The Transport Co-efficients of Two Component Hot Hadronic Matter

U. Gangopadhyaya[1],* S. Ghosh, S. Mitra, and S. Sarkar
Theoritical Physics Division, Variable Energy Cyclotron Centre, 1/AF Bidhannagar Kolkata-700064, INDIA

Introduction

Heavy ion collision experiments at RHIC showed large elliptic flow of emitted hadrons. This lead to the conclusion that the quark gluon plasma behaves as a nearly perfect fluid. This interpretation is based on the small but finite value of shear viscosity to entropy density ratio η/s. This gave rise to a great interest in transport coefficients of both partonic as well as hadronic matter.

Hydrodynamic equations may be derived from entropy considerations using the second law of thermodynamics, a microscopic approach is necessary in order to determine the parameters, e.g., the coefficients of shear and bulk viscosity, thermal conductivity. The Boltzmann transport equation has been used extensively to estimate the transport coefficients of relativistic imperfect fluids. Pions form the most significant part of hadronic system, and quite a few estimations of the transport coefficients of pion gas are available. Nucleons also form a significant bulk of the hadronic matter produced in heavy ion collision. We aim to find the medium effect on the transport coefficients[1–3] of this hadronic matter composed of mainly pions and nucleons. Here we try to find an estimation of the medium effect on the transport coefficient by employing relaxation time formalism.

Relaxation time Formalism

We begin with the relativistic Boltzmann transport equation for the phase-space density,

$$p^\mu \partial_\mu f_\pi = C_{\pi\pi} + C_{\pi N}$$

$$p^\mu \partial_\mu f_N = C_{N\pi} + C_{NN}$$

The slight deviation from equilibrium of the distribution function δf is given by the relation $p^\mu \partial_\mu f = -\frac{\delta f}{\tau}$, where τ represents the relaxation time. Since the distribution functions are supposed to be slightly deviated from equilibrium, the distribution functions of the pions and the nucleons are taken to be Bose-Einstein and Fermi-Dirac distribution functions respectively.

Since the energy momentum flux is given by

$$T^{\mu\nu} = \int d\Gamma p^\mu p^\nu f$$

The irreversible part of the energy momentum tensor which is parametrised by the transport coefficients, $\Pi^{\mu\nu} = \eta\{\frac{1}{2}(\triangle^\mu_\rho \triangle^\nu_\sigma + \triangle^\nu_\rho \triangle^\mu_\sigma) - \frac{1}{3}\triangle^{\mu\nu}\triangle_{\rho\sigma}\}\partial^\rho U^\sigma - \zeta \triangle^{\mu\nu}\partial_\alpha U^\alpha$ is give by

$$\Pi^{\mu\nu} = \int d\Gamma p^\mu p^\nu \delta f$$

Using the above formulas we get $\eta = \eta_\pi + \eta_N$ and $\zeta = \zeta_\pi + \zeta_N$. Where

$$\eta_\pi = \frac{g_\pi}{30\pi^2 T}\int \frac{d|\overrightarrow{p}|}{p_0}|\overrightarrow{p}|^2 f_\pi(1+f_\pi)\tau_\pi$$

$$\eta_N = \frac{g_N}{30\pi^2 T}\int \frac{d|\overrightarrow{p}|}{p_0}|\overrightarrow{p}|^2 f_N(1-f_N)\tau_N$$

and,

$$\zeta_\pi = \frac{g_\pi}{6\pi^2}\int \frac{d|\overrightarrow{p}|}{p_0}|\overrightarrow{p}|^2 Q_\pi \tau_\pi f_\pi(1+f_\pi)$$

$$\zeta_N = \frac{g_N}{6\pi^2}\int \frac{d|\overrightarrow{p}|}{p_0}|\overrightarrow{p}|^2 Q_N \tau_N f_N(1-f_N)$$

*Electronic address: `utsabgang@gmail.com`

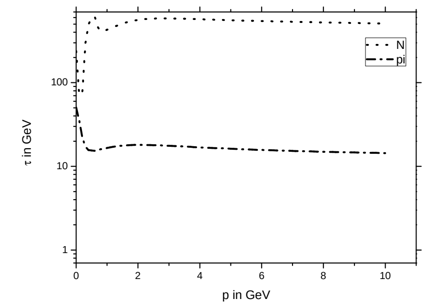

FIG. 1: The relaxation time of the pion and the nucleon at temperature MeV

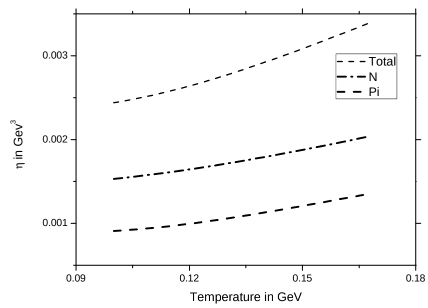

FIG. 2: The Shear viscosity coefficient for π, N and for the two component system. The chemical potential for pion and nucleon is taken to be 0MeV and 150 MeV respectively.

The relaxation time is given by

$$\tau_1^{-1} = \sum_2 \frac{g_2}{1+\delta_{12}} \tau_{12}^{-1}$$

Where τ_{12}^{-1} is the rate of reaction of particle (1) with particle (2).

Fig. 1 shows a shows the τ vs momentum of the incident particle at temperature 150 MeV. the chemical potential of pion and nucleon is taken to be zero and 150 MeV respectively.

Results

Fig. 2 shows the η vs temperature graph using vacuum cross-section, where the chemical potential of pion is taken to be zero and the chemical potential for nucleon is taken to be 150 MeV. The viscous contributions, of pions and nucleons have been plotted separately.

Plotting the Shear viscosity with temperature we see that the coefficient of shear viscosity increases with temperature, it is mainly due to the fact that the interaction decreases with increasing temperature i.e. increasing energy of the interacting particle, hence larger relaxation time. With the introduction of medium effects, the relaxation time is expected to increase; hence a larger value of coefficient of shear viscosity is expected.

References

[1] Sukanya Mitra, Sabyasachi Ghosh and Sourav Sarkar, Phys. Rev. C85, 064917 (2012)

[2] Sukanya Mitra and Sourav Sarkar Physical Review D87(2013)094026

[3] Sukanya Mitra, Utsab Gangopadhyaya and Sourav Sarkar, Phys. Rev. D91 094012 (2015)