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Density-Temperature-Softness Scaling of the Dynamics of Glass-forming Soft-sphere Liquids[1]

MAGDALENO MEDINA-NOYOLA, Instituto de Física, Universidad Autónoma de San Luis Potosí

We employ the principle of dynamic equivalence between soft-sphere and hard-sphere fluids [Phys. Rev. E **68**, 011405 (2003); Phys. Rev. Lett. **107**, 155701 (2011)] to describe the interplay of the effects of varying the density n, the temperature T, and the softness (characterized by a softness parameter ν^{-1}) on the dynamics of glass-forming soft-sphere liquids in terms of simple scaling rules. The main prediction is the existence of a dynamic universality class associated with the hard sphere fluid, constituted by the soft-sphere systems whose dynamic parameters, such as the α-relaxation time and the long-time self-diffusion coefficient, depend on n, T, and ν only through the reduced density $n^* \equiv n\sigma_{HS}^3(n,T,\nu)$, where the effective hard-sphere diameter $\sigma_{HS}(n,T,\nu)$ is determined by the Andersen-Weeks-Chandler condition for soft-sphere–hard-sphere structural equivalence. A number of scaling properties observed in recent experiments and simulations involving glass-forming fluids with repulsive short range interactions are found to be a direct manifestation of this general dynamic equivalence principle. The self-consistent generalized Langevin equation (SCGLE) theory of colloid dynamics [Phys. Rev. E **76**, 041504, 062502 (2007)] is shown to accurately capture these scaling rules. The non-equilibrium extension of this theory [Phys. Rev. E **82**, 061503, 061504 (2010)] is employed to describe the manifestation of this scaling on the aging of instantaneously-quenched soft-sphere liquids.

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