Ryszard Zieliński
Chair of General Technology

THERMODYNAMICS OF VISCOUS FLOW IN AQUEOUS SOLUTIONS OF ALKYLTRIMETHYLAMMONIUM BROMIDES

INTRODUCTION

In aqueous surfactant solutions the solute molecules can exist in the monomeric form below the critical micelle concentration, CMC, but they can be either in the monomeric or micellar forms, at surfactant concentrations exceeding the value of the CMC. Dissolution of an ionic surfactant in water below the CMC causes a contraction of volume and a decrease in compressibility of the solution due to electrostriction or interaction between the ionic groups of the surfactants and water as well as to strong hydrophobic interactions between water and alkyl chain of the solute.

In the previous paper [1] we have discussed the solute-solvent interactions in dilute aqueous solutions of several alkyltrimethylammonium bromides in terms of the effect of temperature and the solute structure on the constants of the Joles-Dole equation [2].

In this paper the interaction between the amphiphilic solute and water will be discussed on the basis of the Einstein-Vand's equation [5] and the enthalpy and entropy of activation for the viscous flow in aqueous solutions of alkyltrimethylammonium bromides, C_NTAB, having alkyl chains of hexyl, octyl, decyl, dodecyl and tetradecyl.

EXPERIMENTAL

A special grade samples of n-hexyltrimethylammonium bromide (C_6TAB), n-octyltrimethylammonium bromide (C_8TAB), n-decyltrimethylammonium bromide (C_{10}TAB), n-dodecyltrimethylammonium bromide (C_{12}TAB), and n-tetradecyltrimethylammonium bromide (C_{14}TAB), were the same as those used previously [1, 3]. Densities of the solutions were measured using Ostwald type pycnometers of ca. 20 cm^3 capacity. Pycnometers were calibrated as described previously [3]. Viscosity measure-

ments have been performed using the Ubbelohde type viscosimeter. Since the samples are known to exhibit surface activity the results of viscosity measurements were corrected for the surface tension effect of the solutions at each temperature. All measurements have been performed at different temperatures within the range 15 - 45°C at 5°C intervals. The temperature of the solutions was adjusted within ±0.01°C of the specified temperature.

TREATMENT OF VISCOSITY DATA

According to the hydrodynamic theory of viscosity the relative viscosity of the solution, $\eta_{rel}=\eta/\eta_o$, is related to the volume fraction of the solute, Φ and the molal solute concentration, C. The relationship can be represented by equations proposed by Breslau and Miller [4] or that of Vand [5].

The Breslau-Miller equation [4] is given by

$$\eta_{rel}=1+2.5\,\Phi+B\,\Phi^2=1+2.5\,V_{BM}\,C+B\,V_{BM}^2C^2 \tag{1}$$

which is usually used in the following form

$$\frac{\eta_{rel}-1}{C}=2.5\,V_{BM}+B\,V_{BM}^2\,C \tag{2}$$

where η and η_o are the viscosities of the solution and the solvent, respectively. V_{BM} is the hydrodynamic volume of the solute and B is a constant related to the solute-solvent interactions.

The Einstein-Vand [5] relation is given by

$$\ln\eta_{rel}=\frac{2.5\,\Phi}{1-Q\,\Phi}=\frac{2.5\,V_{EV}\,C}{1-Q\,V_{EV}\,C} \tag{3}$$

and it is usually represented in a linear form as

$$2.5\,C/\ln\eta_{rel}=1/V_{EV}-QC \tag{4}$$

where V_{EV} is the hydrodynamic volume of the solute and Q is the experimental constant and it is supposed to be a sensitive measure of the solute-solvent interactions.

Viscosity data have also been analysed on the basis of the theory of absolute reaction rates developed by Eyring et al. [6]. According to the theory the free energy of activation for the viscous flow per mole of the solution is given by

$$G^{\#}=RT\ln(\eta V/h\,N_A) \tag{5}$$

and that per mole of the pure solvent is

$$G_0^{\#} = RT \ln (\eta_o V_o / h N_A) \quad (6)$$

where V and V_o are the molar volumes of the moving unit and the pure solvent, respectively, h — Planck's constant, N_A — Avogadro's constant. The change in the value of the activation free energy for the viscous flow, $\Delta G^{\#}$, due to the presence of the solute is defined as

$$\Delta G^{\#} = G^{\#} - G_0^{\#} = RT \ln (\eta V / \eta_o V_o) \quad (7)$$

The values of the quotient V/V_o in eq. (7) can be calculated from the density of the solutions

$$V/V_o = [1 + 1000\, C\, (\tilde{V}_1 - M_1/\varrho_o)]\, n_o/(n_o + n_1) \quad (8)$$

where C is the molar solute concentration, M_1 (g mol^{-1}) and $\tilde{V}_1$ (cm^3 mol^{-1}) are the molecular weight and the apparent molar volume of the solute in the solution, n_1 and n_o are the numbers of the solute and solvent molecules in the solution, respectively, and ϱ_o (g cm^{-3}) is the solvent density.

