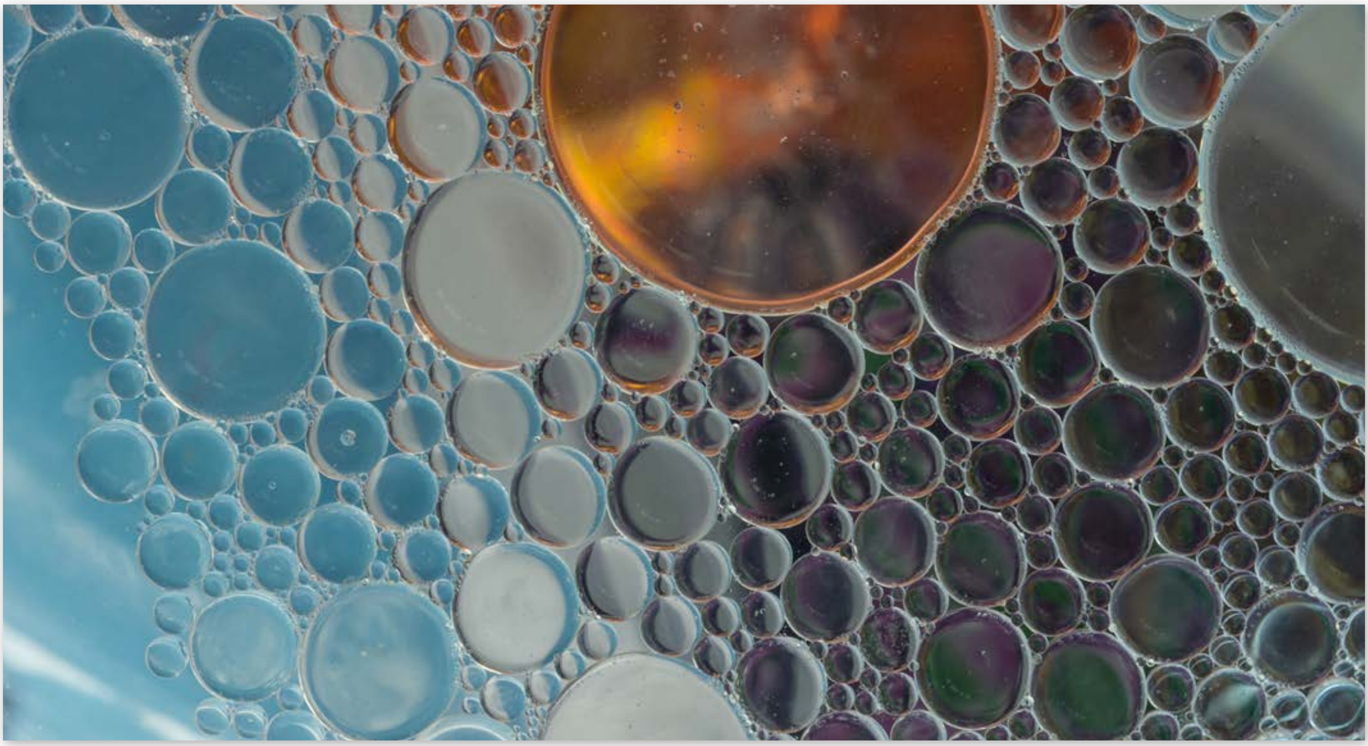
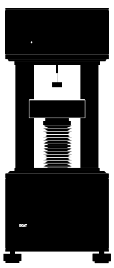


Application Note

CMC determination by surface tension measurement with a tensiometer of the DCAT Series

The critical micelle concentration (CMC) is a key parameter for understanding and optimizing surfactant performance in a wide range of applications, including cleaning agents, pharmaceuticals, cosmetics, and enhanced oil recovery. Below the CMC, surfactant molecules mainly exist as monomers and changes in surfactant concentration strongly influence interfacial properties such as surface tension. Once the CMC is reached, additional surfactant molecules preferentially form micelles, and many physicochemical properties change only slightly with further increases in concentration. Determining the CMC is therefore essential for selecting an effective surfactant concentration, minimizing material consumption, improving formulation stability, and controlling application-relevant properties. Among the techniques used to determine the CMC, tensiometric methods are particularly direct and widely used, because micelle formation is clearly reflected by a characteristic change in the surface tension–concentration curve. In this application note, the CMC is determined by ***tensiometric surface tension measurements*** *using the* ***DCAT series from DataPhysics Instruments***[1]*. Lutensol® AO7 is used as a model surfactant to demonstrate the measurement method and evaluation procedure.*

