Effect of Hydroxyl Groups on Solubilization States of Alkandiols in DTAB Micelles: Application of a Differential Conductivity Technique

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Abstract: The partition coefficients, $K_x$, of 1,2-alkanediols and $\alpha,\omega$-alkanediols between dodecyltrimethylammonium bromide (DTAB) micelles and water, and the change of the degree of counter-ion dissociation, $d\alpha/dX_a^m$, on DTAB micelles associated with solubilization of the alkanediols are determined by a differential conductivity technique. The standard Gibbs energy change of transfer per methylene group, $\Delta G_0(CH_2)$, is estimated from a dependence of logarithmic value of the $K_x$ on the carbon number of alkyl chain in the alkanediols. The $d\alpha/dX_a^m$ is independent of the carbon number of alkyl chain in the alkanediols. Comparing the present results with those of DTAB/1-alkanols system, it is suggested that solubilization states of the alkanediols in DTAB micelles are as follows: 1,2-alkanediols are solubilized as its alkyl chain is oriented to micellar interior just like 1-alkanols, while $\alpha,\omega$-alkanediols are solubilized as its alkyl chain is partly located in micellar surface region.

Key words: dodecyltrimethylammonium bromide, alkanediols, micelles, partition coefficient, degree of counter-ion dissociation, differential conductivity

1 INTRODUCTION

Surfactants form molecular assemblies such as micelles and vesicles in water, and these molecular assemblies have been used as models for biomembranes and drug carriers. From a viewpoint of fundamental research necessary for the use, the partition coefficients, $K_x$, of amphiphiles such as alkanols between the molecular assemblies and water, and solubilization states of the amphiphiles in the molecular assemblies have been determined by various methods.

We have utilized a differential conductivity technique for determining $K_x$ of 1-alkanols between sodium dodecylsulfate (SDS) micelles and water. This technique also allowed us to determine the change of the degree of counter-ion dissociation, $d\alpha/dX_a^m$, on SDS micelles caused by the solubilized 1-alkanols. The obtained $d\alpha/dX_a^m$ was used to estimate the solubilization states of 1-alkanols in SDS micelles. We have applied this technique to didodecyldimethylammonium bromide (DDAB) vesicles/1-alkanols system, and evaluated the two quantities, i.e., $K_x$ and $d\alpha/dX_a^m$. By comparing the results of DDAB vesicles/1-alkanols system with those of SDS micelles/1-alkanols one, it was suggested that both of surfactant molecules and 1-alkanol molecules are packed more closely in DDAB vesicle membranes than in SDS micelles.

It is interesting to determine the two quantities for other amphiphiles, and to estimate solubilization states of the amphiphiles in the molecular assemblies. In the present study, 1,2-alkanediols and $\alpha,\omega$-alkanediols homologs are used as the amphiphiles and the micelles formed by dodecyltrimethylammonium bromide (DTAB), which is a cationic surfactant as well as DDAB, are used as a molecular assembly. The two quantities for the alkanediols are determined by the differential conductivity technique, and solubilization states of the alkanediols in DTAB micelles are discussed based on the effect of hydroxyl groups of the alkanediols on the two quantities.

2 EXPERIMENTAL PROCEDURES

2.1 Materials

Dodecyltrimethylammonium bromide (DTAB) was purchased from Tokyo Kasei (>99%), and recrystallized three times from a mixed solvent of dehydrated ethanol and
acetone. Commercially available 1,2-alkanediols (1,2-octanediol (>96%, Tokyo Kasei) and 1,2-nonanediol (>99%, Tokyo Kasei) and α,ω-alkanediols (1,8-octanediol (>99%, Tokyo Kasei) and 1,9-nonanediol (>98%, Tokyo Kasei)) were used as additives without further purification. Water was deionized through ion-exchange resin and distilled before use.

2.2 Conductivity measurements of DTAB solution and DTAB solution containing an alkanediol

A solution with a given concentration of DTAB was prepared and added stepwise to a definite amount (about 50 g) of water in a conductivity cell using an injection syringe. On each addition of the solution, the conductivity measurements were made at least 15 minutes after the addition to obtain a constant value of resistance.

