

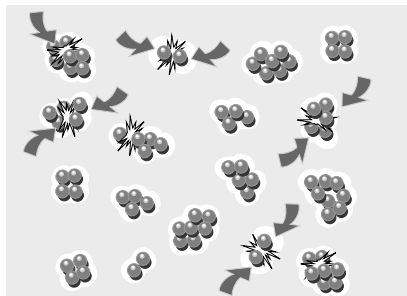
Zeta Potential: A Complete Course in 5 Minutes

The Interaction of Colloids

Electrokinetics and Colloid Behavior

Zeta potential can help you understand and control colloidal suspensions. Examples include complex biological systems such as blood and functional ones like paint. Colloidal suspensions can be as thick as paste (like cement) or as dilute as the turbidity particles in a lake. Water, milk, wine, clay, dyes, inks, paper and pharmaceuticals are good examples of useful colloidal systems. Water is a common suspending liquid, although non-aqueous liquids are used as well. In many cases, the performance of a suspension can be improved by understanding the effect of colloidal behavior on such properties as viscosity, settling and effective particle size.

We can often tailor the characteristics of a suspension by understanding how individual colloids interact with one another. At times we may want to maximize the



Uncharged Particles are free to collide and aggregate.

repulsive forces between them in order to keep each particle discrete and prevent them from gathering into larger, faster settling agglomerates. Examples include pharmaceuticals and pastes. Sometimes we have the opposite goal and want to separate the colloid from the liquid. Removing the repulsive forces allows them to form large flocs that settle fast and filter easily. Viscosity is another property that can be modified by varying the balance between repulsion and attraction.

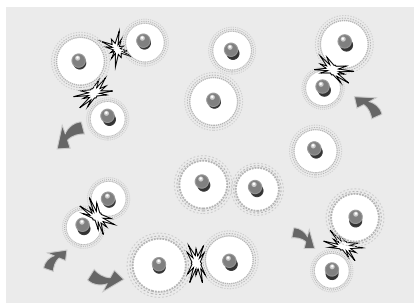
In some cases, an in-between state of weak aggregation can be the best solution. Paints are a good example. Here, the weak aggregation causes viscosity to be a function of shear rate. Stirring will produce enough shear to reduce the viscosity and promote blending.

Reversible aggregation is also useful in controlling the settling

behavior of concentrated suspensions. On standing, a weak matrix of flocculant particles is formed. This prevents the closely packed sediment that would form and cause “caking” problems if the particles were highly stabilized and remained completely discrete.

Surface forces at the interface of the particle and the liquid are very important because of the microscopic size of the colloids. One of the major surface effects is electrokinetic. Each colloid carries a “like” electrical charge which produces a force of mutual electrostatic repulsion between adjacent particles. If the charge is high enough, the colloids will remain discrete, disperse and in suspension. Reducing or eliminating the charge has the opposite effect — the colloids will steadily agglomerate and settle out of suspension or form an interconnected matrix. This agglomeration causes the characteristics of the suspension to change.

Particle charge can be controlled by modifying the suspending liquid. Modifications include changing the liquid’s pH or changing the ionic species in solution. Another, more direct technique is to use surface active agents which directly adsorb to the surface of the colloid and change its characteristics.



Charged Particles repel each other.

The diffuse layer can be visualized as a charged atmosphere surrounding the colloid.

The Double Layer

The double layer model is used to visualize the ionic environment in the vicinity of a charged colloid and explains how electrical repulsive forces occur. It is easier to understand this model as a sequence of steps that would take place around a single negative colloid if its neutralizing ions were suddenly stripped away.

We first look at the effect of the colloid on the positive ions (often called *counter-ions*) in solution. Initially, attraction from the negative colloid causes some of the positive ions to form a firmly attached layer around the surface of the

colloid; this layer of counter-ions is known as the *Stern layer*.

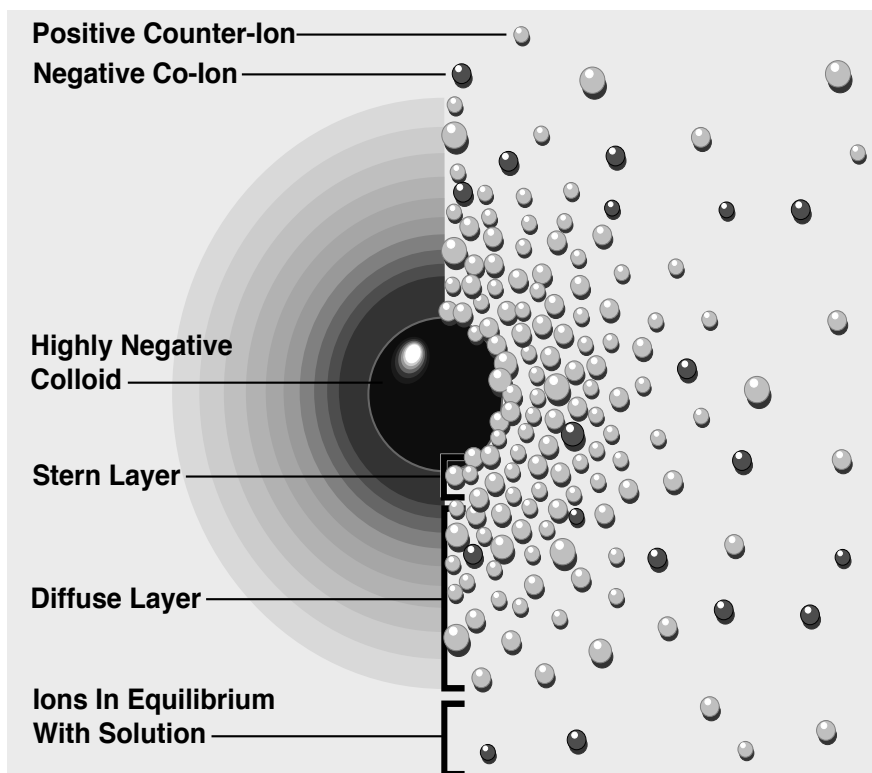
Additional positive ions are still attracted by the negative colloid, but now they are repelled by the Stern layer as well as by other positive ions that are also trying to approach the colloid. This dynamic equilibrium results in the formation of a *diffuse layer* of counter-ions. They have a high concentration near the surface which gradually decreases with distance, until it reaches equilibrium with the counter-ion concentration in the solution.