The values of $\Delta G^{\#}$ have been described by means of the second degree function of temperature. By differentiation of the fitted curve with respect to temperature, T, the values of the activation entropy for the viscous flow, $\Delta S^{\#}$, have been determined at each temperature from the slope of the fitted curve using the Gibbs — Helmholtz relationship

$$\Delta S^{\#} = -[d(\Delta G^{\#})/dT]_P \quad (9)$$

where P is the external pressure.

The activation enthalpy for the viscous flow, $\Delta H^{\#}$, was calculated basing on the well known thermodynamical relation

$$\Delta H^{\#} = \Delta G^{\#} + T\, \Delta S^{\#} \quad (10)$$

RESULTS AND DISCUSSION

The values of empirical parameters of eqs. (1) and (3) at various temperatures are listed in Tables 1 and 2, respectively.

The value of V_{BM} (or V_{EV}) allows us to estimate the value of the effective number of water molecules (the hydration parameter, Z) involved in the viscous flow of the solute. The values of Z defined by

$$Z = V_{EV}/V_o \quad (11)$$

where V_o stands for the molar volume of the pure solvent (water) at the temperature of the experiment, are listed in Table 3.

Table 1

V_{BM}(cm^3 mol^{-1}) and B Parameters of the Breslau-Miller's Equation for Alkyltrimethylammonium Bromides in the Monomeric Form in Aqueous Solutions at Various Temperatures

Temp. (°C)		15	20	25	30	35	40	45
C_6TAB	V_{BM}	228.3	216.5	208.7	204.9	197.2	189.4	181.8
	B	−2.0	−2.3	−2.5	−2.6	−2.8	−3.1	−3.5
C_8TAB	V_{BM}	293.4	283.6	277.8	266.1	258.3	242.7	226.9
	B	−1.3	−1.4	−1.5	−1.6	−1.8	−2.0	−2.4
$C_{10}TAB$	V_{BM}	386.7	371.2	355.7	332.9	328.6	313.5	278.0
	B	−9.2	−10.2	−11.2	−11.1	−13.4	−15.1	−19.4
$C_{12}TAB$	V_{BM}	543.8	513.1	486.5	465.2	450.6	427.9	397.3
	B	−71.5	−81.2	−91.4	−102.1	−110.1	−123.3	−144.6
$C_{14}TAB$	V_{BM}	–	600.0	563.1	532.6	510.2	487.7	457.2
	B	–	−174.5	−202.3	−228.5	−251.6	−278.2	−319.7

Table 2

V_{EV}(cm^3 mol^{-1}) and Q Parameters of the Einstein-Vand's Equation for Alkyltrimethylammonium Bromides in the Monomeric Form in Aqueous Solutions at Various Temperatures

Temp. (°C)		15	20	25	30	35	40	45
C_6TAB	V_{EV}	228.3	216.5	208.8	205.0	197.2	189.0	181.9
	Q	−2.1	−2.2	−2.3	−2.3	−2.4	−2.6	−2.7
C_8TAB	V_{EV}	293.3	283.6	277.8	266.1	258.3	242.8	227.0
	Q	−1.8	−1.8	−1.8	−1.9	−2.0	−2.1	−2.2
$C_{10}TAB$	V_{EV}	387.1	371.6	356.1	333.2	329.0	314.0	278.6
	Q	−5.2	−5.6	−6.1	−6.1	−7.1	−7.9	−9.9
$C_{12}TAB$	V_{EV}	545.4	514.9	488.4	467.3	452.8	430.4	400.1
	Q	−35.7	−40.9	−46.5	−52.7	−57.3	−65.1	−78.1
$C_{14}TAB$	V_{EV}	–	603.8	567.4	537.3	515.2	493.2	463.3
	Q	–	−84.6	−99.5	−113.8	−126.7	−141.8	−165.9

The value of Z can be interpreted as the number of water molecules replaced by the solute in the structure of water and a certain number of water molecules attached to the solute during the viscous flow. It was shown previously [3, 7] that the increase in temperature causes the increase in the value of the apparent (or the partial) molar volume of C_NTAB monomers in aqueous solutions. In contrary, the values of both V_{BM} and V_{EV} show the opposite tendency. It suggests that in spite of the thermal expansion of the solute in the solution the total number of solvent (water) molecules involved in the viscous flow decreases with increasing temperature. This result can be attributed to a decrease of

the solute-solvent interactions with increasing temperature attributable to the partial dehydration of the hydrophobic part of the molecule. A similar temperature induced dehydration process of the hydrophobic part of surfactant monomers in aqueous solutions was suggested basing on the analysis of ultrasound velocity and adiabatic compressibility data in aqueous solutions of C_NTAB [3].