A solution with a given concentration of DTAB was prepared. One portion (about 50 g) of this DTAB solution was put in the conductivity cell. Another portion of the DTAB solution was used to prepare the surfactant solution containing an alkanediol. The DTAB solution containing the alkanediol was added successively to the alkanediol-free DTAB solution in the cell, and conductivity measurements were performed. In this procedure, the conductivity was measured as a function of alkanediol concentration under the condition of a constant DTAB concentration. Conductivity measurements were carried out with a LCR meter (HP, 4284A) at 298.15 ± 0.002 K. The solutions were prepared by weight.

3 RESULTS AND DISCUSSION

Figure 1 shows a plot of specific conductivity, $\kappa$, versus DTAB concentration, $C_s$, in water. The plot is almost linear and breaks at about 15 mmol kg$^{-1}$, and again becomes linear. The $C_s$ corresponding to a break point is the critical micelle concentration (CMC) of DTAB in water and represented as CMC$_0$. A slope of a pair of nearest neighbor points in this plot is calculated as $\frac{(\kappa_2 - \kappa_1)}{(C_2 - C_1)}$, and denoted as $d\kappa/dC_s$. The $d\kappa/dC_s$ is called a differential conductivity. A plot of $d\kappa/dC_s$ against square root of $C_s$, in this case $C_s$ being a mean concentration of $C_s$, calculated as $(C_1 + C_2)/2$, is shown in Fig. 2. The $d\kappa/dC_s$ value decreases linearly with the increase in $C_s$, the change being similar to that of equivalent conductivity vs. square root of concentration in a strong electrolyte solution, and breaks at 3.821 mmol kg$^{-1/2}$ which is taken as the CMC$_0^{1/2}$. The $d\kappa/dC_s$ at this break point is regarded as the differential conductivity of free monomer of DTAB, and is denoted as $\kappa_f$. The values obtained at the break point are CMC$_0 = 14.60$ mmol kg$^{-1}$ and $\kappa_f = 84.17$ mS cm$^{-1}$ kg mol$^{-1}$. Above the break point, the $d\kappa/dC_s$ decreases abruptly and reaches a constant value. This constant $d\kappa/dC_s$ value corresponds to the differential conductivity of micelles of DTAB, and is denoted as $\kappa_m$. The obtained value is $\kappa_m = 22.46$ mS cm$^{-1}$ kg mol$^{-1}$.

The change of $\kappa$, $\Delta \kappa$, caused by the addition of 1,2-nonenediol and 1,9-nonanediol to DTAB solutions above CMC$_0$ is plotted against the alkanediol concentration, $C_a$, in Fig. 3 and Fig. 4, respectively. In the figures, $\Delta \kappa$ denotes $\kappa - \kappa_0$, where $\kappa$ and $\kappa_0$ correspond to the specific conductivity of the DTAB solution with and without the alkanediol, respectively. The $\Delta \kappa$ decreases monotonously with the increase in $C_a$, and the decreasing tendency becomes less remarkable with the increase in $C_a$, and above a certain $C_a$ (denoted as $C_a^*$), $\Delta \kappa$ increases with the increase in $C_a$. We have reported the similar dependence of $\Delta \kappa$ on $C_a$ in SDS/1-alkanols system, and have found that the counter-ion (i.e., sodium ion) concentration in SDS solutions, which was determined from electromotive force measurements using sodium ion selective electrode, decreased by the addition of 1-alkanols.

Fig. 1 Plot of Specific Conductivity ($\kappa$) as a Function of Concentration of DTAB ($C_s$).

Fig. 2 Plot of Differential Conductivity ($d\kappa/dC_s$) as a Function of Square Root of Mean Concentration of DTAB ($C_s$).
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Fig. 3 Plot of Change of Specific Conductivity (Δκ) Caused by Addition of 1,2-Nonanediol to DTAB Solution with Fixed Concentration (C₁₂) as a Function of Concentration of 1,2-Nonanediol (C₁₂). C₁₂/mmol kg⁻¹: 19.913(□); 25.067(■); 30.112(△); 34.926(▲); 44.396(○); 54.847(●); 68.375(◇); 79.751(▲). Solid lines were obtained by fitting the quadratic equation with zero intercept, Δκ = aC₁₂² + bC₁₂, to experimental data.

