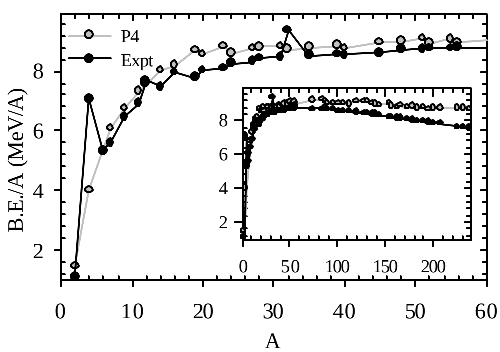


**Fig. 3:** BE/A for most-bound nuclei.

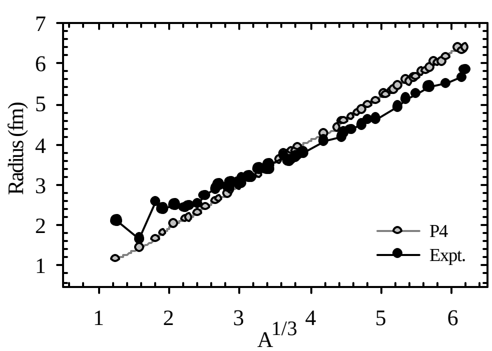


**Fig. 4:** RMS radius for most-bound nuclei.

Calculated values of $R_{rms}$ are shown in the fig. 4 as a function of $A^{1/3}$ and compared with the experimental [7] values. Calculated $R_{rms}$ shows a linear increase as also seen in the experimental data. However, the calculated values show slightly larger slope, resulting in a small underestimation for lighter nuclei and overestimation of radius for heavier nuclei by about 12%.

Quadrupole deformation parameters ($ß_2$) for these most-bound systems are shown in fig. 5 as a function of mass number A and compared with the experimental values [8]. Both prolate and oblate deformations are obtained.

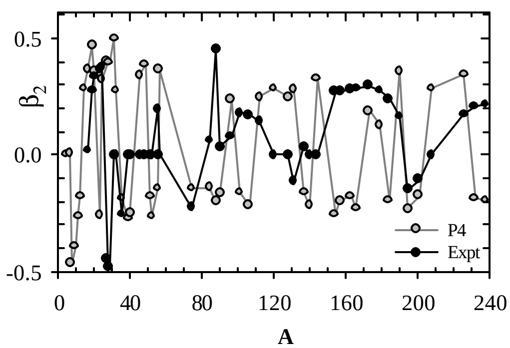


**Fig. 5:** $ß_2$ for most-bound nuclei.

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