We introduce a kinetical description of the hadronization of semi-deconfined quark matter produced in heavy ion collisions. A minimal microscopic model is considered in which the produced quarks and anti-quarks are redistributed into hadrons according to the additive quark model. Assuming thermalized quark matter and hadron matter we determine the appropriate parameters to describe the properties of both matter before and after hadronization. We find an adiabatic hadronization.

In heavy ion collisions the evolution of hadronic fireball was successfully described by the hadrochemical model \cite{1}. This model is based on elementary processes in which hadron-hadron collisions lead to the production of other type of hadrons. The time-evolution of the hadronic system was described by a set of coupled differential equations in which the time-dependent gain and loss terms were determined by means of microscopical cross-sections for the elementary processes. On the basis of the success of the hadrochemistry the quarkochemistry model \cite{2} was developed to describe the evolution of quark matter produced at ultra-relativistic energies. The constituents of the quark-gluon plasma became the ingredients of the microscopical processes and the cross sections could be obtained in various ways.

In recent relativistic heavy ion collisions (see Pb+Pb at CERN SPS) we expect the partial deconfinement of hadronic matter and the appearance of some sort of **semi-deconfined quark matter** \cite{3}. This deconfined state will not be a quark-gluon plasma (QGP) with massless gluons and quarks in full equilibrium, but rather a mixture of quarks and diquarks coming from the wounded nucleons, and of course some newly produced quark-antiquark pairs, diquarks and anti-diquarks. We assume that this mixture is thermalized or very close to it. Further assumption is that the diquarks and anti-diquarks are such objects which are existing just temporally and they are not real degrees of freedom. Thus we have the quarks and anti-quarks as basic colored components. Considering the gluons we assume that they are dressing the quarks which have some effective mass. To describe the hadronization of such a semi-deconfined quark matter, a kinetical model could be very appropriate which would be the framework for the underlying microscopical hadronization processes.

In a recent paper \cite{5} we introduced a model in which the elementary processes contain the constituents of the above mentioned semi-deconfined quark matter as incoming particles and the constituents of the hadron matter as outgoing particles. In this way the elementary processes of the phase transition from quark phase to hadron phase can be modeled. This model, which is essentially an extension of the earlier ALCOR model \cite{6}, may be called **transchemistry**, i.e. the chemical-like description of the phase transition. If the thermalization remains valid during this transition then we can follow the entropy production in the system. But this transition definitely will not be a fully equilibrated one, because the

\footnote{The talk was presented by P. Lévai at the Workshop on Quantum Chromodynamics (3-8 June 1996, AUP Paris, France) and it will be published in the Proceedings of the Workshop.}
microscopical processes will determine the number of the different species, thus the system will stay far from any chemical equilibrium.

Considering the microscopical hadronization mechanisms here we will assume that the production of the hadrons can be connected to the additive quark model, e.g. a meson, which consists of quark and anti-quark, \( M_{ij} \equiv (q_i \bar{q}_j) \), will be produced from quark and anti-quark. Furthermore we can define a minimal transchemistry model, in which we assume that all constituent quarks and antiquarks are present in the semi-deconfined quark matter from the beginning of the hadronization and they will be confined into the hadrons in a minimal way, namely \( q_i + \bar{q}_j \leftrightarrow M_{ij} \), or especially \( q + \bar{q} \leftrightarrow \pi \). In this case one can introduce the following rate-equations for the pion, quark and antiquark numbers [3]:

\[
\frac{d}{dt} N_\pi(t) = \frac{D(\pi) \cdot \langle \sigma_{\pi} v(t) \rangle}{V(t)} \cdot N_q(t) \cdot N_{\bar{q}}(t) - N_\pi(t) \cdot \Gamma_\pi \tag{1}
\]

\[
\frac{d}{dt} N_q(t) = - \frac{D(\pi) \cdot \langle \sigma_{\pi} v(t) \rangle}{V(t)} \cdot N_q(t) \cdot N_{\bar{q}}(t) + N_\pi(t) \cdot \Gamma_\pi \tag{2}
\]

\[
\frac{d}{dt} N_{\bar{q}}(t) = - \frac{D(\pi) \cdot \langle \sigma_{\pi} v(t) \rangle}{V(t)} \cdot N_q(t) \cdot N_{\bar{q}}(t) + N_\pi(t) \cdot \Gamma_\pi \tag{3}
\]

Here \( N_i(t) \) denotes the number of particle \( i \), \( V(t) \) is the reaction volume, and \( \Gamma_\pi \) denotes the loss term for pions related to their ‘decay’ (or re-entering the semi-deconfined quark matter) which is approximately equal to the expected one, \( \Gamma_\pi \approx \frac{E \cdot v}{m_{\pi}} \cdot \text{s}^{-1} \).

The conservation of quark and antiquark number plays a crucial role in the ALCOR model [6], which is the linearized version of the transchemistry.

Note, that we can extend this minimal transchemistry model, introducing different microscopical hadronization mechanisms, which will yield different coefficients in the above equations.

