Global isomorphism between molecular fluids and ising-like models: Yukawa fluid case

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Zeno-line and asymmetry effects of liquid-vapor equilibrium for molecular fluids are considered within the global isomorphism with the Ising-like models. The latter is based on the geometric reformulation of the (approximate) linearities of the density binodal diameter (the rectilinear diameter law) and the unit compressibility line (the Zeno-line). The correspondence takes the form of projective mapping between thermodynamic states of a fluid characterized by density n and temperature T and the Ising-like (lattice gas) model with density x and temperature t variables correspondingly:

$$T = T_*\,\frac{z\,\tilde{t}}{1+z\,\tilde{t}}\,,\quad n = n_*\,\frac{x}{1+z\,\tilde{t}}\,,\quad \tilde{t} = t/t_c \qquad (1)$$

We demonstrate how the parameters n_* and T_* of the transformation (1) depend on the screening parameter λ of the potential:

$$\Phi_{HCYF}(r) = \begin{cases} -\Phi_0\,\frac{e^{-\lambda\, r/\sigma}}{r/\sigma}, & \text{if } r > \sigma \\ +\infty, & \text{if } r \le \sigma. \end{cases}$$

of hard core Yukawa fluid (HCYF) class of systems. These parameters determine the critical point locus. Based on simulation data we show that besides the rectilinear diameter law HCYF demonstrates some other linearities which follow from Eq. (1). In particular we construct the critical point line in reduced variables $(T_c/T_*, n_c/n_*)$. The drastic difference in behavior of $n_*(\lambda)$ and standard Boyle-related parameter $n_B(\lambda)$ of the Zeno-line leads to the theoretical value λ_* above which the liquid branch of the binodal lose its stability. The results are compared to those of computer simulations. The peculiar linear correlation between n_c and $1/T_c$ first observed in simulations of Y. Duda et al. is obtained on the basis of projective isomorphism relations (1) for not too short-ranged potentials ($\lambda < 6$) where the stability of liquid phase takes place.