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Role of Finite Size Baryons in QCD Phase Transition and Critical Point

The physics regarding the existence of the critical point on the QCD phase boundary still remains unclear and its precise location is quite uncertain. We follow the suggestion of T. D. Lee et. al. [Phys. Rev. D9, 2291 (1974)] that a phase transition at high baryon density in a bulk matter can be realized in which nucleon loses part of its mass and thus baryons play a significant role in the phase transition. We suggest that the hadron gas consists of pointlike mesons and each baryon having a geometrical hard-core size. It means that mesons can fuse into one another while baryons experience a repulsive force with other baryons when densely packed. We formulate an excluded volume model existing for the equation of state (EOS) of hot, dense hadron gas and for the quark gluon plasma we use a thermodynamically consistent quasiparticle model (QPM). We construct a first order phase transition using Gibbs' equilibrium criteria. This leads to an interesting and surprising finding that a critical point exists in such a formulation beyond which a cross-over region appears. We find that such a picture always appears in all excluded volume models considered in the literature. For ideal hadron gas model, there is no critical point in the diagram. In the mean field model also, we do not get a critical point unless we incorporate an excluded potential effect. Our analysis strongly suggests that the existence of a critical point and a cross-over region owes its explanation in the finite size baryons in the hadron gas. We find an interesting result that the ratio of the baryons to the total hadrons at the critical point is around 0.2 in all types of models and thus a cross-over region starts as soon as this ratio becomes smaller than 0.2.

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