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Multi-modal Particle Size Distributions with DLScat

Measurement of Large Polystyrene Sphere Particles and Smaller Gold Nanoparticles Mixed in Solution Resulting in a Multi-Modal Distribution

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Dynamic Light Scattering (DLS) determines the hydrodynamic size distribution of particles, which accounts for the particle core plus any surface-bound solvent molecules or stabilizing layers (e.g., surfactants, adsorbed ions). Multi-Angle Simultaneous Dynamic Light Scattering (MASDLS) is an advanced analytical technique designed to enhance the precision and reliability of particle size characterization in liquid suspensions. By simultaneously collecting scattered light at multiple angles, this method provides a more comprehensive scattering profile compared to conventional single-angle DLS [1–3]. This approach mitigates angle-dependent artifacts and improves resolution for polydisperse samples.

For gold colloids and polystyrene spheres dispersed in water, a thin hydration shell forms around each particle, slightly increasing the effective size of the particles in solution. In this study, we demonstrate that multi-angle DLS, combined with CONTIN, solves in a single acquisition the problem of distinguishing between two populations of a bimodal mixture of 40 nm gold colloids and 600 nm polystyrene spheres [4].

METHODS & INSTRUMENTATION

Standard, nearly monodisperse (PDI ≈ 0.05) 600 nm diameter polystyrene spheres (PS) in suspension at 10% w/v in water (Sigma-Aldrich, Germany) were used as the large particles. Gold nanoparticle solution (AuNP) of 40 nm diameter, PDI ≈ 0.08, 0.01 % concentration (BBI Solutions, Germany) was used as the smaller particles. 1 µL of PS and 100 µL of AuNP were mixed with 25 mL of Milli-Q water (Sigma-Aldrich, Germany), and 1 mL of the diluted suspension was transferred to a square polystyrene cuvette with a 10 mm path length.

The samples were measured with Swabian Instruments' turnkey multi-angle simultaneous Dynamic Light Scattering system (DLS*cat*). Data was acquired from five scattering angles simultaneously, thanks to the software acquisition approach powered by the Time Tagger 20. Both CONTIN and Cumulant algorithms were utilized since typically CONTIN algorithm is more suitable for complex, multimodal distributions, while the Cumulant is best suited for samples exhibiting low polydispersity (PDI ≈ 0.05)[5].

RESULTS

Au/PS size distributions were obtained at the five simultaneous scattering angles (Fig 1a). The large PS dominated the forward angle while Au contribution was suppressed. At side (74.4°, 90.0°, 105.6°) and backscattering (163.0°) angles, CONTIN resolved two size modes corresponding both populations. For each angle, the intensity autocorrelation function (ACF) was analyzed using CONTIN to obtain decay rates, Γ, for the two peaks. These decay rates are plotted as a function of Γ versus the squared scattering vector q^2 (Fig 1b). Two Γ branches are observed at all angles except the forward angle, where only the PS particle contribution was clearly visible due to the dominance of the large particles' scattering. By performing a linear fit and extrapolating to $q^2 = 0$, two diffusion coefficients D_0 are obtained. Using the Stokes–Einstein equation, these yield hydrodynamic radii of 20.4 nm (Au) and 307.7 nm (PS).
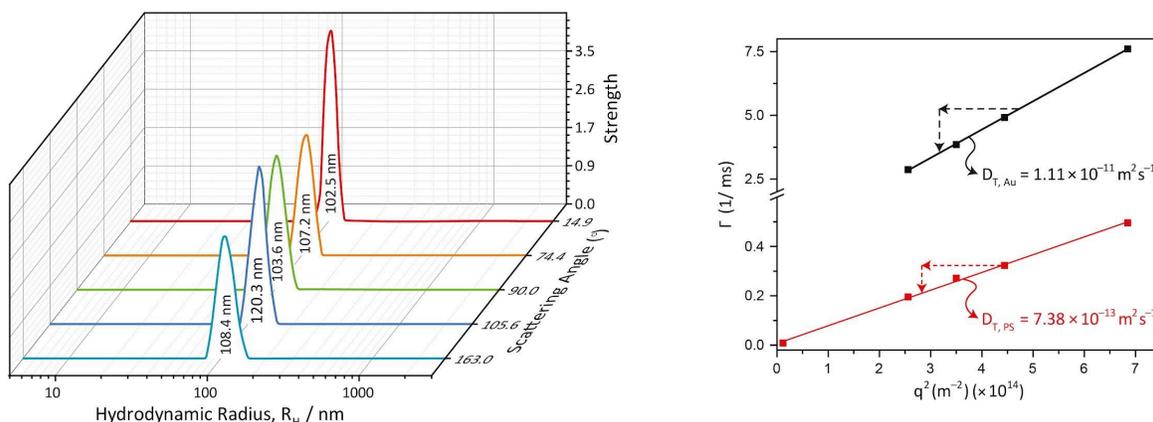
Fig. 1: (Left) Particle size distribution of a mixture of 40 nm gold colloids and 600 nm polystyrene spheres at multiple scattering angles (Right) Calculation of both the translational diffusion coefficients (D_T,Au and D_T,PS)

DISCUSSION

To gain insight into the sample's behavior, the *Dapp* vs q^2 plot can be plotted and studied in detail. *Dapp* is the diffusion coefficient calculated from each scattering angle. The negative slope suggests that the particles are either unstable or still growing. The positive slope refers to particles with a certain amount of polydispersity. However, if the slope is close to 0, the particles are either monodispersed or nearly monodispersed, or they are too small to be angle-dependent and do not show any changes in the diffusion coefficient upon changing the scattering angle.

CONCLUSION

The DLS*cat* system, powered by Swabian Instruments' Time Tagger 20, enables Multi-Angle Simultaneous DLS (MASDLS) with higher temporal resolution and sensitivity than with single-angle measurements, addressing the limitations of goniometer-based DLS systems. These capabilities are particularly important for multi-modal samples that contain particles at different sizes.

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