Status of liquid-gas phase transition studies

Definition:

Liquid phase = well bound nuclear fragments
gas = nucleons and weakly bound light particles

• Large multiplicities of fragments and light particles.
  – also observed in light ion collisions.
• Two fragment correlations indicate fragments and particles produced in close proximity.

> Indicates interacting mixture of liquid and gas phases: mixed phase
  > Not necessarily in equilibrium
Observed “boiling”

Au+Au, E/A = 35 MeV
Central collisions
Huang, PRL 78, 1648 (1995).

- Consistent temperatures $T \approx 4-4.5$ are observed for heavy systems near multi-fragmentation threshold.

$T_{em} = 4.2 \pm 0.6$ MeV  $T_{em} = 4.4 \pm 0.2$ MeV

- Enhanced heat capacity observed.
- Clearest evidence near threshold.
  - Secondary decay and other corrections are small there.

$^{5}$Li $^{4}$He $^{10}$B

Xi et al., PRC 54, R2163 (1996).

Huang, PRL 78, 1648 (1997).
Other issues

- Scaling laws observed - necessary requirement for P.T.
  - Scaling of multiplicity distributions.
  - Scaling of charge distributions.
  - Scaling of isotopic distributions.

- Models indicate fragmentation occurs at densities consistent with a mixed phase.
  - Equilibrium models: multi-fragmentation is low density P.T.
  - Rate equations: fragmentation occurs within isothermal spinodal.
  - Dynamical models: spinodal decomposition.
  - Correlations indicate commensurate densities.
  - Major question: what is the degree of thermalization? i.e. is equilibrium achieved?

- Observables are largely phase space dominated:
  - Equilibrium models are relatively successful, but malleable.
    - Success ≠ proof.
  - Cooling, non-equilibrium effects are broadly observed. Need to understand them better.

- New signals: negative heat capacity, bimodality, fossil signals of spinodal decomposition.
  - Are they robust?
  - Are their interpretations unique?

- Major task: how does one extract information about P.T from finite, short-lived, dynamically evolving systems?

- Extrapolation to astrophysical environments: asymmetry dependence?