

Homework 6 Properties of Materials

- 1) The Einstein-Stokes equation defines the diffusion coefficient for colloidal particles.
- Give Stokes' law and show by a unit balance that the friction factor should depend on the first power of the particle size.
 - Give the Einstein-Stokes equation and explain why the diffusion coefficient should increase with temperature and decrease with particle size.
 - The Einstein-Stokes equation includes the shear viscosity which is defined by

$$\tau_{x,y} = \eta \dot{\gamma}_{x,y}$$
 Explain what the subscripts x and y refer to in $\tau_{x,y}$ and in $\dot{\gamma}_{x,y}$ using a sketch of shear flow with Cartesian coordinates (define the directions of force and velocity).
 - Compare the friction factor with a drag coefficient such as is used to rank the drag in automotive body design.
 - Explain how the specific surface area is measured by gas adsorption.
 - What is BET theory (look this up on the web). Compare the BET theory with the Langmuir isotherm.
- 2) Atoms and molecules interact through bond formation but can also have weaker electrostatic interactions. Electrostatic interactions are important to colloids and are related to the Lennard-Jones 6-12 potential.
- List the three types of van der Waals interactions and describe each in terms of mechanism.
 - What is the 6-12 potential and what are the origins of each of the two terms in this potential.
 - Why are van der Waals forces insufficient to describe the interaction between colloidal particles?
 - For two plates the attractive potential that is derived from van der Waals interactions is $-A_H/(12\pi h^2)$ while the attractive potential between two spherical particles (Derjaguin approximation) is $-A_H R/(12h)$. At what length h do the attractive potential of plates with an area of 10nm diameter and spheres of 10nm diameter equal each other?
 - Explain the answer to part d.
- 3). The Hamaker Constant varies when colloidal particles are immersed in a solvent

$10^{20} \times \text{Hamaker Constant (J)}$

Material	Vacuum	Water	n-Dodecane
6H-SiC	25	13	1
tetra-ZrO ₂	20	8.8	6.8
β -Si ₃ N ₄	18	7.0	5.0
Al ₂ O ₃	15	5.2	3.6
Y ₂ O ₃	13	4.0	2.6
MgO	12	3.2	1.9
MgAl ₂ O ₄	13	3.5	2.1
SiO ₂	6.5	0.83	0.15

$A_H = \pi \times 10^{-20} \text{ J}$

- Explain why the Hamaker constant changes with solvent and why the values is lowest in dodecane when compared to water for silica particles.
- If one were interested in a stable colloidal dispersion of silica what solvent would be useful? Explain why.

- c) Surface charge can stabilize colloidal particles. Does the Hamaker constant describe charged colloidal particles? Explain.
- d) Sketch the ions surrounding a charged colloidal particle following the Helmholtz model, the Stern model (Stern Layer and Stern Plane) and the Gouy-Chapman model with the Debye Screening Length.
- e) What is the difference between the Stern potential and the Zeta potential?