



Colloidal Stability

Many industrial products are two phase systems such as solid in liquid suspensions or liquid/liquid emulsions. When the scale length of the dispersed phase ranges from 1 nm to 1 micron we can call the product a colloidal dispersion. The goal of most colloidal dispersions is to keep the product in a state similar to the original conditions, avoiding problems such as aggregation, flocculation or phase separation. Measuring the particle size and zeta potential of the colloidal dispersion is helpful for formulators creating new products and QC chemists monitoring batches of product.

		Dispersed Phase		
		Gas	Liquid	Solid
Continuous Phase	Gas	None (gases are inherently miscible)	Liquid aerosol <i>Fog, mist</i>	Solid aerosol <i>smoke</i>
	Liquid	Foam <i>Whipped cream</i>	Emulsion <i>Salad dressing</i>	Suspension (Sol) <i>Paint, ink</i>
	Solid	Solid foam <i>Styrofoam</i>	Gel <i>Jelly</i>	Solid sol <i>Certain types of glass</i>

Table 1: Classification of colloidal systems

Introduction

A colloid is typically a two phase system consisting of a continuous (the dispersion medium) and dispersed (the particles or emulsion droplets) phase. The size range of the dispersed phase is typically from 1 nm to 1 μm . Examples of colloidal dispersions include solid/liquid (suspensions), liquid/liquid (emulsions), and gas/liquid (foams). A more complete range of colloidal dispersions is shown in the Table 1 above.

As particle size decreases, surface area increases as a function of total volume. In the colloidal size range there is much interest in particle-particle interactions. Most colloidal commercial products are designed to remain in a stable condition for a defined shelf life. Milk is an example where homogenization is used to reduce droplet size to delay the onset of phase separation (creaming with the fat rising to the surface). Commercial suspensions may be formulated to keep particles suspended without sedimenting to the bottom. Examples of phase separation mechanisms are shown in Figure 1.

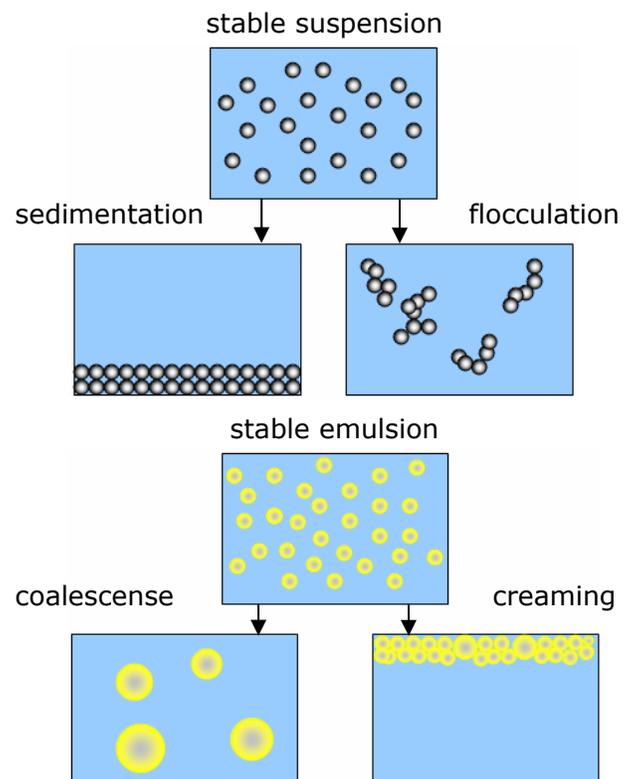


Figure 1



Applications Note

Colloidal Stability

The following forces play an important role in the interaction of colloid particles:

- **van der Waals forces:** This is due to interaction between two dipoles that are either permanent or induced.
- **Electrostatic interaction:** Colloidal particles often carry an electrical charge and therefore attract or repel each other.
- **Steric repulsive forces** between polymer-covered surfaces arise due to osmotic repulsion and volume restriction.

Colloidal Stabilization

Stabilization serves to prevent colloids from aggregating or phase separating. The two main mechanisms for colloid stabilization are steric and electrostatic.

Steric stabilization refers to the prevention of flocculation and aggregation through the adsorption of nonionic polymer molecules to the surface of the dispersed phase (see Fig. 2). Sterically stabilized colloidal dispersions have advantages of being less sensitive to the addition of electrolytes, mechanical shear, and freeze-thaw cycles than electrostatically stabilized systems.

