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Comparison of different methods for determining the critical micell concentration

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SUMMARY

Introduction. A micellization process is particularly needed for drug technology to design dosage forms with desired properties. The study of micelles has contributed to the discovery of new pharmaceutical areas, such as targeted drug delivery. The boundary between surfactants and micelles is small and is represented by the critical micelle concentration (CMC). There is no clear definition of CMC in the literature; the authors confine themselves to the certain concentration at which a significant number of micelles are formed. Uncertainty in the definition of CMC actualizes a comparative study of methods for its determination.

Material and methods. Sodium oleate as a white powder (manufactured by Sigma Life Science Co.) was used as a modelling sample. This sample contained 0.5% admixture of alkali in its pure form NaOH. Calculations were carried out at a temperature of 19±1°C. The study of CMC determined parameters, such as electrical conductivity, particle size, viscosity, and optical density.

Results. An electrical conductivity-solution concentration diagram and a viscosity-solution concentration one clearly show a sharp inflection. At the inflection point there is a sharp change in the properties of the solution, which is due to micelle formation. The determination of CMC from the change in properties, such as the particle size obtained by dynamic light scattering, yields a less pronounced result.

Conclusion. The CMCs viscosimetrically and conductometrically determined were found to coincide and are $1.9 \cdot 10^{-2}$ mol/l. Dynamic light scattering gives a value of $2.0 \cdot 10^{-2}$–$2.1 \cdot 10^{-2}$ mol/l, which agrees with the data available in the literature.

Key words: sodium oleate, critical micelle concentration, viscosimetry, conductometry, dynamic light scattering.

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СРАВНЕНИЕ РАЗЛИЧНЫХ МЕТОДОВ ОПРЕДЕЛЕНИЯ КРИТИЧЕСКОЙ КОНЦЕНТРАЦИИ МИЦЕЛЛООБРАЗОВАНИЯ

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РЕЗЮМЕ

Введение. Процесс мицеллообразования особенно востребован в технологии лекарств для создания лекарственных форм с заданными свойствами. Изучение мицелл способствовало открытию таких новых фармацевтических направлений, как целевая доставка лекарственных веществ. Граница между поверхностно-активными веществами и мицеллой небольшая и представлена критической концентрацией мицеллообразования (ККМ). В литературе нет четкого определения ККМ; авторы ограничиваются некоторой концентрацией, при которой образуется значимое количество мицелл. Неопределенность в определении делает актуальным сравнительное изучение методов определения ККМ.

Материал и методы. В качестве модельного образца был использован олеат натрия (производство компании Sigma Life Science) в виде порошка белого цвета. Данный образец имеет 0,5% примеси щелочи в чистом виде NaOH. Расчеты осуществлялись при температуре 19±1°С. В ходе исследования ККМ определялись такие показатели, как электрическая проводимость, размер частиц, вязкость, оптическая плотность.

Результаты. На графиках зависимости электрической проводимости от концентрации раствора и вязкости от концентрации раствора наглядно представлен резкий перегиб. В точке перегиба происходит резкая смена свойств раствора, которая обусловлена мицеллообразованием. Определение ККМ по изменению таких свойств, как размер частиц, получаемый методом динамического светорассеяния, дает менее выраженный результат.

Заключение. Установлено, что ККМ, определенные вязкозиметрически и кондуктометрически, совпадают и составляют 1,9•10^{-2} моль/л. Метод динамического светорассеяния дает результат 2,0•10^{-2}–2,1•10^{-2} моль/л, что согласуется с данными литературы.

Ключевые слова: олеат натрия, критическая концентрация мицеллообразования, вязкозиметрия, кондуктометрия, динамическое рассеяние света.

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Introduction

The process of micelle formation is often used in the technology of drugs to create medicinal forms with specified properties. The study of micelles promoted the discovery of new pharmaceutical directions, such as, for example, targeted drug delivery. Surface-active substances (surfactants) are unique molecules due to their difilinity. Such molecules are both hydrophilic and hydrophobic particles. The special structure and uniqueness of the phenomenon of diffusion affords SAW molecules with interesting and new properties uncharacteristic of other substances. One of these properties is micelle formation.

