Asymmetry Effects in Nuclear Fragmentation

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With the development of the physics of radioactive beams it is of great interest to determine the asymmetry part of the nuclear equation-of-state. While the value at saturation density is well known from the mass formula the behavior at higher and lower densities is rather uncertain. One way to study this is in the compression and expansion phases of heavy ion collisions.

Information on dynamic effects and phase transitions can also be obtained from linear response theory. In two compound systems one has to distinguish between two types of instabilities, the usual mechanical instability $\frac{\partial P}{\partial \rho} < 0$, and the chemical instability $\frac{\partial \mu}{\partial y} < 0, (y = 3D\,\frac{Z}{A})$, associated with charge fluctuations. Linear response theory shows that the instability region shrinks with increasing asymmetry and that the instability is driven by chemical instabilities [1]. One also finds that the response is less asymmetric than the initial asymmetry. Transport calculations in a box show that infinite nuclear matter fractionates into more symmetric heavy fragments ("liquid") and very asymmetric, neutron rich nucleons and light clusters ("gas") [2]. We studied how these behaviors manifest themselves in finite systems, i.e. in heavy ion collision, in the Fermi energy domain. Since we are investigating fragment formation the physical amount of fluctuations is important in the transport calculation. In this work we are using a stochastic transport approach which inserts statistical density fluctuations into the evolution [3].

We have performed systematic calculations of symmetric $Sn + Sn$ collisions of neutron-rich (^{124}Sn) and neutron-poor (^{112}Sn) species. We have studied these for central and peripheral collisons and for different assumptions on the symmetry part of the EOS. We observe the following interesting effects: (1) There is a strong difference in asymmetry in liquid and gas depending on the initial asymmetry with a characteristic evolution during the reaction. (2) This charge fractionation is very different in central and peripheral collisions, in particular, for the intermediate mass fragments originating from the neck. (3) We observe significant differences in the primary charge fractionation for different density dependence of the asymmetry EOS. It has to be seen how these effects survive the secondary decay of the excited fragments and how they can be observed experimentally [4].

References

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