

Application Note 11

Zeta Potential – Electrophoresis, Electroacoustics and Streaming Potential

Introduction

All particles in suspension exhibit a zeta potential, or surface charge due to their ionic characteristics and dipolar attributes. The measurement and knowledge of zeta potential is critical for optimising processing, predicting interactions and formulation stability. Furthermore, zeta potential can be used as a simple method for quality control. Methods for measuring a particle's zeta potential are dependent on the nature of both the particle and the suspension formulation.

Theory

In solution, the presence of a net charge on a particle affects the distribution of ions surrounding the particle, 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): The inner region (Stern layer) consists of strongly bound ions, whilst the outer region (diffuse layer) consists of loosely associated ions.

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.**

Zeta potential is crucial in determining the stability of a colloidal suspension; for colloidal stability the repulsive forces must be dominant i.e. the greater the zeta potential the more likely the suspension is 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.

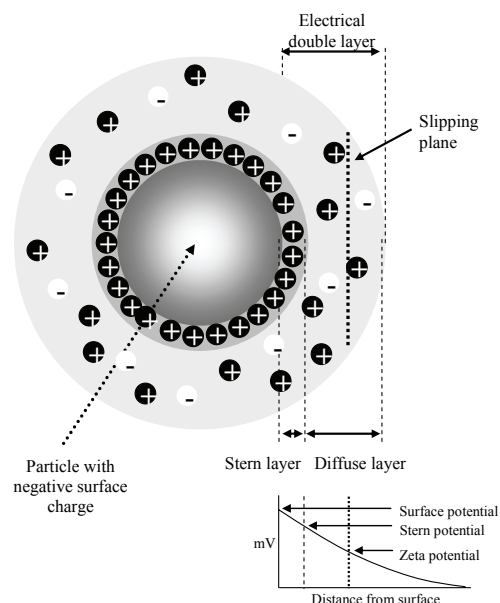


Figure 1: Schematic representation of the distribution of ions around a charged particle in solution.

Electrophoresis

Perhaps the most widely used technique for measuring zeta potentials is electrophoresis which is frequently used to measure stable suspensions of small particles (<10 μm). 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. By directly measuring the electrophoretic mobility of a particle, the zeta potential may then be determined using the *Henry Equation*¹. Henry's function $f(Ka)$ typically 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 velocity of a particle in an electric field is dependent on zeta potential, strength of the electric field, dielectric constant and viscosity of the liquid, figure 2.

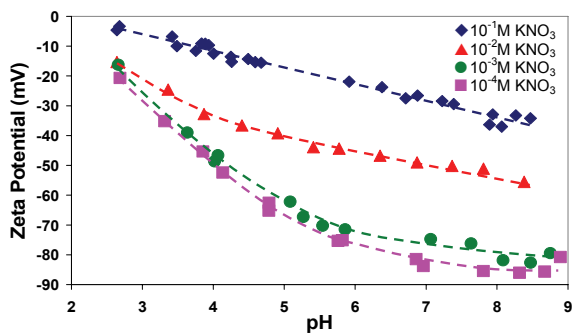


Figure 2: Zeta potential vs. pH for 0.1wt% dispersion of 1 μm SiO_2 particles in aqueous solution of different electrolyte concentration.

ElectroAcoustics

The electroacoustic technique characterises the **dynamic mobility** of particles in suspension. Typically this technique is used to measure stable suspensions of small particles (1 nm to 10 μm). A high frequency ($\sim 10^6$ Hz) electric field is applied to the samples, causing charged particles to oscillate, and to produce a sound wave of the same frequency. The oscillation (dynamic mobility) of the particles is described by its *magnitude* and *phase angle* (how far the particle motion lags behind the applied field). The sound wave is detected and analysed to determine the motion of the particles².

The main advantage of this technique over 'traditional' electrophoretic machines is the ability to measure zeta potential in slurries of greater than 10 wt% solids concentration (up to 60 wt% depending on the sample), figure 3.

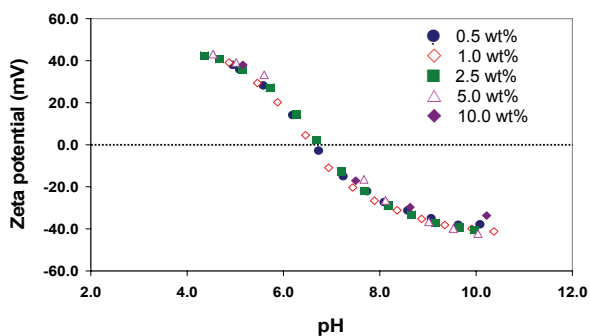


Figure 3: Zeta potential vs. pH for nanoparticles of TiO_2 in aqueous suspension of different concentration.

Streaming Potential

Streaming potential can be used to measure the surface charge of larger particles, which do not form stable suspensions. As described previously, every solid object in solution has a surface charge, and so a distribution of ions near the surface occurs. Passing a liquid over the surface

disrupts this distribution and creates a potential difference, the *streaming potential*. In this technique, fluid is passed over the solid sample at different pressures, and the streaming potential measured. This is then converted to zeta potential³.

The technique is applicable to solid substrates, such as silica, mica or polymer membranes, and plugs of almost any material such as fibres or large particles. Autotitration allows rapid sample characterisation, giving data such as that shown in figure 4.

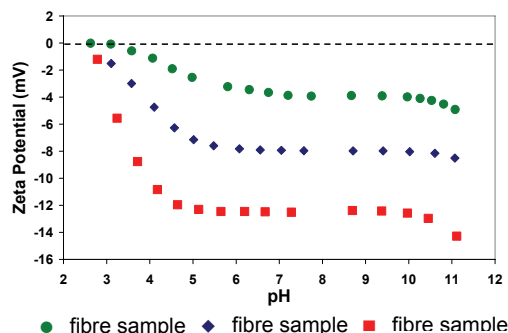


Figure 4: Zeta potential vs. pH for three different fibre samples.

Zeta Potential Applications

Pharmaceutical /Healthcare A stable suspension does not cake and will have a longer shelf life.

Paints The pigments in paint must be well dispersed for successful performance.

References

- 1 R.J. Hunter, 'Zeta Potential in Colloids Science', Academic Press, NY, 1981
- 2 R.J. Hunter, 'Recent developments in the electroacoustic characterizations of colloidal suspensions and emulsions', Colloids and Surfaces, A: Physicochemical and Engineering Aspects, 1998, 141(1), 37 – 66
- 3 M. Smoluchowski, 'Handbook of Electricity and Magnetism', Volume 2, Barth, Leipzig, 1921, 366

ParticlesCIC

Houldsworth Building • Leeds •
LS2 9JT • UK
Tel: +44 113 343 2378 •
Fax: +44 113 343 2377

www.particlescic.com