Fluid Density Fluctuations in Porous Systems with Quenched Correlated Disorder

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Phase transitions can be drastically modified by confinement and disorder. The liquid-vapor critical behavior in porous systems with quenched correlated disorder, such as aerogels, is of particular interest since it may provide an experimental realization of the Random Field Ising Model (RFIM). Theoretical considerations suggest that a new set of critical indices may appear in the fluid with quenched correlated impurities implying possible transition to a new universality class for confined systems. Experiments on the phase diagrams reported the bulk (Ising model) values of the critical index β of the coexistence curves of confined ^{4}He and N_2. At the same time, studies of the superfluid transitions and heat capacity of ^{4}He in aerogels demonstrated substantial difference between critical indices for bulk and confined fluid. Evidently, much more experimental work is needed in order to elucidate the influence of quenched disorder on the phase behavior of confined fluids.

Small angle neutron scattering (SANS) is an ideal tool for investigating the correlation length ξ and susceptibility χ of confined systems as it can probe the local structure and thermodynamic properties of fluids in small pores of the order on 1 - 100 nm. In this paper we report results of the first SANS investigations of the temperature variation of ξ and χ of carbon dioxide (CO_2) confined in porous matrix of an aerogel. We demonstrate that, despite the fact that scattering from blank aerogel exceeds that from blank CO_2 by two orders of magnitudes, the temperature and pressure variation of thermodynamic properties of confined fluids can be extracted and explored. The structure factor of the confined fluid can be described by equation based on the RFIM. Experiments demonstrate that quenched disorder moderates the density fluctuations of confined fluid even at off-critical average fluid density at length scales smaller than the correlation length of the aerogel. The effects of confinement should become more pronounced in the critical region of confined fluids and more experiments are in progress in order to investigate the critical behavior of confined CO_2. Possible extensions of the initiated SANS studies to various porous matrices and fluids will be discussed.