

Determine Hydrodynamic Size of Surfactant Micelles with DelsaMax CORE

Particle Characterization Application Note

Abstract

Understanding the experimental properties and thermodynamics of detergent solutions is important for the cleaning industry, basic encapsulation research, and increasingly, in protein studies. Accurately sizing small surfactant micelles at low concentrations is difficult to do quickly and accurately, especially while in solution. In this application note, we demonstrate how the DelsaMax CORE accurately determined the hydrodynamic size of Sodium Dodecyl Sulfate micelles, a representative surfactant. The measurements in this work all took just a few minutes thanks to the state-of-the-art dynamic light scattering detection system on the DelsaMax CORE.

Introduction

Sodium Dodecyl Sulfate (SDS) is a commonly used amphiphilic surfactant with wide-ranging applications, including chemical disinfection to protein denaturation in SDS-PAGE gels, cell lysing for DNA extraction,¹⁻³ and nanoparticle solubilization.⁴ SDS has well-known structure and properties (Figure 1), including a critical micelle concentration of 8.3 mM at 25° C.⁵ Critical micelle concentration (CMC) is the amphiphilic surfactant concentration at which 50% of the surfactant exists in micelles while 50% is free surfactant. As the concentration of the surfactant increases, a higher percentage becomes incorporated into micelles. The ultra-small SDS micelles are difficult to accurately size in solution but experimental evidence and theoretical predictions estimate the micelle radius at approximately 1.6 to 2.1 nm.^{6,7} A free energy model for micelle formation has been developed and rigorously tested against many surfactants, including SDS. The mathematical underpinnings are beyond the scope of this technical note, but it is important to point out that the micelle radius depends to a degree on several variables, including temperature, pH, and ionic strength of the solution.⁸ As a single hydrophobic

chain surfactant, SDS preferentially forms into spherical micelles above the CMC. The DelsaMax software optimization calculator is a very helpful feature for studying micelle formation. If the concentration and molecular weight of a sample are known, the calculator can determine the minimum number of acquisitions and time per acquisition needed to acquire accurate data. The calculator saves time and eliminates uncertainty for dynamic light scattering measurements with DelsaMax series instruments; the feature is most useful when working with smaller particles that scatter exponentially less light, such as surfactant molecules or protein. Within this study, the optimization calculator was used for determining the measurement parameters for all three SDS solutions that were studied (Figure 2).

Experimental

SDS (Sigma Aldrich) was weighed and dissolved in deionized water. Three solutions were prepared of SDS (molecular weight 288.4 g/mol); 20 mM, 8 mM, and 2 mM. Solutions were filtered with a 0.02 micron filter (Anatop) before running in the DelsaMax CORE to remove any dust particles. Using a volumetric pipette, 50 µl of SDS solution was placed into the disposable DelsaMax CORE cuvette. A magnifying glass was used to confirm that no bubbles were present in the 4 µl sample reservoir. The DelsaMax CORE was run at 25° C using the conditions listed in Figure 3. Eight trials were run at 20 mM, 4 trials were run at 8 mM, and 4 trials were run at 2 mM. The number of acquisitions/acquisition time was determined using the optimization calculator on the DelsaMax Software.

20 mM: 41 acquisitions, 2 seconds/acq.

8 mM: 103 acquisitions, 2 seconds/acq.

2 mM: 414 acquisitions, 2 seconds/acq.

Results

The formation of micelles was apparent at 20 mM SDS, while 2 and 8 mM SDS had no indication of micelles. The fact that no micelles were present at 8 mM—approximately at the CMC—may be due to some loss of SDS during filtration of the solution, lowering the actual concentration. It is apparent that the 2 mM and 8 mM SDS solutions contain mostly small molecules because of the rapid decay of the auto-correlation function (ACF) (Figure 4). The ACF is the direct output from a dynamic light scattering measurement and can be constantly displayed on the DelsaMax CORE touch screen.

The published values for the diameter of an SDS micelle are between 3.5 to 4 nm^{6,7} agreeing well with the average value found of 3.72 nm at 20 mM SDS (Figure 5). At 2 mM, where predominantly free surfactant exists in solution, the average diameter was 0.5 nm with low polydispersity (Figure 5), demonstrating the ultra-low limit of detection for the DelsaMax CORE. This study helps confirm that the DelsaMax CORE is capable of handling tricky surfactant sizing experiments.