Measurement device
Force tensiometers of the DCAT series



Measurement method
Wilhelmy plate method

Measured quantities
Surface tension
CMC

Environmental conditions
20 °C

Samples
Lutensol® AO7 solution

Industries
Detergents and cleaning products
Cosmetics and personal care
Pharmaceuticals
Food and beverage
Oil recovery

dataphysics

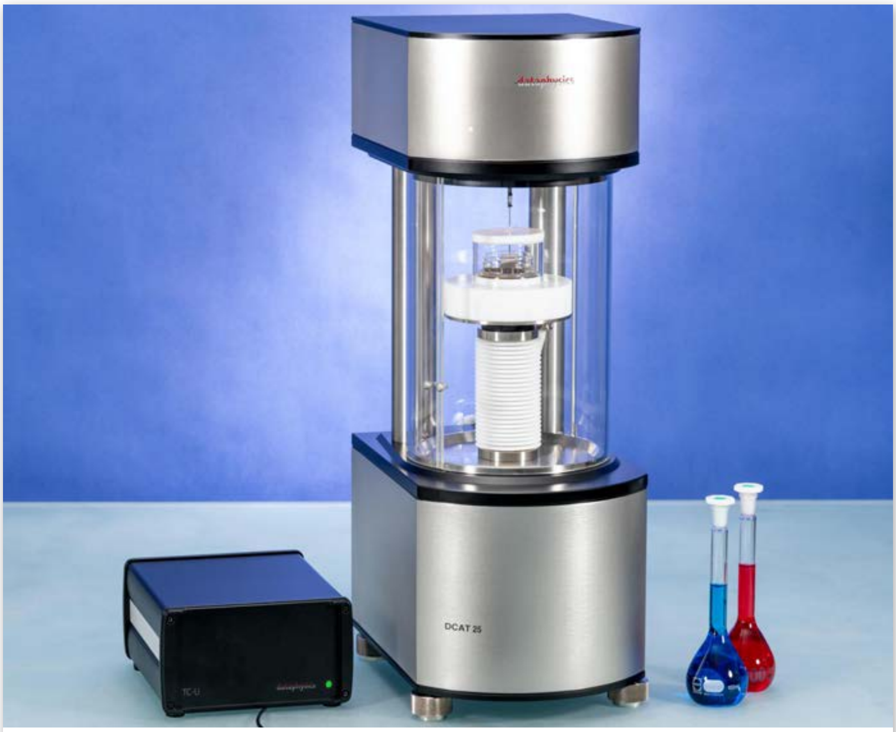


Fig. 1: Force tensiometer DCAT 25 with optional Peltier temperature control unit

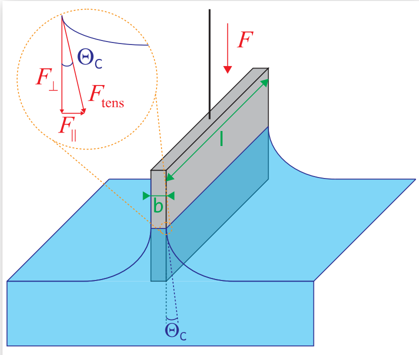


Fig. 3: Wilhelmy plate with liquid lamella

What is the CMC?[2]

Surfactants are surface-active substances that consist of a hydrophilic, polar head group and a hydrophobic, non-polar chain (as shown in Fig. 2). Due to this molecular structure, surfactants preferentially adsorb at interfaces, where they reduce the surface or interfacial tension and facilitate the interaction between two phases, such as water and oil or water and air.

The critical micelle concentration (CMC) is the surfactant concentration at which micelles begin to form in a solution. At low concentrations, surfactant molecules mainly adsorb at the surface or interface between two phases, where they reduce the surface or interfacial tension. As more surfactant is added, the interface becomes increasingly covered with surfactant molecules.

Once the interface is saturated, additional surfactant molecules can no longer adsorb effectively at the interface. Instead, they start to aggregate in the liquid phase and form micelles. This concentration marks the CMC.

The CMC can be determined by measuring the surface or interfacial tension at different surfactant concentrations. Below the CMC, the surface or interfacial tension decreases strongly with increasing surfactant concentration. Above the CMC, it remains nearly constant, because additional surfactant molecules mainly form micelles rather than further reducing the surface or interfacial tension. In a logarithmic plot of surface or interfacial tension versus surfactant concentration, the CMC can be identified as the intersection point of the regression lines before and after micelle formation.

