Transport of nanoparticles in a temperature gradient

SHAWN PUTNAM, DAVID CAHILL, Center of Advanced Materials for the Purification of Water with Systems, Univ. of Illinois — Thermodiffusion, mass transport in a temperature gradient, is commonly characterized by either the thermodiffusion coefficient $D_T$ or the Soret coefficient $S_T$; e.g., at low particle concentration $c$, the particle flux of a colloidal suspension subjected to a temperature gradient $\nabla T$ is

$$J = -c D_T \nabla T - D_c \nabla c,$$

where $D_c$ is the diffusion coefficient and the Soret coefficient is $S_T = D_T / D_c$. We present our measured $D_T$ data for aqueous suspensions of charged polystyrene spheres, alumina nanoparticles, and globular proteins of lysozyme. Special emphasis is given to our published work on charged polystyrene spheres with different surface functionalities. For example, in solutions with large concentrations of monovalent salts, $\gtrsim 100 \text{ mM}$, $D_T$ for 26 nm spheres with carboxyl functionality can be varied within the range $-0.9 \times 10^{-7} \text{ cm}^2 \text{ s}^{-1} \text{ K}^{-1} < D_T < 1.5 \times 10^{-7} \text{ cm}^2 \text{ s}^{-1} \text{ K}^{-1}$ by changing the ionic species in solution; in this case $D_T$ is the product of the electrophoretic mobility $\mu_E$ and the Seebeck coefficient of the electrolyte $S_e = (Q^*_C - Q^*_A) / 2 e T$, $D_T = -S_e \mu_E$, where $Q^*_C$ and $Q^*_A$ are the single ion heats of transport of the cationic and anionic species respectively. On the contrary, in low ionic strength solutions of LiCl, $\lesssim 5 \text{ mM}$, $D_T$ for the 26nm carboxyl spheres is negative, independent of particle concentration, and independent of the Debye length; $D_T = -0.73 \pm 0.05 \times 10^{-7} \text{ cm}^2 \text{ s}^{-1} \text{ K}^{-1}$. The temperature dependence of $D_T$ is also discussed with results from our current work with polystyrene spheres, alumina nanoparticles, and protein solutions of lysozyme.