

The SediGraph Method of Particle Sizing

Presented by Micromeritics Instrument Corporation

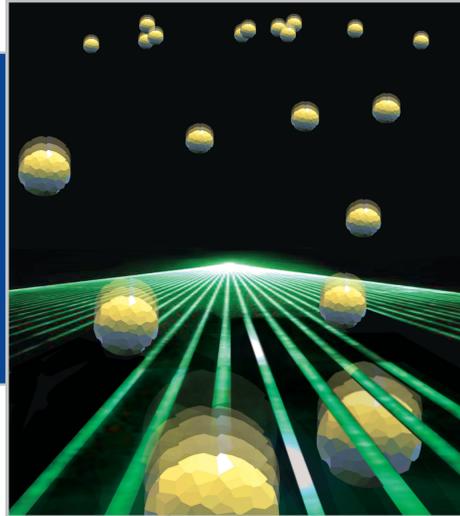
The X-ray Sedimentation technique for determining the relative mass distribution of a sample by particle size is based on two physical principles: sedimentation theory and the absorption of X-radiation. These two theories are embodied in an analytical instrument called the SediGraph.

Sedimentation Theory (Stokes' Law)

A particle settling in a liquid will achieve a terminal velocity when the gravitational force balances the buoyancy and drag forces on the particle and is dependent on the size and the density of the particle, and the density and viscosity of the liquid.

Translation:

If all other variables are held constant, settling velocity is proportional to particle size.



Absorption of X-radiation (Beer-Lambert Law)

A beam of photons (X-rays, in this case) passing through a medium is attenuated in proportion to the path length through the medium, its concentration, and the extinction coefficient of the medium.

Translation:

If all other variables are held constant, X-ray attenuation is proportional to mass concentration.

The elegant simplicity of Stokes and Beer-Lambert laws means that interpretation of raw data is straight-forward; the analyst easily can understand the relationship between the basic measurements and the reported size distribution. All experimental parameters are easily determined and data reduction is uncomplicated and fast.

Figure 1

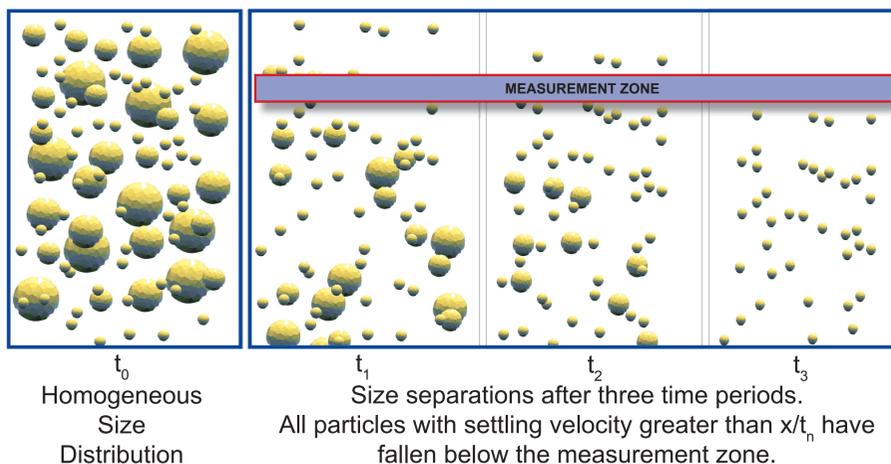
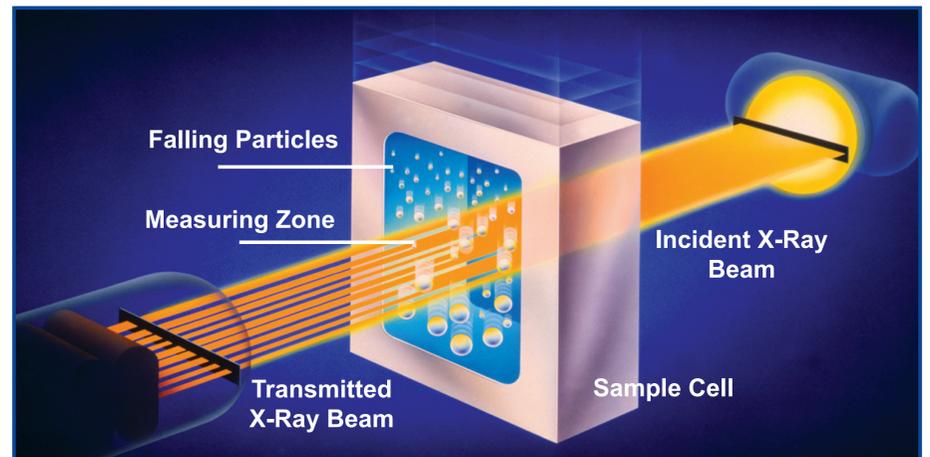