Technique & Method[3]

The Wilhelmy plate method is a force-based technique for determining the surface tension of liquids. A high-precision tensiometer measures the force acting on a wetted plate, from which the surface tension is calculated.

As shown in Fig. 3, a liquid lamella forms when the Wilhelmy plate contacts the liquid. At the three-phase contact line, surface tension generates a tensile force, F_{tens}. This force can be divided into components parallel and perpendicular to the liquid surface. Only the perpendicular component acts on the weighing system and corresponds to the gravitational force of the formed lamella, $m_{lamella}{\cdot}g$. Since the balance is calibrated with the Wilhelmy plate attached before the measurement, the weight of the plate itself does not affect the result. Using the measured force $m_{lamella}{\cdot}g$, the contact line length L, and the contact angle Θ_c, the surface or interfacial tension σ is calculated according to the Wilhelmy equation:

$$\sigma = \frac{F_{tens}}{L} = \frac{F_{\perp}}{L \cdot \cos\Theta_C} = \frac{m_{lamella} \cdot g}{L \cdot \cos\Theta_C}$$

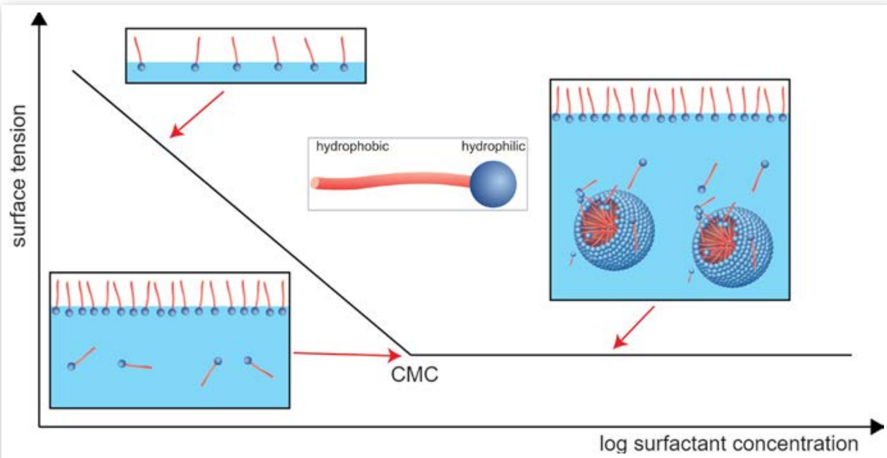


Fig. 2: Surface tension decreases with increasing surfactant concentration until the critical micelle concentration (CMC) is reached, after which it remains nearly constant.

Fig. 4:Liquid dosing unit LDU 25 for automatic concentration variation

Because platinum-iridium has a very high surface energy, the plate is completely wetted by most liquids, resulting in a contact angle of approximately 0°. This allows direct determination of the surface tension from the measured force and the known plate dimensions.

The tensiometers of the DCAT series from DataPhysics Instruments are universal measuring systems for force-based investigations of surface and interfacial properties. Equipped with a **high-precision weighing system**, they are well suited for surface tension measurements and CMC determination using the Wilhelmy plate method.

Experiment

The CMC of a surfactant solution was determined using a DataPhysics DCAT tensiometer equipped with an LDU 25 Liquid Dosing Unit (Fig. 4). A Lutensol® AO7 stock solution with an initial concentration of 1 g/L was prepared by diluting the surfactant in water. To prevent contamination during dosing, all tubes and the LDU 25 were thoroughly flushed with water before use. The LDU 25 was then calibrated, checked for air bubbles, and filled with the Lutensol® AO7 solution.

For the measurement, a sample vessel was filled with 50 mL of pure water and equipped with a magnetic stir bar. Surface tension was measured using the Wilhelmy plate method. Between individual measurements, defined volumes of Lutensol® AO7 solution were automatically added to the vessel by the LDU 25. After each dosing step, the solution was stirred for 10 s and then allowed to rest for 10 s to ensure homogeneous mixing before the surface tension measurement.

The CMC measurement was performed over a concentration range from 2.0×10^{-4} to 0.3 g/L. The Lutensol® AO7 solution was added in 20 logarithmically spaced dosing steps.

