ABSTRACT

The aim of present work is to study the clusterization in heavy-ion collisions using dynamical microscopic theory and compare the results with experimental data. The theoretical investigations are carried out using microscopic Quantum Molecular Dynamics model. We aim to discuss the role of model ingredients as well as of different clusterization models for symmetric and asymmetric colliding nuclei. We shall also present the calculation of mass dependence in multifragmentation.

The present thesis is divided into following eight chapters:

Chapter 1 outlines the status of available experimental and theoretical attempts made to understand the clusterization.

Chapter 2 gives the details of various theoretical models used in the literature to study the heavy-ion reactions and clusterization. We shall discuss the quantum molecular dynamics model and minimum spanning tree method in detail.

In Chapter 3, we discuss the importance of momentum dependent interactions in explaining the multifragmentation in asymmetric reactions by comparing the results with $^{16}O$ induced emulsion data. Our results clearly indicate that the inclusion of momentum dependent forces improves the agreement with the measured atomic charge distribution. The simple static interaction fails to explain the experimental data. We also discuss the universal dependence of the effect of momentum dependent interactions on the asymmetry of a reaction.

In Chapter 4, we study the relative role of the momentum-dependent interactions and larger nucleon-nucleon cross-section in multifragmentation. We find that the sensitivity of the larger cross section towards multifragmentation reduces in the presence
of momentum-dependent interactions which make it difficult to extract the magnitude of nucleon-nucleon cross-section from multifragmentation. However, a large effect of different cross sections can be seen if a simple static equation of state is used.

In Chapter 5, we present a systematic comparison of different clusterization methods based on simple spatial correlation, spatial-momentum correlation and energy minimization (simulated annealing clusterization algorithm [SACA]) by simulating the reaction of O + Ag/Br. We find that the response of different clusterization algorithms depends on the asymmetry of a reaction. With the inclusion of momentum correlation (in terms of either a momentum cut or energy minimization of the system), the fragments originate between 60-100 fm/c. The response of larger nucleon-nucleon cross section and also of momentum dependent interaction is different in different clusterization algorithms. It is maximum with spatial correlation method whereas it is least with SACA. Interestingly, in the presence of a larger nucleon-nucleon cross section, the momentum cut and energy minimization methods yield similar evolution. This is true at higher incident energies where the frequency of the nucleon-nucleon collisions is very large.

The role of spatial correlations (i.e., the range of clusterization) along with the role of the range of interaction in multifragmentation is investigated in Chapter 6. The clusterization of phase space is done with minimum spanning tree method. We find that the effect of different ranges of clusterization and interactions depends on the physical conditions and excitation energy of the system. The impact of different clusterization ranges is more than marginal in the presence of a momentum dependent interaction which is different than that obtained with a static equation of state.

In Chapter 7, we analyze the time evolution of the multiplicity of different fragments as well as entropy of the system. We also investigate the dependence of the multiplicity of various light fragments (with mass ≤ 10) on the size of the system. This was achieved by studying the symmetric reactions of Ca+Ca, Ni+Ni, Nb+Nb, Xe+Xe, Er+Er, Au+Au and U+U at incident energies between 50 MeV/nucleon and 1 GeV/nucleon. We
find that the light mass fragments are formed at a very early stage of the reaction. The lighter colliding nuclei generate less density whereas higher density is achieved with heavy nuclei. The relative yields of the light fragments \((d, t, a)\) depend strongly on the impact parameter as well as on the bombarding energy. Similarly, the entropy of the system increases linearly with bombarding energy. Our detailed analysis shows that the triggering of multifragmentation and its saturation is delayed in heavier systems. The striking result, which is independent of the incident energy and impact parameter, is that the mass dependence of the multiplicity of any kind of fragment exhibits a power law behavior \(\propto A_{\text{tot}}^{\tau}\) where \(A_{\text{tot}}\) is the mass of the composite system. Similar mass dependencies have already been reported in the literature for the fusion process at low incident energy and for the production of kaon and collective flow (and its disappearance) at intermediate energies. As reported for the production of kaons, the parameter \(\tau\) depends on the colliding geometry as well as on the incident energy. No unique dependence of \(\tau\) (like in the case of disappearance of flow) exists. The value of \(\tau\) in central low energy collisions is close to 2/3 which suggests the dominance of the mean field. On the other hand, a linear dependence occurs at higher incident energies. The rapidity distribution of the various fragments is also affected by the size of the system. The fragments emitted from the heavier system seem to be better thermalized compared to the one emitted from lighter colliding nuclei. Similar trends can also be seen in the preliminary reports of the FOPI experiments.

Finally, we will summarize our results along with an outlook in chapter 8.