

Zeta Potential – Electrophoresis

Introduction

All particles in suspension exhibit a zeta potential, or surface charge. The measurement and knowledge of which is critical for optimising processing, predicting formulation stability and interactions, and also as a simple method of quality control.

Methods of measuring a particle's zeta potential are dependent on the nature of both the particle and the suspension formulation. In general, the size and concentration of particles are the key parameters that determine which technique is applicable.

Theory

In solution, the presence of a net charge on a particle affects the distribution of ions surrounding it, resulting in an increase in the concentration of counter-ions. The region over which this influence extends is called the *electrical double layer*¹. Conventionally, this layer is thought of as existing as two separate regions (figure 1):

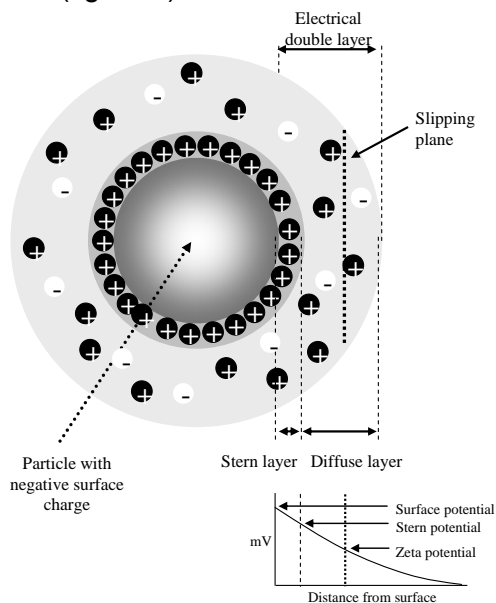


Figure 1: Schematic representation of the distribution of ions around a charged particle in solution.

- An inner region of strongly bound ions known as the *Stern layer*
- An outer layer of loosely associated ions called the *diffuse layer*.

As the particle moves through solution, due to gravity or an applied voltage, the ions move with it. At some distance from the particle there exists a “boundary”, beyond which ions do not move with the particle. This is known as the surface of hydrodynamic shear, or the *slipping plane*, and exists somewhere within the diffuse layer. **It is the potential that exists at the slipping plane that is defined as the zeta potential**

The zeta potential is crucial in determining the stability of a colloidal suspension. When all the particles have a large negative or large positive they will repel each other, and so the suspension will be stable. If the zeta potential is low the tendency for flocculation is increased. Another important consideration when discussing zeta potentials is pH; in fact, quoting a zeta potential without an accompanying pH is almost meaningless. This is due to the fact that, for suspensions of most materials, a plot of zeta potential versus pH exhibits an *isoelectric point*, a particular value of solution pH where the net charge on the particles is **zero**. At this point the suspension is highly unstable, and flocculation is at its most likely (figure 2)

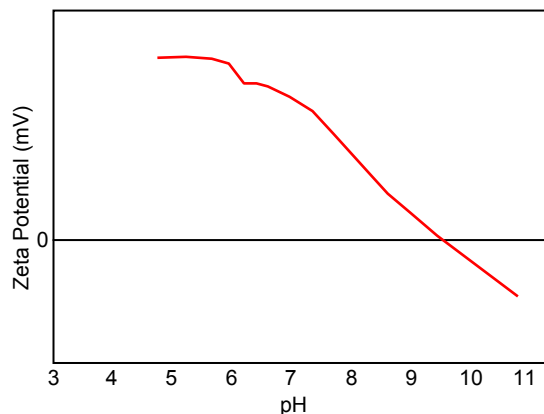


Figure 2: Zeta potential vs. pH for alumina slurry

Electrophoresis

Perhaps the most widely used technique for measuring zeta potentials in electrophoresis. An electric field is applied across a sample, which induces charged particles to move. The direction and velocity (electrophoretic mobility) of the particles depends on the applied field.

The velocity of a particle in an electric field is dependent on:

- the strength of the electric field
- the dielectric constant of the liquid
- the viscosity of the liquid
- the zeta potential

By directly measuring the electrophoretic mobility of a particle, the zeta potential may then be determined using the *Henry Equation*:

$$U_E = \frac{2\varepsilon f(Ka)}{3\eta}$$

where U_E is the electrophoretic mobility, ε is the dielectric constant, z is the zeta potential, $f(Ka)$ is Henry's function, and η is the viscosity. Henry's function generally has value of either 1.5 or 1.0. For measuring zeta potential in aqueous solutions of moderate electrolyte concentration, a value of 1.5 is used and this is referred to as the *Smoluchowski approximation*. If measuring zeta potential in a non-polar solvent, the *Huckel approximation* is used, where $f(Ka)$ is set to 1.0.

The major difference between instruments based on the electrophoresis is the way in which the movement of the particles is detected. Indeed, this aspect will ultimately determine the sensitivity and accuracy of the instrument. Care must be taken when establishing which samples may be measured in a particular instrument.

An additional technique for electrophoresis uses a combination of Laser Doppler Velocimetry (LDV) and phase analysis light

scattering (PALS) to track the motion of particles in suspension. This relatively new detection method enables accurate determination of zeta potential of particles in the size range 6 – 6000nm, and in suspensions of 0.02 – 0.2wt% (200 – 2000 parts per million) depending on the sample. It also offers the ability of automatic pH titrations.

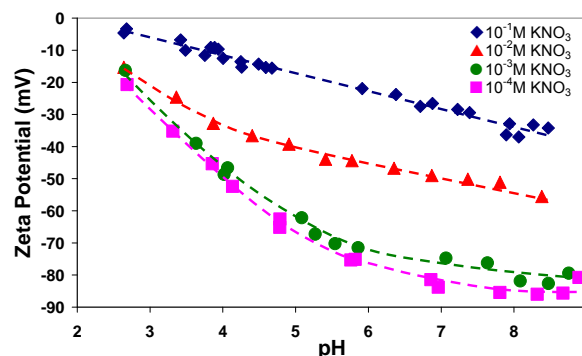


Figure 3: Zeta potential vs. pH for 0.1 wt% dispersion of 1µm SiO₂ particles in aqueous solution of different electrolyte concentration.

An important point to remember when using the electrophoretic technique is that zeta potential is not directly measured. Instead, the electrophoretic mobility is measured, and the zeta potential calculated by application of the Henry Equation. Thus, the reliability of the zeta potential data depends upon the applicability of the Henry Equation to the system under investigation.

References

- ¹ R.J. Hunter, 'Zeta Potential in Colloids Science', Academic Press, NY, 1981

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