Table 3

Hydration Parameter, Z, of Alkyltrimethylammonium Bromides in the Monomeric Form in Aqueous Solutions at Various Temperatures

Temp. (°C)	C_6TAB	C_8TAB	C_{10}TAB	C_{12}TAB	C_{14}TAB
15	12.7	16.3	21.5	30.3	–
20	12.0	15.8	20.6	28.6	33.5
25	11.6	15.4	19.8	27.1	31.5
30	11.4	14.8	18.5	26.0	29.9
35	11.0	14.3	18.3	25.2	28.6
40	10.5	13.5	17.4	23.9	27.4
45	10.1	12.6	15.5	22.2	25.7

The parameters B and Q in eqs. (1) and (3), respectively, can be regarded as sensitive measures of the solute-solvent interactions. Figure 1 shows the values of the interaction parameter, Q, of the Einstein-Vand equation plotted as a function of the number of carbon atoms of the alkyl chain of the solute. For comparison, the value of Q reported by Choudhury and Majumdar [8] for C_1TAB at 35°C was also included in Fig. 1. The most striking in the plot is of course the discontinuity in the behavior of value of Q observed above ca. C_9 at each temperature which can be attributed to the difference in the mode of hydration around the alkyl chain of the surfactant monomer, i.e., to the absence or presence of hydrophobic hydration.

The analysis of the numerical values of the interaction parameters, B or Q, can give some information on the shape of the moving units. Low negative value of B or Q indicates that the moving units can be regarded as approximately spherical, while the increase in negative values of B or Q observed at higher temperatures and for longer derivatives, suggests larger deviations from the spherical shape of the moving units.

The activation parameters for the viscous flow depend on the solute concentration and temperature. Effect of concentration on the activation parameters for hexyltrimethylammonium bromide (C_6TAB) in aqueous solutions at 25° is given in Table 4.

