Classical microscopic configuration of nuclei for heavy ion collision calculations with a suitable NN-potential

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Introduction

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 in classical microscopic approaches. These ground-state (g.s.) configurations of colliding nuclei are obtained by a potential energy minimization procedure "STATIC" [1] with a soft-core Gaussian form of NN-potential given by

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

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

A potential parameter set P4 (V_0=1155 MeV, C=2.07 fm and r_0=1.2 fm) has been used earlier to generate g.s. configurations of many stable nuclei [6, 7]. It reproduces the overall features of binding energy (BE) and R_{rms} for many nuclei over the periodic table. However, there are deviation of about 15% in BE/A and about 10% in R_{rms} for A=238 nucleus. It is desirable in heavy-ion collision calculation that the g.s. properties of at least the heavy collision partner should be as close to the experimental value as possible for correct reproduction of fusion cross-section calculation. This may be achieved by finding a new parameter set for the reduced range parameter r_0. Therefore, in this paper we choose r_0=1.1fm instead of r_0=1.2fm (P4) and study the g.s. properties of a large number of stable nuclei across the periodic table.

Calculational Details

The nuclei in their 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. Choosing r_0=1.1fm, potential parameters V_0 and C are adjusted such that the BE/A for the most-bound isomeric configuration of many nuclei matches well with the experimental data.

Results and Discussion

Ground-state BE per nucleon (BE/A) for various nuclei generated with the potential parameters V_0=1000MeV, C=1.87 fm with r_0=1.1fm are shown in fig. 1 and compared with the corresponding experimental values [8].

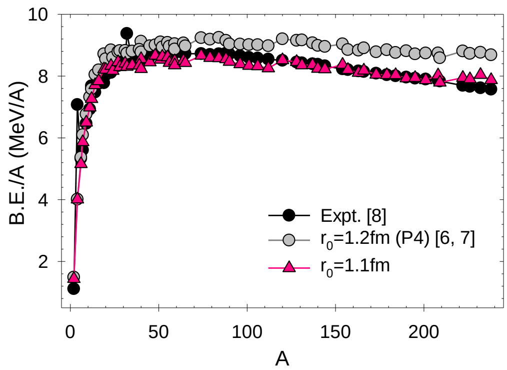

Fig. 1 BE/A for most-bound nuclei.

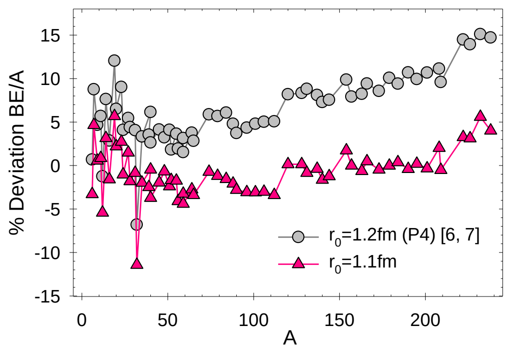

Fig. 2 Percentage deviation of BE/A for most-bound nuclei.

Not only the essential features of the experimental BE/A curve are reproduced by these calculated values but are in much more closer agreement with the experiment than that with the potential P4 with r_0=1.2fm.

The percentage deviation of BE/A is shown in Fig. 2. From fig. 2 it can be seen that BE/A with potential P4 have percentage deviation of around 8-16% for medium and heavy mass nuclei and the current potential shows percentage deviation of about 1-5% in the same mass range.

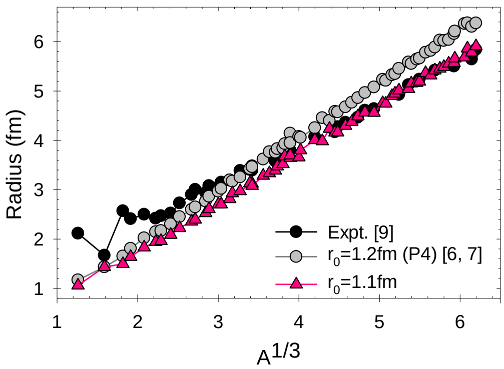

Fig. 3: RMS radius for most-bound nuclei.

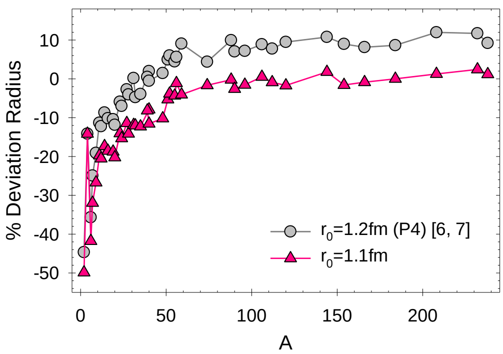

Fig. 4: Percentage deviation of RMS radius for most-bound nuclei.

Calculated values of R_{rms} for both the potentials are shown in the fig. 3 and compared with the experimental [9] values. Calculated R_{rms} show a linear increase as seen in the experimental data. Calculated values for the potential with r_0=1.1fm are in much closer agreement with the experimental values in medium and heavy mass range.

The percentage deviation in R_{rms} is shown in Fig. 4. From fig. 4 it can be seen that R_{rms} with potential P4 have percentage deviation of around 5-12% and the potential with r_0=1.1fm shows percentage deviation of 1-2% only. Potential P4 (r_0=1.2fm) results in underestimation for lighter nuclei and overestimation of radius for heavier nuclei, while new potential (r_0=1.1fm) also shows underestimation in radius for lighter nuclei but matches well for medium to heavier nuclei.

Conclusion

We have readjusted the potential parameters of NN-potential with the chosen range parameter r_0=1.1fm which is slightly smaller than r_0=1.2fm of the potential parameter set P4 used in many classical heavy ion collision studies. The new set of potential parameters reproduces the BE and Rrms of many light, medium and heavy nuclei in much closer agreement with the experimental values than those reproduced by the parameter set P4 (r_0=1.2fm). Therefore, this parameter set will be of better use in classical heavy-ion collision calculations involving one of the colliding partner being in medium or heavy mass range.

References

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