The boundary between surfactant and micelle is small and is represented by the critical concentration of micelle formation (CMC). Above the CMC, surfactant molecules self-assemble into micelles [1]. In the literature there is no clear definition of CMC, the authors limit themselves to a certain concentration at which a significant amount of micelles is formed [1]. However, such a definition is not specific. Therefore, it is relevant to compare the various methods by which a CMC can be established on the basis of an analysis of the sharp change in the physical and chemical properties of surfactant solutions associated with micelle formation.

CMC is the most important characteristic of surfactants. This parameter depends primarily on the nature of the polar group and on the length of the hydrocarbon radical [6]. In [3] two CMCs points are isolated. Above the CMC_1, spherical micelles are present in the solution, with CMC_2 the concentration of spherical particles is maximal. At a concentration above the CMC_2, cylindrical particles are formed, in which the degree of aggregation is higher than that of spherical molecules. Also, the authors note that with the increase in the concentration of micelles, fusion of micelles and their decay are possible [3].

It should be noted that at this concentration there are also other phenomena: changes in light scattering, refractive index and a sharp increase in detergency (Figures 1, 2).

In this study, sodium oleate, which is an anionic surfactant, was chosen to study CMC. At present, some data on the micelle formation of sodium oleate are known. Thus, Table 1 shows the already available data on the determination of the value of the CMC of sodium oleate in an aqueous solution at 25°C.

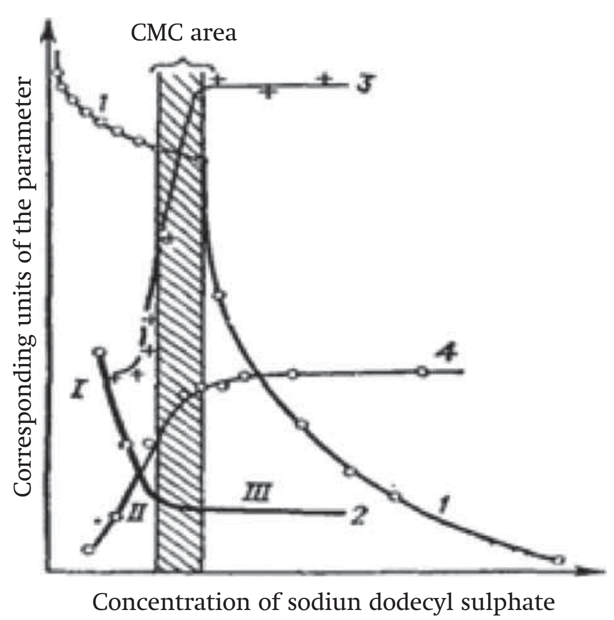

Figure 1. Properties of solutions at the moment of CMC on the example of sodium dodecyl sulfate (1 equivalent conductivity, 2 surface tension, 3 detergent properties 4 osmotic pressure) [4].

Similar work was carried out in [10], however, the precise value of the CMC was not singled out. The authors indicated an interval of micelle formation from 1,8 • 10^{-3} to 2,1 • 10^{-3} mol/l.

Purpose of the Study. The purpose of this study is to compare the application of such methods as conductometry, viscosimetry, spectrophotometry, dynamic light scattering to determine the critical conglomeration of micelle formation.

Material and methods

Sodium oleate, manufactured by Sigma Life Science in the form of a white powder, was used as a model sample. This sample has a 0.5% alkali impurity in pure NaOH. The measurements were carried out at a temperature of 19 ± 1°C. Various measurements were carried out in the CMC studies. The electrical conductivity, the particle size, the viscosity, and the optical density were measured. Measurements of electrical conductivity were conducted by a conductometric method using the HM Digital AquaPro 2 conductivity meter (AP2). The viscosity in this work was determined on a Brookfield DV2T rotary viscometer with a color touch screen.

The Brookfield viscometer allows the viscosity and yield strength to be measured using special spindles. LV2C spindles were used for work. The measurements lasted 90 seconds.

The optical density was measured with a Lambda 950 spectrophotometer. The optical density was measured at a wavelength of 195 nm in cuvettes 10 mm thick. The particle size was measured by dynamic light scattering using a NanophoxPSS nanoparticle size analyzer. Automatic particle counting was used to calculate the particle size. Based on the results obtained, the mean values of particle sizes were calculated.

Experimental part

Solutions of sodium oleate with a concentration in the range were prepared. for the solutions obtained, the viscosity, optical density, electrical conductivity, particle size were determined. According to the obtained data, graphs of the dependence of the studied properties on the solution concentration were constructed.