The values of $\Delta G^{\#}$ are positive in the temperature range investigated

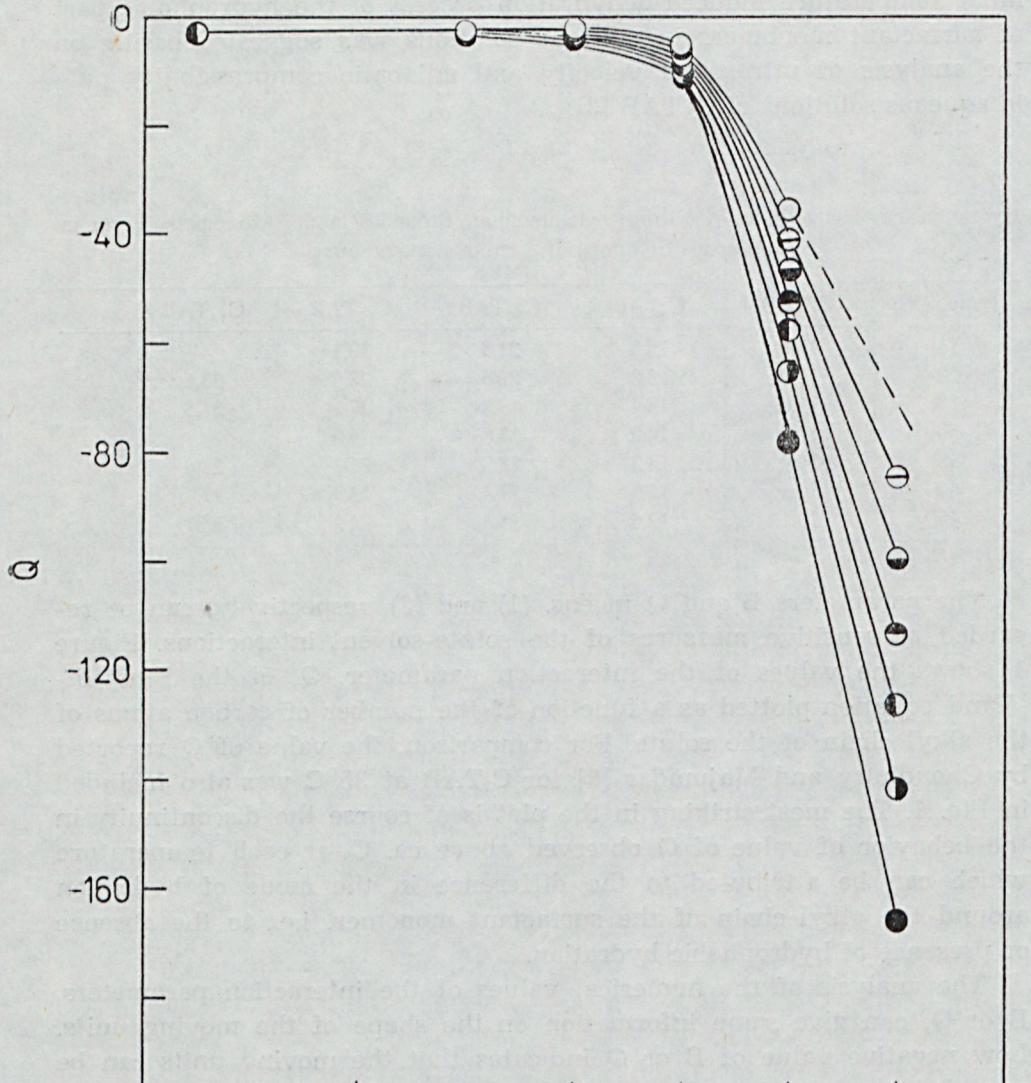


Fig. 1. Effect of the number of carbon atoms in the alkyl chain of the alkyl chain of alkyltrimethylammonium bromides on the value of the Einstein-Vand interaction parameter, Q, in aqueous solutions at various temperatures.
Symbols: (○) — 15°C; (⊖) — 20°C; (◒) — 25°C; (◓) — 30°C; (◐) — 35°C; (◑) — 40°C; (●) — 45°C. The value for C_1 TAB at 35°C from Ref. [8].

and they linearly increase with the solute concentration. According to Singh and Tomar [12] the non-linearity of free energy of activation for the viscous flow with the concentration of the added solute indicates the formation of the solute-solvent agregates, as the principal kinetic entity. Therefore, one can suppose that the possible solute-solvent aggregation does not occur in the solutions.

Table 4
Effect of Hexyltrimethylammonium Bromide Concentration on Activation Parameters for the Viscous Flow in Aqueous Solutions at 25°C

Concentration mol dm^{-3}	$\Delta G^{\#}$ J mol^{-1}	$\Delta H^{\#}$ J mol^{-1}	$\Delta S^{\#}$ J mol^{-1} K^{-1}
0.010	12.5	26.8	0.05
0.017	20.5	45.8	0.08
0.023	27.2	62.1	0.12
0.040	46.8	108.0	0.21
0.058	65.3	155.8	0.30
0.084	92.8	220.3	0.43
0.101	110.5	266.9	0.52
0.129	139.3	336.8	0.66

As can be seen in Table 4 the activation enthalpy for the viscous flow, $\Delta H^{\#}$, increases with increasing solute concentration. The value of $\Delta H^{\#}$ can be regarded as a measures of the energy barier to the fluid motion. The increase in the value of $\Delta H^{\#}$ with the solute concentration indicates the decrease in fluidity of the solution.

Effect of temperature on the thermodynamical parameters of the activation for the viscous flow is shown in Table 5. The values reported in Table 5 are based on the solute concentration of 1 mol/kg in orded to be compared with the values published in literature [13, 14]. It should be noted, however, that the data for higher derivatives are of only hypothetical nature, because for C_NTAB having alkyl chains longer than C_8 the micelle formation takes place at much lower solute concentrations [15]. Nevertheless, it allows us to compare the thermodynamical quantities for the viscous flow for different solutes at the same concentration.

One can see that the value of $\Delta G^{\#}$ increases with increasing length of the hydrocarbon moiety of the solute, while it decreases with temperature. The negative slope of the plot of $\Delta G^{\#}$ vs. temperature corresponds to the positive value of the entropy of activation for the viscous flow. It indicates that the flow is favored entropically.

