Dynamical approach to study fragmentation in ^{16}O+^{80}Br/^{108}Ag reactions at various incident energies

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Introduction

Heavy-ion collisions have always played a fascinating role in explaining various aspects of nuclear dynamics such as fusion-fission, multifragmentation etc. The multifragmentation has been studied using a variety of nuclei and over a wide range of incident energies and colliding geometries. The experiments carried out for multifragmentation are broadly classified into symmetric and asymmetric collisions. This division is due to the fact that the former leads to higher compression whereas the latter lacks compressional effects and therefore, a large share of excitation energy is available in the form of thermal energy. One of the early attempts to study multifragmentation was done by Jakobsson *et al.* [1] who measured the charge distributions in ^{16}O induced reactions between 25 and 200 MeV/nucleon. This range of incident energy covers fusion-fission, particle emission, and multifragmentation. Therefore, these experiments make a stringent test for any theoretical multifragmentation model. With this in mind, we use one of the dynamical approaches namely isospin-dependent quantum molecular dynamics (IQMD) [2] model for calculating charge distributions of ^{16}O induced reactions at different incident energies. We will also compare our calculated model results with the available experimental data. A brief introduction of the IQMD model is given in the next section.

The Model

The IQMD model [2] treats different charge states of nucleons, deltas, and pions explicitly, as inherited from the Vlasov-Uehling-Uhlenbeck (VUU) model. The isospin degree of freedom enters into the calculations via symmetry potential, cross sections, and Coulomb interaction. The nucleons of the target and projectile interact by two- and three-body Skyrme forces, Yukawa potential, Coulomb interactions and symmetry potential. The hadrons propagate using Hamilton equations of motion:

$$\frac{d\vec{r_i}}{dt} = \frac{d\langle H\rangle}{d\vec{p_i}}; \quad \frac{d\vec{p_i}}{dt} = -\frac{d\langle H\rangle}{d\vec{r_i}}, \tag{1}$$

with

$$\begin{aligned}\langle H\rangle &= \langle T\rangle + \langle V\rangle \\ &= \sum_i \frac{p_i^2}{2m_i} + \sum_i \sum_{j>i} \int f_i(\vec{r_i}, \vec{p_i}, t) \\ & \quad V_{ij}(\vec{r_i}, \vec{r_j}) f_j(\vec{r_j}, \vec{p_j}, t) d\vec{r_i} d\vec{r_j} d\vec{p_i} d\vec{p_j}\end{aligned} \tag{2}$$

The baryon potential V_{ij}, in the above relation, reads as

$$\begin{aligned}V_{ij}(\vec{r_i} - \vec{r_j}) &= V_{ij}^{Sky} + V_{ij}^{Yuk} + V_{ij}^{Coul} + V_{ij}^{sym} \\ &= [t_1\delta(\vec{r_i} - \vec{r_j}) + t_2\delta(\vec{r_i} - \vec{r_j})\rho^{\gamma-1} \\ & \quad (\frac{\vec{r_i} + \vec{r_j}}{2})] + t_3 \frac{\exp(-|(\vec{r_i} - \vec{r_j})|/\mu)}{(|(\vec{r_i} - \vec{r_j})|/\mu)} \\ & \quad + \frac{Z_i Z_j e^2}{|(\vec{r_i} - \vec{r_j})|} \\ & \quad + t_4 \frac{1}{\varrho_0} T_{3i} T_{3j} \delta(\vec{r_i} - \vec{r_j}).\end{aligned} \tag{3}$$

Here Z_i and Z_j denote the charges of *ith* and *jth* baryon, and T_{3i} and T_{3j} are their respective T_3 components (i.e., 1/2 for protons and −1/2 for neutrons).

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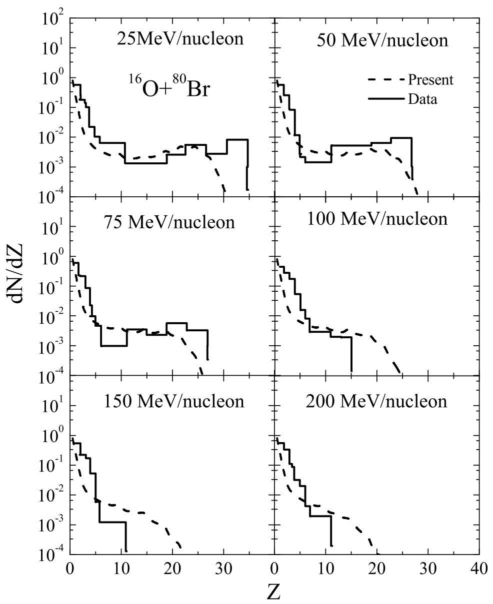

FIG. 1: The normalized charge distributions for the reaction of $^{16}O+^{80}Br$ at various incident energies (preliminary results).

Calculations and discussions

We simulated thousands of events for the central collisions of $^{16}O+^{80}Br$ and $^{16}O+^{108}Ag$ at six different incident energies ranging from 25 and 200 MeV/nucleon using soft equation of state. The phase space of nucleons is then clusterized using minimum spanning tree (MST) [3] method which is based on spatial constraints.

In Fig. 1, we display the calculated charge distributions for the asymmetric collisions of $^{16}O+^{80}Br$ (dashed lines). The charge distributions become steeper with the incident energy reflecting the violence of binary collisions. This means that as the incident energy increases, the yield of highly charged fragments decreases and one gets more number of light charged particles/fragments. Similar results have been obtained for the reactions of $^{16}O+^{108}Ag$ (results not shown).

A comparison of the calculated charge distributions with the available experimental results [1] is also shown. One can conclude that our IQMD model calculations using soft equation of state reproduces nicely the experimental data (solid lines); contrary to the disagreement of QMD model calculations [4] using soft equation of state for the same reaction. This ability of IQMD model in reproducing the measured charge distributions is because of additional features such as symmetry potential, high Fermi momentum and isospin-dependent nucleon-nucleon cross-section. All of the above mentioned attributes lead to an extra repulsion which otherwise has been added via momentum-dependent interactions in the QMD model. Therefore, while static (soft) equation of state in QMD model calculations fails to reproduce the measured charge distributions and need of momentum-dependent interactions was advocated [4], contrary, a nice agreement has been found with soft equation of state when one uses IQMD model. Further studies in this direction are in progress.

References

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