Results and discussion

Based on the results of the measurements, the graphs (Figures 3,4,5) were plotted for the dependence of various properties of the solution on their concentrations.

On the graphs of the dependence of electrical conductivity on the solution concentration and viscosity on the solution concentration, there is a sharp kink. At the inflection point, a sharp change in the properties of the solution occurs, which is caused by micelle formation. The determination of CMC from the change in such properties as particle size, determined by the method of dynamic light scattering, gives a less pronounced result. It is established that the CMC, which is determined viscosometrically and conductometrically, coincide and constitute 1,9 • 10^{-3} mol/l. The method of dynamic light scattering yields the result mol/l, which agrees with a number of literature data. Spectrophotometry in this range of experimental conditions does not give a clear idea of the critical concentration of micelle formation.

Based on the results of conductometric analysis, a plot of the electrical conductivity versus the solution concentration was obtained (Figure 3). The graph clearly shows the peak area at a concentration of constitute 1,9 • 10^{-3} mol/l. This value can be considered a CMC.

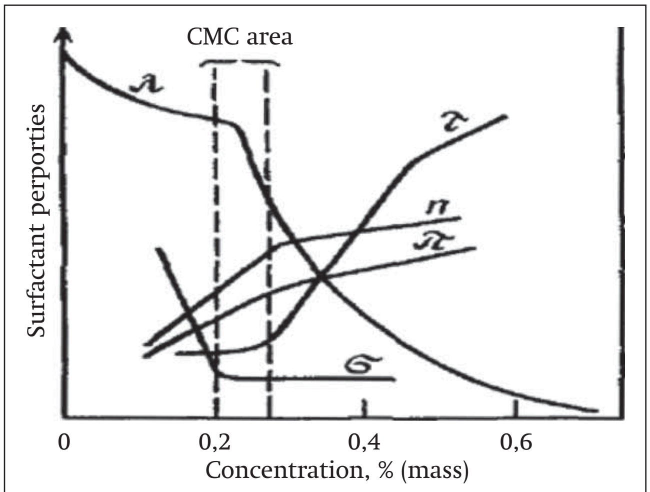

Figure 2. Dependence of turbidity, equivalent to electrical conductivity, surface tension, refractive index, osmotic pressure on concentration.

Table 1

Litereture data of sodium oleate CMC

Litereture data	CMC$_1$, mol/l	CMC$_2$, mol/l	Determination method
1 [5]	2,0 • 10^{-5}		Unknown
2 [2]	1,1 • 10^{-3} 2,1 • 10^{-3}		Conductometry Rebinder
3 [6]	4,5 • 10^{-4}		Rebinder
4 [7]	9,0 • 10^{-4}	2,4 • 10^{-3}	Calometry
5 [9]	1,3 • 10^{-5}	4,0 • 10^{-4}	Rebinder

By the results of viscometric analysis, a plot of the viscosity versus the solution concentration was

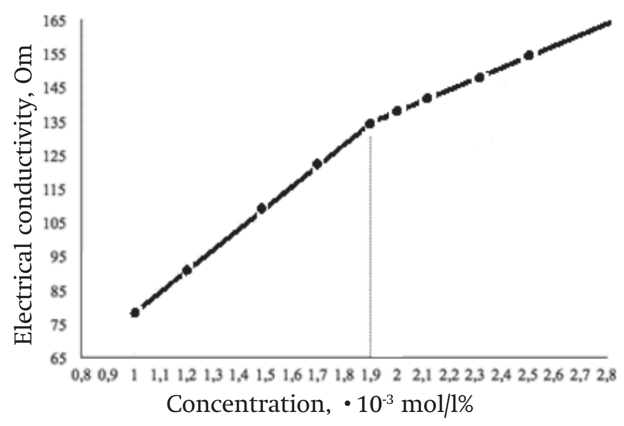

Figure 3. Graph of the dependence of electrical conductivity on the concentration of the solution.