It can be seen in Table 5 that the value of $\Delta H^{\#}$ increases with increasing number of carbon atoms in the alkyl chain of the solute. Although it is difficult to compare our values of $\Delta H^{\#}$ with the values of the acti-

vation energy for the viscous flow, $E^{\#}$, published by Tanaka et al. [13], it can be easily shown that the two sets of data give the same contribution (within the experimental error) from the CH_2 group to the value of $\Delta H^{\#}$, derived from the viscosity measurements carried out at 25°C. The contribution of one methylene group to the value of $\Delta H^{\#}$, $d\Delta H^{\#}/dN$, is (0.555 ± 0.05) kJ mol^{-1}, while the corresponding contribution to the value of $E^{\#}$, $dE^{\#}/dN$, amounts to (0.553 ± 0.09) kJ mol^{-1}.

Table 5

Activation Free Energy, $\Delta G^{\#}$ (kJ mol^{-1}), Enthalpy, $\Delta H^{\#}$ (kJ mol^{-1}), and Entropy, $\Delta S^{\#}$ (J mol^{-1}K^{-1}), for the Viscous Flow in Aqueous Solutions of Alkyltrimethylammonium Bromides at Various Temperatures

Temp. (°C)		15	20	25	25*	30	35	40	45
C_6TAB	$\Delta G^{\#}$	0.91	0.88	0.86	–	0.86	0.84	0.82	0.80
	$\Delta H^{\#}$	0.91	1.14	1.39	2.01	1.66	1.96	2.03	2.12
	$\Delta S^{\#}$	0.0	0.9	1.8	2.5	2.7	3.6	3.9	4.2
C_8TAB	$\Delta G^{\#}$	1.15	1.14	1.13	–	1.11	1.10	1.06	1.01
	$\Delta H^{\#}$	1.74	1.81	1.89	2.68	1.96	2.04	2.08	2.13
	$\Delta S^{\#}$	2.1	2.3	2.5	3.4	2.8	3.0	3.3	3.5
C_{10}TAB	$\Delta G^{\#}$	1.40	1.37	1.35	–	1.39	1.29	1.26	1.24
	$\Delta H^{\#}$	3.20	3.12	3.03	3.56	2.93	2.86	2.76	2.56
	$\Delta S^{\#}$	6.3	6.0	5.7	5.7	5.4	5.1	4.8	4.5
C_{12}TAB	$\Delta G^{\#}$	1.63	1.56	1.51	–	1.46	1.43	1.37	1.28
	$\Delta H^{\#}$	5.09	4.85	4.60	5.40	4.36	4.12	3.84	3.52
	$\Delta S^{\#}$	12.0	11.2	10.4	10.9	9.6	8.7	7.9	7.1
C_{14}TAB	$\Delta G^{\#}$	1.81^{+}	1.74	1.66	–	1.60	1.55	1.50	1.41
	$\Delta H^{\#}$	6.38^{+}	6.00	5.58	–	5.17	4.76	4.33	3.85
	$\Delta S^{\#}$	15.9^{+}	14.5	13.1	–	11.8	10.4	9.0	7.7

Note: (*) – data from Ref. [13] correspond to the values $\Delta E^{\#}$ and $\Delta S^{\#}$: (+) – estimated value.

Variation of the activation entropy for the viscous flow, $\Delta S^{\#}$, with temperature is more complex. For lower derivatives the value of $\Delta S^{\#}$ increases, while that for longer ones decreases with increasing temperature. It seems reasonable to suppose that the observed difference in temperature dependence of $\Delta S^{\#}$ reflects, to some extend, the difference in temperature dependence of the contributions from the polar head group and the hydrophobic part of the molecule.

It can be seen in Table 5 that at a given temperature the value of $\Delta S^{\#}$ increases linearly with the length of the hydrocarbon moiety of the solute. Therefore, the value of $\Delta S^{\#}$ can be split into the contributions from the constituent groups, that is

$$\Delta S^{\#} = \Delta S^{\#}(HG) + N\,\Delta S^{\#}(CH_2) \qquad (12)$$

where $\Delta S^{\#}$ (HG) and $\Delta S^{\#}$ (CH_2) are the activation entropy contributions from the polar head group and the CH_2 group, respectively, and N is the number of carbon atoms in the alkyl chain of the solute. It is difficult, however, to compare our results with the values of $\Delta S^{\#}$ at 25°C published by Tanaka et al. [13], since the two sets of the $\Delta S^{\#}$ values

