Name	:	Jan Shabir Ahmad
Supervisor	:	Prof. Saeed Uddin
Co-Supervisors	:	Dr. Mohd. Farooq Mir (Deptt. of Physics, Kasmir University)
Institute	:	Department of Physics, Jamia Millia Islamia, New Delhi-110025.
Title of Ph. D. Thesis	:	Multi-Particle Production and Formation of Quark Gluon Plasma in High Energy Heavy-Ion Collisions.

Abstract

The thesis entitled "Multi-Particle Production and Formation of Quark Gluon Plasma in High Energy Heavy-Ion Collisions" contains a detailed study of the the characteristics of the hot and dense hadronic matter formed in the ultra-relativistic nucleus- nucleus collisions. A thorough analysis is carried out in the framework of statistical thermal models. In the following a chapterwise description of the work done and presented in the thesis is provided.

In Chapter 1 we have provided a detailed description of the Quantum Electrodynamics (QED) and Quantum Chromodynamics (QCD) and in particular have talked about two main features of QCD (Colour Confinement and Asymptotic Freedom). How these properties guide us to know about the much expected novel state of hadronic matter named QGP has also been widely discussed. Besides, the Space-Time diagram of heavy ion collisions has been explained with its different stages i.e., its time evolution. Also, we have examined the present experimental and theoretical scenarios related to the field of ultra-relativistic heavy ion collisions that have emerged with the advent of new collider machines used for the search of this novel state of QGP. Additionally, the future programs in this direction have been specifically highlighted keeping in mind the developments that have taken place in the remote as well as in the recent past. A brief description of our expectations pinned with the LHC machine is also placed in writing in the chapter under discussion. Finally, we have shown that statistical thermodynamics is a powerful tool which sets rules for such a system to undergo phase transition. The thermal models can not describe the history of the fireball i.e., its time evolution, however it can still be a powerful tool to calculate the various properties of the system.

In chapter 2, a detailed study of various rapidity spectra described by the extended statistical model has been presented. The motivation of the model in hand is based on the fact that the mid-rapidity region of the interacting nuclear matter shows partial transparency at the highest RHIC energy (200 GeV). The

model essentially rests on the assumption that the formation of hot and dense regions (fireballs) occurs along the beam axis with increasing rapidities $y_{FB.}$ Besides, the chemical potentials of these different regions are assumed to be dependent on the corresponding rapidities of the fireball regions. The final state hadrons are assumed to have emerged out from these local fireball regions at the time of freeze-out following a (local) thermal distribution. A Gaussian profile in y_{FB} has been incorporated to weigh the contributions of these local regions to the population of the final state hadrons where the parameter σ controls the width of the Gaussian distribution. The baryon chemical potentials of various regions is being fixed by using a quadratic profile in y_{FB} . With the present model we could explain not only the net proton, ratio $\bar{p}/p$ and pion flow but also the individual proton, antiproton, Kaon, antiKaon, $\bar{\Lambda}/\Lambda$ and the $\bar{\Xi}/\Xi$ rapidity spectra. Therefore, we find that the model can successfully explain the rapidity distribution data of non-strange as well as the strange hadrons, measured in the same experiment by the BRAHMS and the STAR collaborations. All this is achieved by using *single* set of the model parameters. We have calculated the effect of the resonance decay products on the rapidity spectra of the hadrons. We find that the rapidity spectra of the decay products are very slightly narrower than that of the parent hadrons. It has also been noticed that the *mass dependence* of rapidity spectra is one of the important features of this model. This is seen from the fact that the lower mass spectra are slightly flatter than the higher mass spectra.

In chapter 3, we have suitably modified the previously discussed thermal model to describe the rapidity as well as transverse momentum spectra of various strange and non-strange hadrons in a single thermal freeze-out model. This is achieved by incorporating a longitudinal as well as a transverse flow simultaneously. The system size is assumed to decrease in the transverse directions following a Gaussian profile in the z-coordinate. The model provides a very good simultaneous description of the rapidity and transverse momentum spectra of protons and antiprotons obtained from the 0 – 5% most central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at RHIC. We also obtained various results on rapidity and transverse momentum spectra of hyperons and antihyperons. The various results are in accordance with the expectations of the theoretical model and the present experimental scenario. The spectra of various particle species and their relative abundance are possible to explain only by invoking a scenario of sequential freeze-out. Under this scenario the chemical freeze-out of different kinds of particles is assumed to take place at different temperatures and also at different chemical potentials.

In chapter 4, we have investigated how strangeness production within a fireball of rapidly expanding matter can strengthen the phase transition between QGP and hadron resonance gas (HRG). This has been done by calculating the number density ratios of various species among which the important ones are $n_{\bar{k}}/n_k$, $n_{\bar{\Lambda}}/n_{\Lambda}$, $n_{\bar{\Xi}}/n_{\Xi}$, n_{Λ}/n_p and $n_{\bar{\Lambda}}/n_{\bar{P}}$. All these have been produced in the QGP scenario and the hadronic phase separately using the full quantum distribution functions and setting the strangeness conservation criteria in each case *individually.* It has been found that the behaviours of the relative abundances in the two environments are quite different. The increasing behavior of $n_{\bar{k}}/n_k$ yield when drawn with temperature, in case of QGP is reverse to the behaviour shown by the same ratio in the hadronic phase thereby giving a clear indication of the environment they have come from. Secondly, the ratio $n_{\bar{k}}/n_k$ is equal to the ratio $n_{\bar{\Xi}}/n_{\Xi}$, in the QGP phase because the two yields corresponding to a particular temperature and chemical potential are found to be same. The values of the same two ratios in the hadronic gas are found to be altogether different and hence can give us the indirect information about the formation of QGP phase. Lastly the enhancement of $n_{\bar{\Lambda}}/n_{\bar{P}}$ abundance in the phase of QGP over that in the hadronic phase is also an indicator to be used for differentiating the two phases.

In nut shell the enhancement of abundances of different particle ratios in the QGP with respect to that in a hadron phase is in agreement with the earlier studies made in this direction.

In chaper 5, we finally present the summary of the research work done and the main results obtained. In particular we have emphasized that how these studies can throw light on the further studies of heavy ion collisions. For instance it can be seen as to how the model fitting will work when it is applied on the experimental data obtained at SPS energies like, 8 GeV/A, 20 GeV/A, 50 GeV/A, and 158 GeV/A. Besides, their power of applicability can be judged by applying them on compressed baryonic matter (CBM) at comparatively lower temperatures and high baryon chemical potentials.