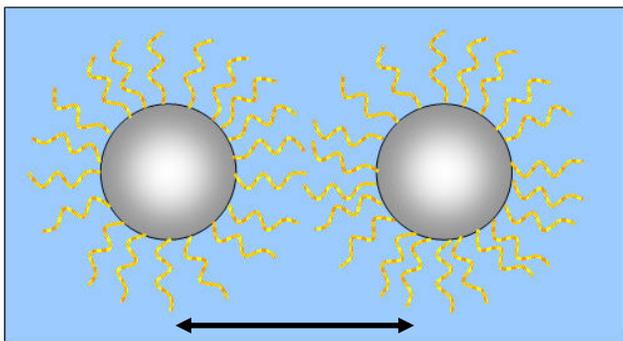


Figure 2

Electrostatic stabilization involves altering the surface chemistry of the system in order to create a charge on the surface of the dispersed phase. Due to the fact that like charges tend to repel each other, the particles or droplets are less likely to get close enough

to stick together. Figure 3 shows a schematic of particles experiencing electrostatic stabilization. The magnitude of the surface charge is often measured and defined by the zeta potential of the system.

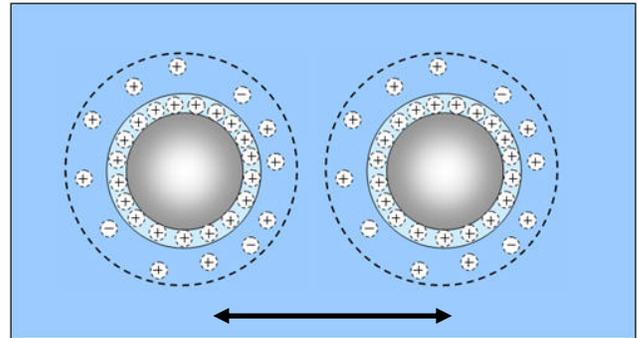


Figure 3

Zeta Potential

Zeta potential is the potential in the interfacial double layer (DL) at the location of the slipping plane versus a point in the bulk fluid away from the interface. In other words, zeta potential is the potential difference between the dispersion medium and the stationary layer of fluid attached to the dispersed particle – see Figure 4.

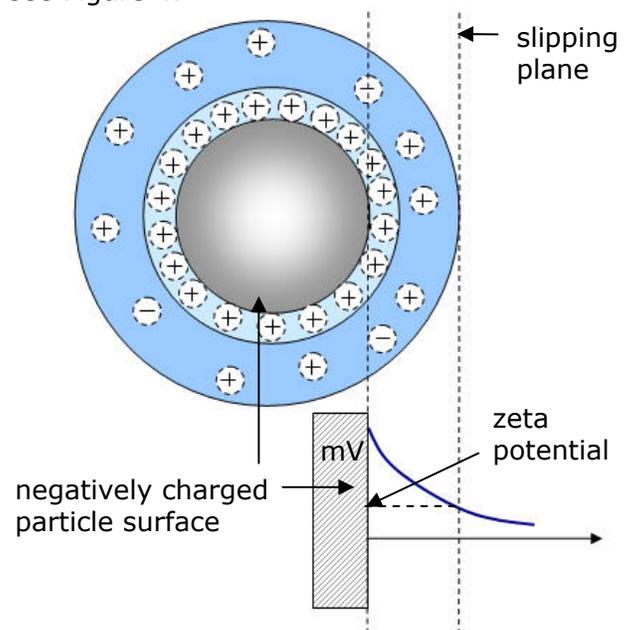


Figure 4



According to general colloid chemistry principles, a dispersed system typically loses stability when the magnitude (i.e. absolute value) of the zeta potential decreases to less than approximately 30 mV. As a result, there will be some region surrounding the condition of zero zeta potential (i.e. the isoelectric point, or IEP) for which the system is not particularly stable. Within this unstable region, the particles may agglomerate, thereby increasing the particle size.

Application: Alumina and Rutile Slurries

Figure 5 shows the results from performing a pH titration of alumina and rutile slurries while also measuring particle size and zeta potential. All measurements were made using the DT-1201 particle characterization system using acoustic and electro-acoustic spectroscopy to examine samples without dilution. The DT-1201 automatically performed the pH titration using a built in two syringe pump system (see Figure 6) containing HCl and KOH in burettes. The zeta potential of the rutile slurry remained unchanged until the pH dropped below 5.5 at which point the zeta potential decreased rapidly and passed through the IEP near pH 4. The zeta potential of the alumina slurry remained unchanged as the pH value increased until the zeta potential reached +30 mV at pH 7, at which point the zeta potential decreased and passed through the IEP at pH 9.5. In both cases, that pH corresponding to the point where the magnitude of the zeta potential decreased below 30 mV became a critical pH, beyond which the pH could not be changed without degrading the stability of the slurry.

The particle size distributions for the stable and unstable conditions for the rutile and alumina slurries were also calculated based on the acoustic attenuation. You can see that the particle size distribution becomes bimodal in the vicinity of iso-electric point (IEP).