All measurement parameters, including dosing steps, stirring time, rest time, and surface tension evaluation, were controlled by the DCAT software. The automatic titration function of the LDU 25 enabled the complete dosing sequence to be performed fully automatically.

Results & Discussion

As shown in Fig. 5, the surface tension decreases continuously with increasing Lutensol® AO7 concentration in the low-concentration range. This behaviour indicates progressive adsorption of surfactant molecules at the air–water interface, where they reduce the surface tension.

At higher concentrations, the decrease in surface tension becomes much less pronounced and the curve reaches a nearly constant plateau. This indicates that the interface is saturated with surfactant molecules and that additional surfactant molecules mainly form micelles in the bulk solution rather than further reducing the surface tension.

The CMC was determined from the intersection of the regression lines fitted to the decreasing and plateau regions of the surface tension curve. For Lutensol® AO7, the resulting CMC was around 0.01 g/L. The corresponding surface tension at the CMC was 27.5 mN/m.

Summary

This application note demonstrates that the critical micelle concentration (CMC) of Lutensol® AO7 can be determined efficiently and reliably using the Wilhelmy plate method with a DataPhysics DCAT tensiometer equipped with an LDU 25 Liquid Dosing Unit.

By combining high-precision surface tension measurement with automated liquid dosing, the DCAT system enables fully automatised CMC analysis over a defined concentration range. The LDU 25 significantly simplifies the measurement workflow and provides a precise, automated, and user-friendly solution for CMC determination in research and industrial applications.

These results highlight the suitability of the DCAT series for surfactant characterization, formulation development, and quality control.

References

[1] https://www.dataphysics-instruments.com/products/dcat/

[2] https://www.dataphysics-instruments.com/knowledge-hub/cmc/

[3] https://www.dataphysics-instruments.com/knowledge-hub/wilhelmy-plate-method/

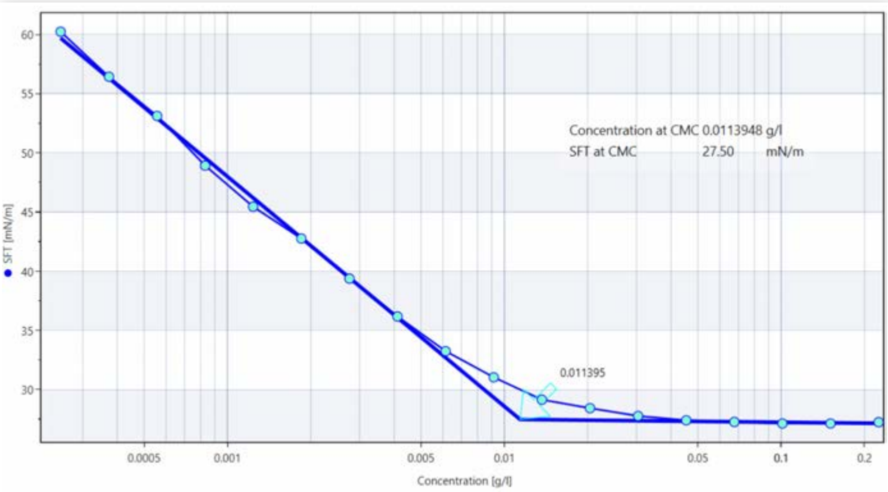
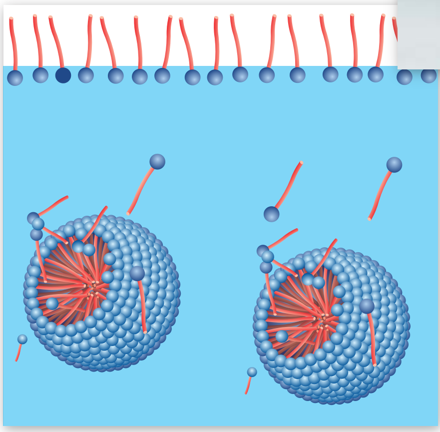


Fig. 5: Surface tension of Lutensol® AO7 as a function of concentration, measured with the Wilhelmy plate method using the DCAT tensiometer and LDU 25. The CMC is determined from the intersection of the fitted curve regions.

DCAT product series

Dynamic contact angle measuring device and tensiometer
-CMC measurement-



We will find a tailor-made solution for your surface science use case and will be pleased to provide you with an obligation-free quotation for the system that fits your needs.
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