Figure 2



Stokes' Law

Stokes' Law describes the drag force on a falling body as a function of its diameter and velocity, and other attributes of the body and the medium in which it is falling. When the drag force balances the gravitational force, terminal settling velocity (V_t) is achieved. Under these equilibrium conditions, a measurement of terminal velocity allows the force equation to be solved for particle diameter as follows:

$$D = V_t^{1/2} [(18\eta) / (\rho - \rho_0)g]^{1/2}$$

where D is the diameter of the spherical particle, V_t its equilibrium sedimentation velocity, and ρ its density. The fluid medium is characterized by viscosity η and density ρ_0 ; g is the acceleration of gravity.

By the SediGraph method, the sample is first dispersed in a liquid. Agitation of the dispersion assures a homogeneous distribution is maintained in the sample cell prior to the beginning of the test. Agitation is ceased and the particles are allowed to settle. The largest particles settle at the highest velocity, so, after each time period, all particles greater than a certain size will have fallen below the measuring zone (Figures 1 and 2). Knowing the position of the measuring zone and the elapsed time since sediment began, the settling velocity can be calculated, and through Stokes' equation, the particle size boundaries defining each size class are determined.

Beer-Lambert Law

The Beer-Lambert Law describes the extent to which a beam of photons (x-rays, in this case) is attenuated by passing through matter. The intensity of the incident beam, I_i , is reduced exponentially to I_f as it passes through the absorber and is a function of the absorptivity (ϵ) of the system, the concentration (c) of the absorber, and the path length (d) of the beam through the absorber. This relationship is:

$$\frac{I_f}{I_i} = \exp(-\epsilon cd) = T$$

which defines transmittance, T , and has a range of values from 0 to 1, zero meaning total absorbance and 1 indicating no absorbance.

In the SediGraph application, there are two conditions that establish the upper and lower limits of T , that is, the maximum and minimum signal from the x-ray detector. The maximum signal occurs when the sample cell contains only the dispersion liquid (sample mass fraction = 0%). The minimum signal occurs with a homogeneous distribution of sample material in the cell (sample mass fraction = 100%). Any signal level between the two extremes is due to the absorbance of x-ray by some mass fraction between 0 and 100 percent. At any time, t , the mass fraction in the measurement zone, M_t , can be calculated from the x-ray transmission, T_t at that time using

$$M_t = \frac{\ln T_i}{\ln T_t}$$

WHY PARTICLE SIZE IS IMPORTANT:

Ceramics:

The size range of particles and the distribution of mass in each size class strongly affect the ability to sinter a ceramic powder and its forming properties as well as the pore size distribution in the finished product. Particle size distribution information helps determine curing and bonding procedures, control pore structure, ensure adequate green body strength, and produce a final product of desired strength, texture, appearance, and density.

Metal Powders:

By controlling particle size, very specific pore characteristics can be designed into a product. Porosity characteristics often are the key to product performance. Similar to ceramics, the particle size distribution is critical to green body and final product strength and density.

Geological/Soil Science:

Grain size affects the moisture-holding capacity of soil, drainage rate, and the soil's ability to hold nutrients. Grain size is directly related to transport of sediment.

Cosmetics:

The appearance, application, and packaging of cosmetics are influenced by the particle size distribution of base powders, such as talc, and the pigments used for coloring.

Pigments:

Particle size alone can affect the tinting strength of a color. As tinting strength goes up, the quantity of pigment needed to produce required color intensity goes down. The particle size affects the hiding power of the paints. Also the particle size distribution influences gloss, texture, color saturation, and brightness.

Catalysts:

Particle size affects the catalytic activity of a metal for structure-sensitive catalytic reactions.

Construction Materials:

Particle size of cement affects setting time and strength characteristics of the finished concrete and cement.

Minerals and Inorganic Chemicals:

Reactivity of materials is dependent upon exposed surface area and thus particle size distribution.

Abrasives:

A properly balanced size distribution of abrasive grains and powders is a fundamental consideration whether the material is to be used in slurries, dry blasting, or bonded abrasive tools. Uniform particle size assures precise flow rates through blast machines and is a critical determination in media management when recycling the abrasive material.