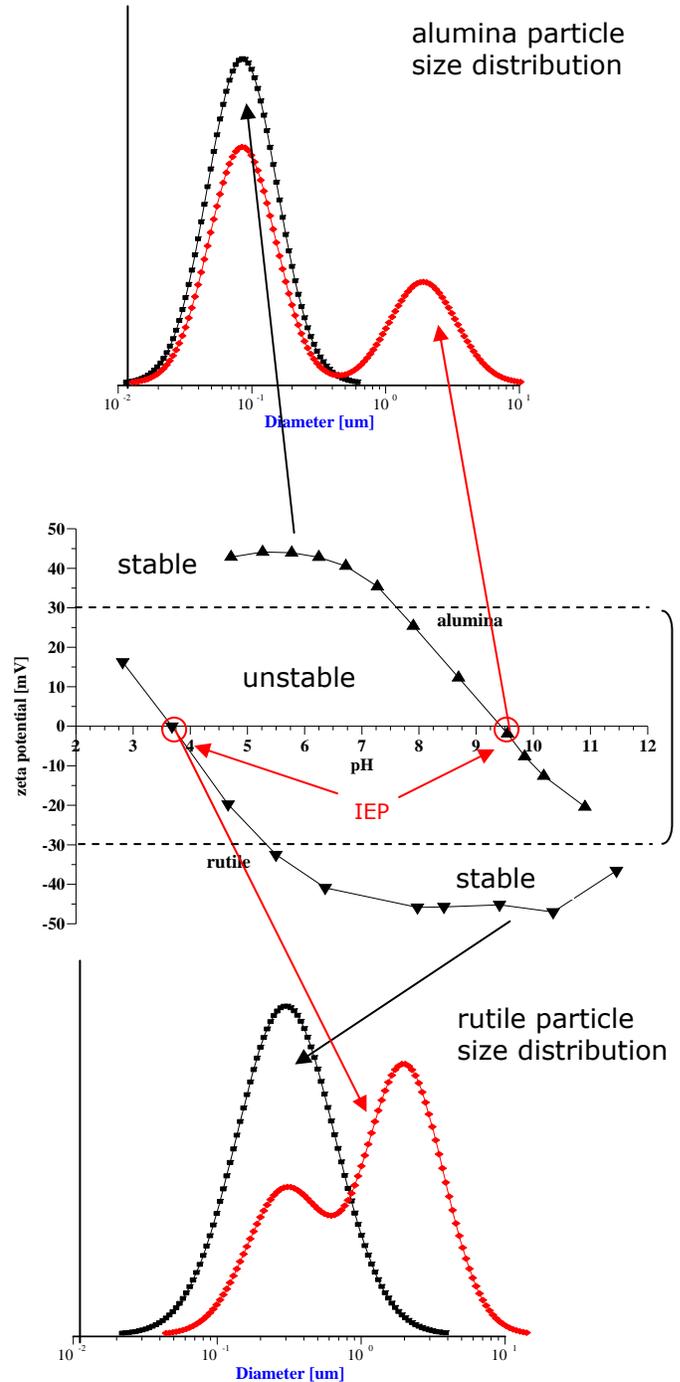


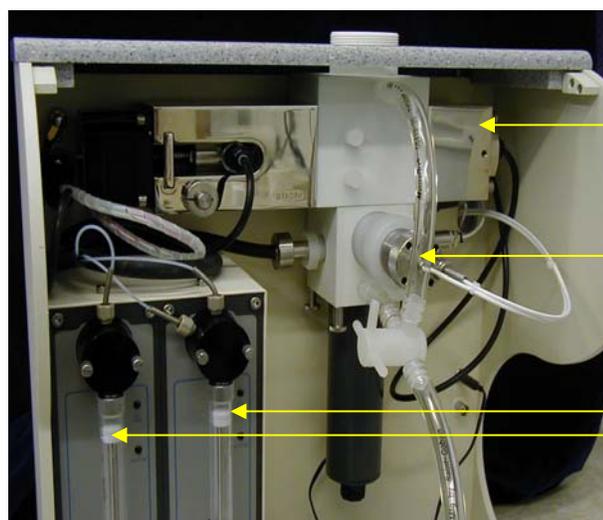
Figure 5



Conclusions

We can summarize this experiment on rutile and alumina slurries with the conclusion that the combination of acoustics and electroacoustics allows us to characterize the aggregation of concentrated colloids.

Electroacoustics yields information about electric surface properties such as ζ -potential, while acoustic attenuation spectra provide data for particle size characterization.



acoustic transmitter and receiver

zeta potential sensor

syringe pumps for titration

Figure 6

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