Fig. 4 Plot of Change of Specific Conductivity (Δκ) Caused by Addition of 1,9-Nonanediol to DTAB Solution with Fixed Concentration (C₁₂) as a Function of Concentration of 1,9-Nonanediol (C₁₂). C₁₂/mmol kg⁻¹: 19.998(□); 25.022(■); 29.907(△); 34.998(▲); 40.017(○); 49.721(●); 59.652(◇); 64.775(▲). Solid lines were obtained by fitting the quadratic equation with zero intercept, Δκ = aC₁₂² + bC₁₂, to experimental data.

in Cₛ region below the Cₛ⁰, and increased in Cₛ region above the Cₛ⁰. Therefore, the decrease of Δκ is attributed to the decrease of concentrations of free monomer DTAB and bromide ion associated with the depression of CMC of DTAB caused by the addition of the alkanediol, while the increase of Δκ is due to the increase of the concentration of bromide ion associated with the counter-ion (i.e., bromide ion) dissociation enhanced by the alkanediol solubilized in DTAB micelles. Around the Cₛ⁰ region, the Δκ is almost constant and closed to zero regardless of Cₓ. The constancy seems to be due to compensation of the two effects described above. The similar dependence of Δκ on Cₓ was also observed for other alkanediols. A slope at infinite dilution, denoted as (Δκ/dCₓ)ₓ→0, in the plot of Δκ vs. Cₓ was estimated by fitting a quadratic equation with zero intercept (i.e., Δκ = aCₓ² + bCₓ) to the experimental data; the solid lines in Fig. 3 and Fig. 4 represent the results obtained by the curve fitting. The coefficient b in the quadratic equation gives (Δκ/dCₓ)ₓ→0, and the (Δκ/dCₓ)ₓ→0 values obtained at each Cₛ for respective alkanediols are summarized in Table 1, and plotted against Cₛ in Fig. 5 for 1,2-alkanediols and in Fig. 6 for α,ω-alkanediols. For a given alkanediol, (Δκ/dCₓ)ₓ→0 increases asymptotically from negative to positive with the increase in Cₛ. A following equation which relate (Δκ/dCₓ)ₓ→0 to Cₛ was derived by Manabe et al.

\[
\frac{\text{dκ}}{\text{dC}_x} \bigg|_{x \to 0} = A + B \cdot \frac{K_x (C_x - \text{CMC}_x)}{1 + \frac{K_x}{n_x} (C_x - \text{CMC}_x)}
\]

where A and B are constants, Kₓ is the partition coefficient of alkanediol in mole fraction unit, and nₓ is the amount of substance of water in unit kg; 55.51 mol kg⁻¹. The Kₓ is defined as,

\[
K_x = \frac{X^m_x}{X^m}
\]

where Xᵐₓ and Xᵐ are the mole fractions of alkanediol in water phase and micellar phase, respectively.

The constants A and B, and Kₓ were estimated by fitting Eq. (1) to the experimental results in Figs. 5 and 6. The solid lines in the figures represent the calculated curves from Eq. (1) using the best-fit values of A, B, and Kₓ, which are summarized in Table 2. Equation (1) predicts that a linear relation holds between (Δκ/dCₓ)ₓ→0 and \(\frac{K_x}{n_x} (C_x - \text{CMC}_x)/(1 + \frac{K_x}{n_x} (C_x - \text{CMC}_x))\). The plot following this relation is shown in Fig. 7 for 1,2-alkanediols and in Fig. 8 for α,ω-alkanediols. A good linear relation for each alkanediol in respective figures supports that the estimated Kₓ values are appropriate ones.

The logarithmic values of Kₓ were plotted against the carbon number of alkanediols, m, in Fig. 9. The Kₓ values for SDS/1-alkanols, SDS/α,ω-alkanediols, and DTAB/1-
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alkanols (Kawamura, H., unpublished data) systems obtained by the differential conductivity technique, and those of DTAB/1,2-alkanediols and DTAB/α,ω-alkanediols systems determined from the NMR paramagnetic relaxation enhancement experiment\textsuperscript{10,11} were also plotted in the figure to compare with the present result. The standard Gibbs energy change of transfer per methylene group, \( \Delta G^0 (\text{CH}_2) \), was calculated from the slope of the straight line in Fig. 6 based on the following equation\textsuperscript{12},

\[
\Delta G^0 (\text{CH}_2) = -(2.303)RT \frac{d \log K}{dm}
\]

where \( R \) and \( T \) are the gas constant and absolute temperature, respectively. The \( \Delta G^0 (\text{CH}_2) \) values evaluated in the

- Table 1: Values of \( (d\kappa/dC_a)_{C_a \rightarrow 0} \) at some concentrations of DTAB \( (C_S) \) for 1,2-alkanediols and α,ω-alkanediols.