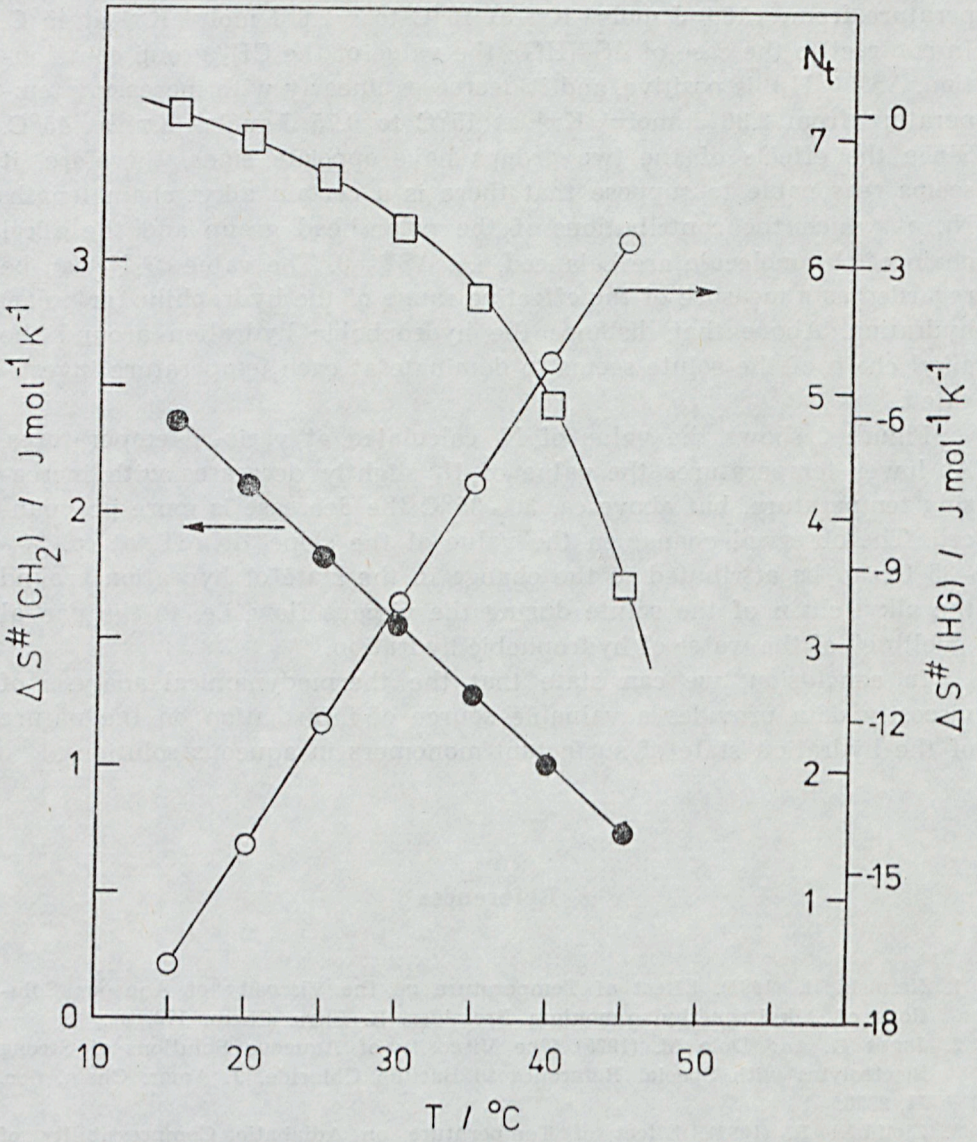


Fig. 2. Effect of temperature on the values of group contributions to the activation entropy of for the viscous flow and the effective hydrophilic hydration radius, N_t, in aqueous solutions of alkyltrimethylammonium bromides.
Symbols: (○) — $\Delta S^{\#}$ (HG);(●) — $\Delta S^{\#}$ (CH_2); (□) — N_t.

were obtained using different treatments of the experimental viscosity data. Nevertheless, it can be easily shown that the two sets of the data give a similar contribution from the CH_2 group, (1.53 ± 0.19) J mol^{-1} K^{-1} and (1.37 ± 0.34) J mol^{-1} K^{-1} [13], respectively.

As can be seen in Fig. 2 the value of $\Delta S^{\#}$ (HG) is negative (in the temperature range investigated), and it increases linearly with temperature from -16.9 J mol^{-1} K^{-1} at 15°C to -2.6 J mol^{-1} K^{-1} at 45°C. In contrast to the case of $\Delta S^{\#}$(HG), the value of the CH_2 group contribution, $\Delta S^{\#}$ (CH_2), is positive, and it decreases linearly with increasing temperature from 2.36 J mol^{-1} K^{-1} at 15°C to 0.75 J mol^{-1} K^{-1} at 45°C. Since the effects of the two groups have opposite signs, therefore, it seems reasonable to suppose that there is a certain alkyl chain length, N_t, at which the contributions of the polar head group and the alkyl chain of the molecule are balanced, i.e. $\Delta S^{\#} = 0$. The value of N_t can be regarded as a measure of the effective range of the hydrophilic (or polar) hydration. Above that distance the hydrophobic hydration around the alkyl chain of the solute seems to dominate at each temperature investigated.