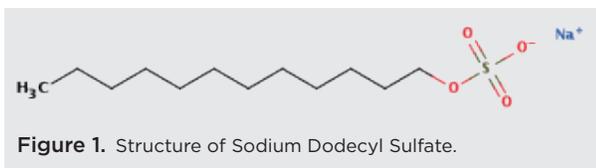


Figure 1. Structure of Sodium Dodecyl Sulfate.

Optimization Calculator

Enter the instrument settings and molecular parameters for your system below. Then select the quantity to minimize to determine the minimum concentration or acquisition parameters for a successful measurement.

Instrument Settings:
 Instrument: DelsaMax Core
 Min Lys Conc (mg/mL): 0.100
 Power (%): 100

Molecular Parameters:
 Molar Mass (kDa): 0.30
 Estimated Radius (nm): 0.4

Molecular Family:
 Globular Proteins (Radius: 0.4 nm)
 Linear Polymers (Radius: 0.3 nm)
 Branched Polymers (Radius: 0.5 nm)
 Starburst Polymers (Radius: 0.8 nm)

Select Quantity to Minimize:
 Concentration (mg/mL): 5.760000
 Acquisition Time (s): 2
 Number of Acquisitions: 41

Figure 2. DelsaMax Software Optimization Software.

Property	Value
DLS Acq Time (s)	2
Read Interval (s)	1
DLS Number Acq	41
DLS Only	Yes
Auto-attenuation	Yes
Attenuation Level (%)	0
Auto-attenuation Time Limit(s)	0
Laser Power (%)	0
Set Temp On Connection	Yes
Set Temp (C)	25
Temp Ramp Enabled	Yes
Temp Ramp Rate (C/min)	15

Figure 3. SDS Sizing Experiment Run Parameters.

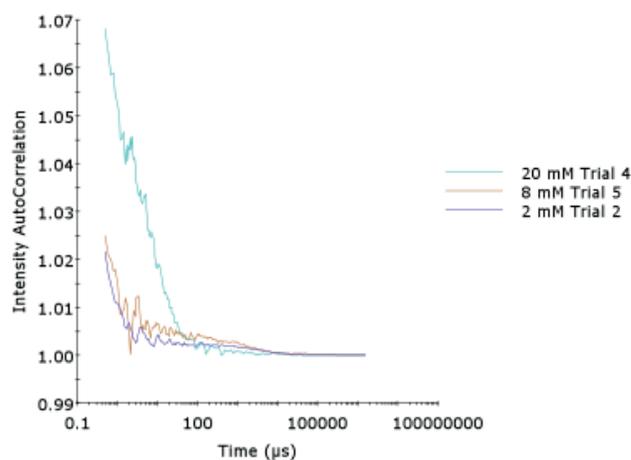


Figure 4. Auto-Correlation Functions. ACF functions were plotted for representative runs of SDS at all three concentrations. Representative runs were selected by having the lowest SOS (Sum of Squares) for Cumulant fitting. Cumulant fitting fits an exponential decay to the ACF in order to directly find the hydrodynamic diameter of the SDS.

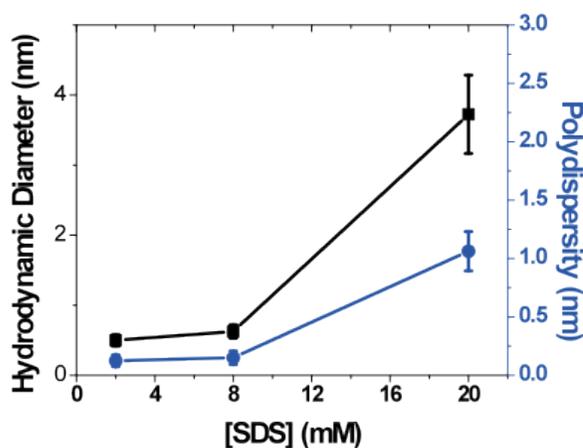


Figure 5. Hydrodynamic Diameter and Polydispersity vs. SDS Concentration.

References

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