Now we will apply the minimal transchemistry model and its linearized version, the ALCOR, for the Pb+Pb collision at 160 GeV/nucleon. bombarding energy. In Table 1 we display the produced particle numbers, entropy and energy for the outcomeing hadron gas. Investigating the experimental results [7], especially the transverse momentum distributions, one can find a cylindrically symmetric thermalized hadronic fireball to fit the measured particle distributions and numbers (for more details see Ref. [3]). We obtained that the fireball can be characterized by a central temperature \( T_0 = 165 \text{ MeV} \) and radial temperature profile \( T(r) = T_0 \cdot [1 - (r/R)^2] \), a linear transverse velocity profile with average transverse flow \( < v_t > = 0.38 \), a transverse radius \( R = 14 \text{ fm} \) and a proper time \( \tau = 6 \text{ fm} \).

The total entropy of the produced hadron gas is \( S = 11745 \). Combining this entropy value with the participant baryon number, \( N_B = 390 \), one obtains that it is \( S/N_B = 30 \) in the Pb+Pb collision. The total energy is \( E = 3267 \text{ GeV} \) (note that this energy contains both the thermal and the flow energy) which is approximately equal to the expected one, \( E_{CM} = 390/2 \cdot 17.4 = 3390 \text{ GeV} \).
Table 1: Particle numbers, entropy and CM energy (in GeV) predicted by the ALCOR model for the Pb+Pb collision at 160 GeV/nucleon bombarding energy.

| Pb+Pb | NUMBER | ENTROPY | ENERGY |
|-------|--------|---------|--------|
| \( h^- \) | 730.41 | —       | —      |
| \( \pi^+ \) | 603.87 | 1931 | 487 |
| \( \pi^- \) | 618.95 | 1959 | 497 |
| \( \pi^0 \) | 634.68 | 1995 | 510 |
| \( K^+ \) | 84.15 | 490 | 121 |
| \( K^0 \) | 84.15 | 490 | 121 |
| \( \overline{K}^0 \) | 41.65 | 271 | 60 |
| \( K^- \) | 41.65 | 271 | 60 |
| \( K_S^0 \) | 62.90 | — | — |
| \( p^+ \) | 170.90 | 1137 | 393 |
| \( n^0 \) | 188.57 | 1247 | 438 |
| \( \Sigma^+ \) | 12.86 | 118 | 34 |
| \( \Sigma^0 \) | 13.63 | 124 | 36 |
| \( \Sigma^- \) | 14.43 | 130 | 38 |
| \( \Lambda^0 \) | 68.20 | 526 | 178 |
| \( \Xi^0 \) | 8.82 | 85 | 25 |
| \( \Xi^- \) | 8.89 | 86 | 25 |
| \( \Omega^- \) | 1.48 | 18 | 5 |
| \( \overline{p} \) | 25.07 | 206 | 55 |
| \( \pi^0 \) | 25.07 | 206 | 55 |
| \( \Sigma^+ \) | 4.18 | 43 | 11 |
| \( \Sigma^0 \) | 4.18 | 43 | 11 |
| \( \Sigma^- \) | 4.18 | 43 | 11 |
| \( \Lambda^0 \) | 20.93 | 181 | 53 |
| \( \Xi^0 \) | 5.98 | 59 | 17 |
| \( \Xi^- \) | 5.98 | 59 | 17 |
| \( \Omega^+ \) | 2.20 | 27 | 8 |
| **Total:** | — | 11745 | 3267 |
Now we assume that the initial quark matter was very much in the same condition as the produced hadron matter, namely the central temperature was $T = 165 \text{ MeV}$ and there were similar temperature and velocity profiles which did not change during hadronization. However, the hadronization takes some time, thus the volume of the quark matter must have been smaller. We assume a hadronization time $\Delta \tau = 4 \text{ fm}$, thus the transverse radius was $R = 10 \text{ fm}$ at proper time $\tau = 2 \text{ fm}$. Furthermore, we need to reproduce the quark and antiquark numbers obtained from ALCOR \cite{5} for this early, partially deconfined state: $N_u = 1007$, $N_{\bar{u}} = 464$, $N_d = 1089$, $N_{\bar{d}} = 464$, $N_s = N_{\bar{s}} = 236$. We can reproduce these quark numbers at the above parameters, if the quark effective masses are $m_q = 150 \text{ MeV}$ and $m_s = 300 \text{ MeV}$. (Note, that we are in the non-perturbative region, on the other hand the expression $m_q = gT/\sqrt{6}$ yields the same effective mass value for light quark at temperature $T = 165 \text{ MeV}$ and $\alpha_s = 0.4$. For the effective strange quark mass one can use that $m_s \approx gT/\sqrt{6} + m_{s,0}$, where $m_{s,0} = 150 \text{ MeV}$ is the bare mass.) For the semi-deconfined quark matter we obtained total entropy $S = 11390$ and total energy $E = 3306 \text{ GeV}$, which are approximately the same values than for the hadronic matter.

In conclusion we obtained that our minimal hadronization model, which based on the idea of redistribution of quarks and anti-quarks, yields an adiabatic hadronization process with $\Delta \tau = 4 \text{ fm}$ hadronization time in the Pb+Pb collision at SPS energy. A more extended numerical calculation containing other microscopical hadronization mechanisms is in progress to obtain more details about the time-evolution of hadronization and entropy production.

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