An Experimentalist's Perspective on the Phase Behaviour and Transport Properties of Nano Colloids

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The phase behavior and properties of nanocolloids is driven by the interplay between inherently attractive dispersion energies leading to particle flocculation and potentially to phase separation, and repulsive energies that stabilize particles in a dispersed form. For dispersion energies large relative to thermal energy all individual particles become flocculated over time. The state/structure of flocs is time and flocculation mechanism(s) dependent but largely temperature independent. Macroscopic phase(s) may emerge over time. For dispersion energies comparable to thermal energy, equilibrium between flocculated and individual particles occurs and distinct macroscopic phases where species have equal chemical potentials may form. For dispersion energies weak compared to thermal energy, particle flocs do not form. The colloid comprises a single stable phase. Repulsive energies can arise from electrostatic forces among particles, sorption of species from solution onto particles and they help stabilize dispersed particles. In this contribution, we review key concepts, then focus on the phase behaviour and properties of sols (nanoscale domains are dispersed in a liquid) and gels (nanoscale domains form a three-dimensional network in a liquid) where equilibrium concepts apply. The nanoscale domains comprise well-defined and discrete particles (silica, diamond, carbon nanotubes, gold) with and without ligands on their surfaces, and poorly defined asphaltene-rich domains in mineral oils. Phase diagrams and rheology of sols + nonsorbing polymer, transitions from Fickian to Single-File diffusion as sols become more concentrated, and interfacial tension results are presented. Parallels among these cases provide surprises and insights worth pursuing, and illustrate challenges for modelling equilibrium, interfacial and transport properties both for well-defined and poorly defined nano colloids. Applications from mining to medicine, and from petroleum to pesticides are implicated!