| Alkanediol      | \( C_a \)/mmol kg\(^{-1}\) | \( (d\kappa/dC_a)_{C_a \rightarrow 0} \)/mS cm\(^{-1}\) kg mol\(^{-1}\) |
|-----------------|--------------------------|--------------------------------------------------|
| 1,2-octanediol | 20.060                   | -19.46                                           |
|                 | 25.059                   | -14.86                                           |
|                 | 30.004                   | -10.90                                           |
|                 | 35.093                   | -8.243                                           |
|                 | 40.143                   | -5.795                                           |
|                 | 44.928                   | -4.326                                           |
|                 | 50.436                   | -2.646                                           |
|                 | 54.571                   | -1.225                                           |
|                 | 60.071                   | 0.9913                                           |
|                 | 67.577                   | 2.268                                            |
| 1,2-nonanediol  | 19.913                   | -38.75                                           |
|                 | 25.067                   | -25.68                                           |
|                 | 30.112                   | -18.32                                           |
|                 | 34.926                   | -13.71                                           |
|                 | 39.862                   | -9.751                                           |
|                 | 44.396                   | -6.660                                           |
|                 | 50.634                   | -4.559                                           |
|                 | 54.847                   | -2.790                                           |
|                 | 59.847                   | -1.932                                           |
|                 | 69.375                   | 1.437                                            |
|                 | 79.751                   | 4.050                                            |
| 1,8-octanediol  | 21.598                   | -7.230                                           |
|                 | 25.004                   | -5.881                                           |
|                 | 30.186                   | -4.284                                           |
|                 | 34.955                   | -2.878                                           |
|                 | 39.993                   | -1.586                                           |
|                 | 46.572                   | -0.2192                                          |
|                 | 49.941                   | 0.7540                                           |
|                 | 50.230                   | 1.050                                            |
|                 | 54.874                   | 1.631                                            |
|                 | 59.882                   | 2.457                                            |
|                 | 65.471                   | 3.695                                            |
| 1,9-nonanediol  | 19.998                   | -16.97                                           |
|                 | 25.022                   | -12.08                                           |
|                 | 29.907                   | -8.559                                           |
|                 | 34.998                   | -5.312                                           |
|                 | 40.017                   | -2.792                                           |
|                 | 44.828                   | -0.7225                                          |
|                 | 49.721                   | 0.8843                                           |
|                 | 54.873                   | 2.427                                            |
|                 | 59.652                   | 3.618                                            |
|                 | 64.775                   | 4.669                                            |

Fig. 5 Dependence of Slope \( (d\kappa/dC_a)_{C_a \rightarrow 0} \) at Infinite Dilution in Plot of \( \Delta \kappa \) vs. \( C_a \) on Concentration of DTAB \( (C_S) \). Added alkanediols are 1,2-octanediol \( (\bigodot) \) and 1,2-nonanediol \( (\square) \). The solid lines were obtained by fitting Eq. (1) to experimental data.

Fig. 6 Dependence of Slope \( (d\kappa/dC_a)_{C_a \rightarrow 0} \) at Infinite Dilution in Plot of \( \Delta \kappa \) vs. \( C_a \) on Concentration of DTAB \( (C_S) \). Added Alkanediols are 1,8-octanediol \( (\bigodot) \) and 1,9-nonanediol \( (\square) \). The solid lines were obtained by fitting Eq. (1) to experimental data.
Table 2  Values of $A$, $B$ and $K_x$ in Eq. (1), and change of the degree of counter-ion dissociation ($\Delta d/dX_m$) caused by solubilization of alkanediols.

| Alkanediol       | $A$/mS cm$^{-1}$ kg mol$^{-1}$ | $B$/mS cm$^{-1}$ kg mol$^{-1}$ | $K_x$  | $\Delta d/dX_m$ |
|------------------|-------------------------------|-------------------------------|--------|-----------------|
| 1,2-octanediol   | $-22.89$                      | $44.96$                       | $1733$ | $0.227$         |
| 1,2-nonanediol   | $-62.27$                      | $77.50$                       | $4624$ | $0.180$         |
| 1,8-octanediol   | $-10.18$                      | $31.71$                       | $818.5$| $0.256$         |
| 1,9-nonanediol   | $-24.20$                      | $45.65$                       | $1922$ | $0.255$         |

Fig. 7  Plot of $(d\alpha/dC_w)_{C_w \rightarrow 0}$ against $K_x/(C_w - C_{MC})/\left(1 + K_x/(C_w - C_{MC})\right)$ according to Eq. (1). Added alkanediols are 1,2-octanediol (○) and 1,2-nonanediol (□).