In a similar, but opposite, fashion there is a lack of negative ions in the neighborhood of the surface,

because they are repelled by the negative colloid. Negative ions are called *co-ions* because they have the same charge as the colloid. Their concentration will gradually increase with distance, as the repulsive forces of the colloid are screened out by the positive ions, until equilibrium is again reached.

The diffuse layer can be visualized as a charged atmosphere surrounding the colloid. The charge density at any distance from the surface is equal to the difference in concentration of positive and negative ions at that point. Charge density is greatest near the colloid and gradually diminishes toward zero as the concentration of positive and negative ions merge together.

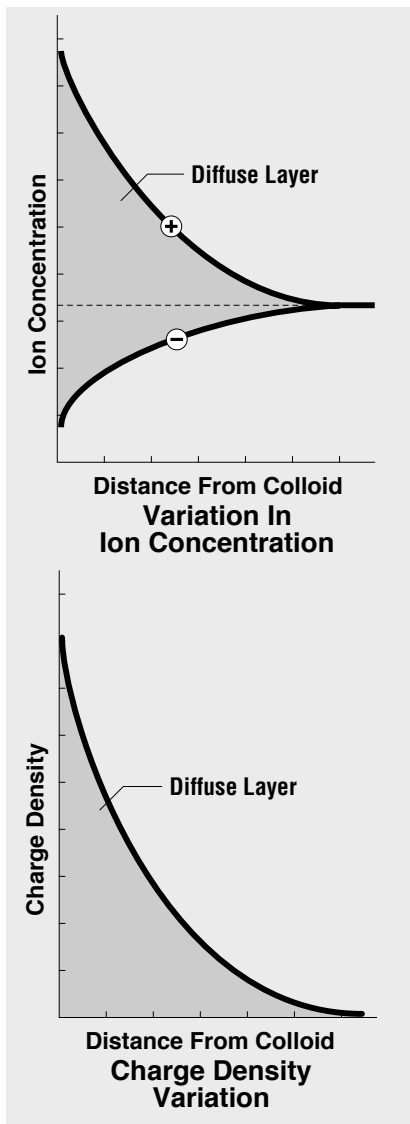
The attached counter-ions in the Stern layer and the charged atmosphere in the diffuse layer are what we refer to as the *double layer*. The thickness of this layer depends upon the type and concentration of ions in solution.



Two Ways to Visualize the Double Layer

The left view shows the change in charge density around the colloid. The right shows the distribution of positive and negative ions around the charged colloid.

The electrokinetic potential between the surface of the colloid and any point in the mass of the suspending liquid is referred to as the surface potential.



Variation of Ion Density in the Diffuse Layer

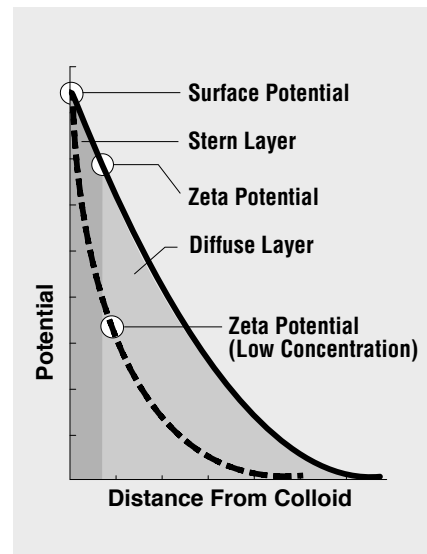
The figures above are two representations of the change in charge density through the diffuse layer. One shows the variation in positive and negative ion concentration with distance from a negative colloid. The second shows the net effect — the difference in positive and negative charge density.

Zeta Potential

The double layer is formed in order to neutralize the charged colloid and, in turn, causes an electrokinetic potential between the surface of the colloid and any point in the mass of the suspending liquid. This voltage difference is on the order of millivolts and is referred to as the surface potential.

The magnitude of the surface potential is related to the surface charge and the thickness of the double layer. As we leave the surface, the potential drops off roughly linearly in the Stern layer and then exponentially through the diffuse layer, approaching zero at the imaginary boundary of the double layer. The potential curve is useful because it indicates the strength of the electrical force between particles and the distance at which this force comes into play.

A charged particle will move with a fixed velocity in a voltage field. This phenomenon is called electrophoresis. The particle's mobility is related to the dielectric constant and viscosity of the suspending liquid and to the electrical potential at the boundary between the moving particle and the liquid. This boundary is called the slip plane and is usually defined as the point where the Stern layer and the diffuse layer meet. The Stern layer is



Zeta Potential vs. Surface Potential

The relationship between zeta potential and surface potential depends on the level of ions in the solution.

considered to be rigidly attached to the colloid, while the diffuse layer is not. As a result, the electrical potential at this junction is related to the mobility of the particle and is called the *zeta potential*.

Although zeta potential is an intermediate value, it is sometimes considered to be more significant than surface potential as far as electrostatic repulsion is concerned.

Zeta potential can be quantified by tracking the colloidal particles through a microscope as they migrate in a voltage field.