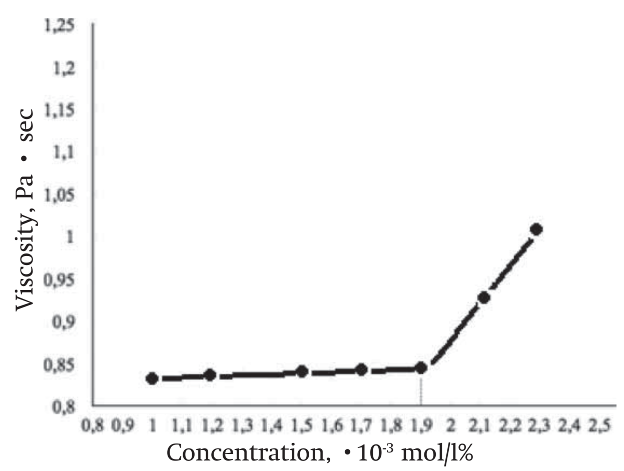

Figure 4. Graph of viscosity versus solution concentration

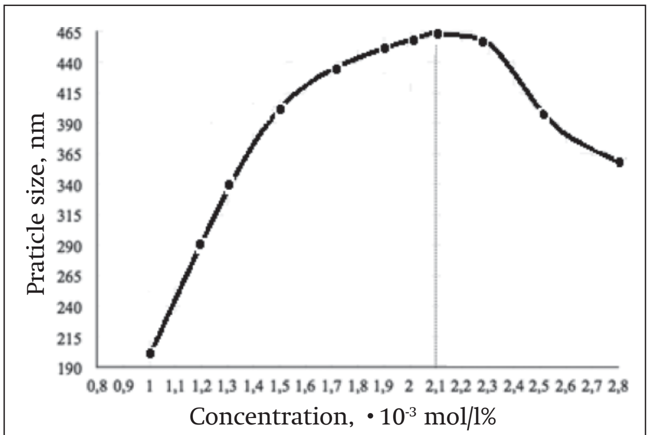

Figure 5. Graph of the dependence of the particle size on the solution concentration

obtained (Figure 4). The area of maximum viscosity is also clearly visible from the graph also at a concentration of $1.9 \cdot 10^{-3}$ M. This value is taken for the CMC.

Based on the analysis of the particle size, a plot was obtained of the particle size dependence on the solution concentration (Figure 5). The maximum particle size indicates the formation of a micelle from the surfactant, and in this case the CMC region falls on the value $2{,}1 \cdot 10^{-3}$ mol/l.

Conclusion

According to the results of this work, the critical concentration of micelle formation of sodium oleate in aqueous solution at a temperature of 19 ± 1 °C was determined by three methods: conductometry, viscosimetry, and particle size measurement. The obtained values of the CMC: ККМ1 = $1{,}9 \cdot 10^{-3}$ M, ККМ2 = $2{,}1 \cdot 10^{-3}$ M. The methods of conductometry and viscosimetry are most suitable for determination of CMC.

Conflict of interest

The authors declare no conflict of interest.

Reference

1. Friedrichsberg, D.A. Course of colloid chemistry. Proc. for universities. 2nd ed., Revised. and additional. L.: Chemistry, 1984; 368. (in Russian)

2. Mchedlov-Petrosyan N.O., Swan A.V., Swan V.I. Colloidal surface-active substances. Kharkov, 2009; 72. (in Russian)

3. Kinetics of micelle formation with allowance for the fusion and decay of spherical and cylindrical micelles. 1. System of non-linear equations of slow relaxation. Colloid Journal, 2011; vol. 73, (3): 404.

4. Frolov Yu.G. Course of colloid chemistry. Surface phenomena and disperse systems. Moscow: Chemistry, 1988; 464. (in Russian)

5. Abramzon A.A. Surface-active substances: properties and application. L .: Chemistry, 1981; 304. (in Russian)

6. Kakehashi R., Shizuma M., Yamamura S.et al. Mixed micelles containing sodium oleate% the effect of the chain length and the polar head group. Journal of Colloid and Interface Science, 2004; 279: 253.

7. Hildebrand A., Garidel P., Neubert R. et al. Thermodynamics of demicellization of mixed micelles composed of sodium oleate and bile salts. Langmuir., 2004; 20 (2): 320.

8. Theander K., Pugh R.J., Rutland M.W. Forces and friction between hydrophilic and hydrophobic surfaces: Influence of oleate species. Journal of Colloid and Interface Science, 2007; 313: 735.

9. Yakovleva A.A., Chuong S.N., Pridatchenko Yu.V. et al. To the question of the critical concentration of micellization of sodium oleate. Izvestiya Vuzov. Applied Chemistry and Biotechnology, 2013; 4 (1): 105. (in Russian)

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