The present study were $-2.43$ kJ mol$^{-1}$ for DTAB/1,2-alkanediols system and $-2.12$ kJ mol$^{-1}$ for DTAB/α,ω-alkanediols one. The value for DTAB/1,2-alkanediols system is in fair agreement with $-2.38$ kJ mol$^{-1}$ for SDS/1-alkanols system$^{5,6}$, and $-2.50$ kJ mol$^{-1}$ and $-2.44$ kJ mol$^{-1}$ (Kawamura, H., unpublished data) for DTAB/1-alkanols one. These values are also close to $-2.46$ kJ mol$^{-1}$ for DTAB/1,2-alkanediols system and $-2.13$ kJ mol$^{-1}$ for DTAB/α,ω-alkanediols one evaluated by the use of the $K_x$ determined from the NMR experiment$^{10}$ although these $K_x$ values are somewhat smaller than those obtained in the present study. The $\Delta G^\circ$ (CH$_2$) value$^{10}$ is regarded as a measure of hydrophobicity of a medium to which alkanediols transfer from water phase. The larger absolute value of $\Delta G^\circ$ (CH$_2$) suggests that the environment around alkyl chain in alkanediols is more hydrophobic, i.e., the environment around the alkyl chain of solubilized 1,2-alkanediol in DTAB micelles is more hydrophobic than that of solubilized α,ω-alkanediol, and resembles that of solubilized 1-alkanol in hydrophobicity. This result suggests that solubilization states of the alkanediols in DTAB micelles are as follows: 1,2-alkanediols are solubilized as its alkyl chain is oriented to micellar interior just like 1-alkanols, while α,ω-alkanediols are solubilized as its alkyl chain is partly located in micellar surface region.

The constants $A$ and $B$ in Eq. (1) are related to each other as the following equation$^{5,6}$,

$$B = \bar{\alpha}\left(\frac{d\alpha}{dX_m}\right) - A$$

(4)

where $\alpha$ is the degree of counter-ion dissociation on micelles, $\bar{\alpha}$ is a hypothetical differential conductivity of completely ionized micelles ($\bar{\alpha} = 1$). The change of the degree of counter-ion dissociation on DTAB micelles associated with the solubilization of alkanediols, $d\alpha/dX_m$, was calculated from Eq. (4) assuming that $\bar{\alpha}$ is identical with $\bar{\alpha}$.$^{5,6}$ The $d\alpha/dX_m$ values were summarized in Table 2 and plotted against $m$ in Fig. 10. The $d\alpha/dX_m$ values for SDS/1-alkanols$^{5,6}$, SDS/α,ω-alkanediols$^{9}$, and DTAB/1-alkanols (Kawamura, H., unpublished data) systems were also plotted in the figure. The mean values for DTAB/1,2-al-
kanediols and DTAB/α,ω-alkanediols systems are 0.204 and 0.255, respectively. The mean value for DTAB/1,2-alkanediols system is about 1.7 times larger than the corresponding value (0.117) for DTAB/1-alkanols system. As mentioned above, 1,2-alkanediols are considered to be solubilized in DTAB micelles in a similar manner to 1-alkanols because the hydrophobic environment around the alkyl chain is similar to each other. We have determined the da/dXαm values in SDS/amphiphiles system9. The obtained da/dXαm values were positive and increased monotonically with increasing the molecular weight of hydrophilic group of the amphiphiles taken as a parameter of size of the hydrophilic group9. The result suggests that the larger size of hydrophilic group incorporated in the micellar surface region reduces the surface charge density on micelles more effectively, and accelerates counter-ion dissociation. The micellar charge density must be more reduced by the solubilization of 1,2-alkanediols than that of 1-alkanols, because the former have two hydroxyl groups residing at the micellar surface region, while the latter have just one hydroxyl group. Thus, the present result that the da/dXm value for 1,2-alkanediols is larger than that for 1-alkanols looks quite reasonable. When α,ω-alkanediols are compared with 1,2-alkanediols, the mean value of da/dXαm value for DTAB/α,ω-alkanediols system is larger than that for DTAB/1,2-alkanediols system. This result suggests that in addition to two hydroxyl groups, the alkyl chain of α,ω-alkanediol also contributes to the reduction of surface charge density on DTAB micelles, which implies, in turn, that the alkyl chain is partly located in the micellar surface region. These solubilization models being schematically shown in Fig. 11 are consistent with those suggested from comparison of the ΔGα(CH2) values as described above.