Figure 2 shows the value of N_t calculated at various temperatures. At lower temperatures the value of N_t slightly decreases with increasing temperature, but above ca. 30 - 35°C the decrease is more pronounced. The observed change in the value of the slope, dN_t/dT, at ca. 30 - - 35°C can be attributed to the change in the state of hydration around the alkyl chain of the solute during the viscous flow, i.e. to the partial „melting" of the water of hydrophobic hydration.

In conclusion, we can state that the thermodynamical analysis of viscosity data provides a valuable source of information on the nature of the hydration state of surfactant monomers in aqueous solutions.

References

1. Zieliński R. (1991). Effect of Temperature on the Viscosity of Aqueous Solutions of Alkyltrimethylammonium Bromides. Z. Phys. Chem. **173**, 63.
2. Jones G. and Dole M. (1929). The Viscosity of Aqueous Solutions of Strong Electrolytes with Special Reference to Barium Chloride. J. Amer. Chem. Soc. **51**, 2950.
3. Zieliński R. (1992). Effect of Temperature on Adiabatic Compressibility of Aqueous Solutions of Hexyltrimethylammonium Bromide. Polish J. Chem. **66**,193.
4. Breslau B. R., and Miller T. F. (1970). On the Viscosity of Concentrated Aqueous Electrolyte Solutions. J. Phys. Chem., **74**, 1056.

5. Vand V. (1948). Viscosity of Solutions and Suspensions. I. Theory. J. Phys. & Colloid Chem., **52**, 277.
6. Glasstone S., Laidler K. J., and Eyring H. (1941). Theory of Rate Processes. McGraw-Hill Book Co., New York. p. 477.
7. Zieliński R., Ikeda S., Nomura H., and Kato S. (1988). Temperature Dependence of Adiabatic Compressibility of Aqueous Solutions of Alkyltrimethylammonium Bromides. J. Chem. Soc., Faraday Trans. 1, **84**, 151.
8. Choudhury K. R. and Majumdar D. K. (1983). Viscous Flow in Aqueous Solution of Quaternary Ammonium Salts: High Concentration Range. Electrochimica Acta, **28**, 23.
9. Zieliński R., Ikeda S., Nomura H., and Kato S. (1987). Adiabatic Compressibility of Alkyltrimethylammonium Bromides in Aqueous Solutions. J. Colloid Interface Sci. **119**, 398.
10. Vikingstad E., Skauge A., and Høiland H. (1978). Partial Molar Volumes and Compressibilities of the Homologous Series of Sodium Alkylcarboxylates, R_6COONa—$R_{13}COONa$, in Aqueous Solutions. J. Colloid Interface Sci., **66**, 240.
11. Benjamin L. (1964). Calorimetric Studies of the Micellization of Dimethyl-n--alkylamine Oxides. J. Phys. Chem., **68**, 3575.
12. Singh H., Tomar S. P. S. (1988). Studies on Viscosity of Magnesium Soaps of Higher Fatty Acids in Dilute Aqueous Solutions at Various Temperatures. Polish J. Chem., **62**, 833.
13. Tanaka M., Kaneshina S., Nishimoto W., and Takabatake H. (1973). The Viscosities of Aqueous Sodium Alkylsulfate and Alkyltrimethylammonium Bromide Solutions. Bull. Chem. Soc. Jpn. **46**, 364.
14. Nightingale, Jr. E. R. (1959). Phenomenological Theory of Ion Solvation. Effective Radii of Hydrated Ions. J. Phys. Chem., **63**, 1381.
15. Zieliński R., Ikeda S., Nomura H., and Kato S. (1989). Effect of Temperature on Micelle Formation in Aqueous Solutions of Alkyltrimethylammonium Bromides. J. Colloid Interface Sci., **129**, 175.