4 CONCLUSION

The differential conductivity technique was applied to determine the partition coefficients of 1,2-akanediols and α,ω-alkanediols between DTAB micelles and water, and the change of the degree of counter-ion dissociation (da/dXαm) caused by solubilization of the alkanediols in DTAB micelles. The standard Gibbs energy change of transfer per methylene group (ΔGα(CH2)) was estimated from a dependence of the partition coefficients on carbon number of the alkanediols. Both the da/dXαm and the ΔGα(CH2) suggest that the solubilization states of 1,2-alkanediols and α,ω-alkanediols in DTAB micelles are as follows: 1,2-alkanediols are solubilized as the two hydroxyl groups are located at micelle surface and the alkyl chain is directed to micelle interior, while α,ω-alkanediols are solubilized as not only the two hydroxyl groups but also a part of the alkyl chain is located in micelle surface region.
References
1) Fendler, J.H. Membrane Mimetic Chemistry. John Wiley and Sons, Inc. pp. 113-183 (1982).
2) Fenske, D.B.; Maurer, N.; Cullis, P.R. Encapsulation of weakly-basic drugs, antisense oligonucleotides, and plasmid DNA within large unilamellar vesicles for drug delivery applications. in Liposomes (Torchilin, V.P.; Weissig, V. ed.). Oxford University Press. pp.167-191 (2003).
3) Höiland, H.; Blokhus, A.M. Solubilization in aqueous surfactant systems. in Handbook of Surface and Colloid Chemistry (Birdi, K.S. ed.). 2nd ed. CRC Press. pp. 345-385 (2003).
4) Treiner, C. Partitioning of neutral solutes between micelles and water as deduced from critical micelle concentration determinations. in Solubilization in Surfactant Aggregates (Christian, S.D.; Scamehorn, J.F. ed.). Marcel Dekker, Inc. pp. 383-428 (1995).
5) Manabe, M.; Kawamura, H.; Yamashita, A.; Tokunaga, S. Effect of alkanols on intermicellar concentration and on ionization of micelles. J. Colloid Interface Sci. 115, 147-154 (1987).
6) Manabe, M. The differential conductivity technique and its application to mixed surfactant solutions for determining ionic constants. in Mixed Surfactant Systems (Abe, M.; Scamehorn, J.H. eds.). Marcel Dekker, pp. 93-133 (2005).
7) Kawamura, H.; Manabe, M.; Myoujou, M.; Katsuura, H.; Shiomi, M. Partition coefficients of 1-alkanols between water and DDAB vesicle membrane determined by differential conductivity method. J. Oleo Sci. 58, 177-184 (2009).
8) Manabe, M.; Kawamura, H.; Kondo, S.; Kojima, M.; Tokunaga, S. Determination of partition coefficient of alkanols between bulk water and micelles of an ionic surfactant by a novel method based on surfactant counterion concentration. Langmuir 6, 1596-1600 (1990).
9) Manabe, M.; Kaneko, M.; Miura, T.; Akiyama, C.; Kawamura, H.; Katsuura, H.; Shiomi, M. Counter ion release of ionic surfactant micelles induced by solubilized amphiphiles. Bull. Chem. Soc. Jpn. 75, 1967-1972 (2002).
10) Mullally, M.K.; Doyle, M. J.; Marangoni, D.G. The partitioning of alkanediols into SDS and DTAB micelles from NMR-PRE experiments. Colloid Polym. Sci. 283, 335-339 (2004).
11) Kennedy, C.A.; MacMillan, S.N.; McAliduff, M.J.; Maragoni, D.G. The interaction of isomeric hexanediols with sodium dodecyl sulfate and dodecyltrimethylammonium bromide micelles. Colloid Polym. Sci. 279, 1-7 (2001).
12) Kawamura, H.; Manabe, M.; Miyamoto, Y.; Tokunaga, S. Partition coefficients of homologous ω-phenylalkanols between water and sodium dodecyl sulfate micelles. J. Phys. Chem. 93, 5536-5540 (1989).
13) Tanford, C. The Hydrophobic Effect. 2nd ed. John Wiley and Sons, Inc. pp.42-59 (1980).