Ryszard Zieliński
Katedra Technologii Ogólnej

TERMODYNAMIKA LEPKIEGO PRZEPŁYWU W WODNYCH ROZTWORACH BROMKÓW ALKILOTRIMETYLOAMONIOWYCH

Streszczenie

W pracy przedstawiono analizę wyników pomiarów lepkości wodnych roztworów bromków alkilotrimetyloamoniowych, C_NTAB, zawierających 6, 8, 10, 12 i 14 atomów węgla w łańcuchu alkilowym, dla stężeń niższych od wartości krytycznego stężenia micelarnego, CMC, w zakresie temperatur 15 - 45°C. Lepkość roztworów

3.86
5.97
5.98
S 11
S 15

opisano przy pomocy równań Breslau-Millera i Einsteina-Vanda. Wyznaczono efektywną objętość cząsteczek monomerów w wodnych roztworach oraz wartości parametrów oddziaływań substancja rozpuszczona-rozpuszczalnik. Stwierdzono, że w niższych temperaturach niższe pochodne wykazują niewielkie odchylenia od kształtu kulistego, przy czym wielkość tych odchyleń szybko wzrasta ze wzrostem zarówno temperatury jak i długości łańcucha alkilowego cząsteczki. Obliczono parametry termodynamiczne aktywacji dla lepkiego przepływu: $\Delta G^{\#}$, $\Delta H^{\#}$ i $\Delta S^{\#}$. Stwierdzono różny udział części polarnej i łańcucha alifatycznego cząsteczki C_NTAB do wartości entropii aktywacji dla lepkiego przepływu.

Рышард Зелиньски
Кафедра общей технологии

ТЕРМОДИНАМИКА ВЯЗКОГО ПРОТЕКАНИЯ В ВОДНЫХ РАСТВОРАХ АЛКИЛОТРИМЕТИЛОАММО НИЕВЫХ БРОМИДОВ

Содержание

В работе представлен анализ результатов измерений вязкости водных растворов алкилотриметилоаммониевых бромидов, C_NTAB, имеющих 6, 8, 10, 12 и 14 атомов углерода в алкиловой цепи, для концентраций низших чем величина критической мицеллярной концентрации, CMC, в пределе температур 15 - 45°C. Вязкость растворов была описана с помощью уравнений Бреслау--Миллера и Эйнштейна-Ванда. Обозначено эффективный объём молекул мономеров в водных растворах а также величины параметров взаимодействий растворимое вещество — растворитель. Установлено, что в более низких температирах низшие производные имеют небольшие отклонения от шаровидной формы, причём величина этих отклонений быстро увеличивается как с увеличением температуры так и длины алкиловой цепи молекулы. Были подсчитаны термодинамичные параметры активации для вязкого протекания: $\Delta G^{\#}$, $\Delta H^{\#}$ и $\Delta S^{\#}$. Установлено разную долю полярной части и алифатической цепи молекулы C_NTAB к величине энтропии активации для вязкого протекания.

BIBLIOTEKA AE w Poznaniu

BIBLIOTEKA GŁÓWNA
AKADEMII EKONOMICZNEJ
215887
001-215887-00-0

AKADEMIA EKONOM

Zeszyty Naukowe – Seria I

Ostatnio ukazały się następujące prace:

- Papers of fuzzy sets and their applications, pod red. **J. Albrychta,** ZN s. I nr 187, s. 93
- Planowanie w rynkowej gospodarce polskiej, pod red. **B. Gruchmana i J. Tarajkowskiego**, ZN s. I nr 201, s. 95
- Gospodarka lokalna w warunkach samorządności, pod red. **B. Gruchmana i D. Śniegowskiej,** ZN s. I nr 205, s. 157
- Ekonomiczno-finansowe uwarunkowanie samorządu lokalnego, pod red. **E. Denek, J. Sobiecha i J. Wierzbickiego,** ZN s. I nr 203, s. 209
- Prace z zakresu gospodarki przestrzennej i ochrony środowiska, pod red. **R. Domańskiego,** ZN s. I nr 204, s. 150

W druku znajdują się:

- Filozoficzne i etyczne aspekty życia gospodarczego, pod red. **M. Szczepańskiego,** ZN s. I nr 207
- Strategia zarządzania przedsiębiorstwem, pod red. **Kazimierza Krzakiewicza,** ZN s. I nr 208
- Studia europejskie, pod red. **R. Domańskiego** ZN s. I nr 211

Książki można nabywać w Punkcie Kol
nej w Poznaniu, al. Niepodległości 1
w punkcie przy ul. Dożynkowej 9 G

Prenumeratę prowadzi: ORPAN (Pałac
tel. 200-211 w. 25-16), ARS POLO
03-933 Warszawa, tel. 261-201) or
(60-967 Poznań, al. Niepodległości 1