Thermodynamic properties and contact angles of CTAB and SDS in acetone–water mixtures at different temperatures

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Abstract

The thermodynamic properties of sodium dodecyl sulfate (SDS) and cetyltrimethylammonium bromide (CTAB) in neat water and acetone–water mixtures were studied by measuring the conductivity at 298.15, 308.15, 318.15 and 323.15 K. The critical micelle concentration (CMC), degree of ionization (α), standard Gibbs free energy of micellization (ΔG_m°), standard entropy of micellization (ΔS_m°), standard heat of micellization (ΔH_m°), the heat capacity of micellization ($\Delta_m C_p^\circ$) and free energy of transfer (ΔG_{trans}°) were evaluated from conductivity data. The contact angles (CAs) were measured using a drop shape analyzer (DSA-25E). The correlation of ΔG_m° with solvent parameters and the solvophobic parameter was explored.

Keywords Sodium dodecyl sulfate · Cetyltrimethylammonium bromide · Acetone–water · Conductivity · Contact angle

1 Introduction

Surfactants are defined as the class of compounds tending to form aggregates called micelles [1]. CMC is a concentration at which micelle is formed. Micelle formation of surfactants is caused by hydrophobic interactions of hydrocarbon tails with water balanced by electrostatic repulsions between the surfactant head groups [2]. CMC, α and ΔG_m° depend on the nature of the hydrophobic tail, the hydrophilic head group and the counter ion species [3]. There are few studies on micelle arrangement in a water–acetone system. Miyagishi [4] examined the impact of organic additives such as alcohols, urea, dioxane, acetone and formamide on the micellization of an aqueous solution of dodecyl ammonium halides utilizing a conductivity technique and an emf cell. Moreover, Miyagishi investigated the effect of acetone, 1-propanol and urea on the micellization of dodecylammonium chloride and iodide [5] and the effect of acetone and 1-propanol on the micellization of a series of alkylammonium chlorides (C_{12} – C_{18}) [6]. Miyagishi calculated the CMC, α , the effective coefficient of electrical

energy and thermodynamic parameters. The investigation shows that organic additives show remarkable changes in the thermodynamic properties of the surfactant solution.

Treiner and Besnerais [7] calculated ΔG_{trans}° of SDS and DTAB from neat water to water–acetone mixtures by the method of vapor weight estimations and have additionally found out α and apparent charge of micelles of similar surfactants in water–acetone and water–*n*-propanol solutions by the method of conductivity.

Ionescu and Favere investigated the effect of acetone on the formation of micelle of CTAB in aqueous medium at 25 °C and 40 °C by means of surface tension measurements. In the absence of acetone, they calculated the value of ΔG_m° is – 17.3 kJ/mol with CMC 0.92 mM at 25 °C. But at 0.0755 mol fraction acetone, the value of ΔG_m° is – 14.7 kJ/mol with CMC 2.20 mM at the same temperature. At higher mole fractions of acetone viz. 0.0949 and 0.140 formation of micelles have not been reported [8].

Yadav and Bhattarai [9] investigated the effect of ethanol on the micellization of SDS in an aqueous medium by conductivity measurement and reported that the

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conductivity of SDS in ethanol–water is inversely proportional to the volume of ethanol because of the decrease in the dielectric constant. Bhattarai et al. [10] worked with SDS in the presence of CTAB in neat water and three different methanol–water mixtures (0.1, 0.2 and 0.3 volume fractions methanol) at 298.15, 308.15, 318.15 and 323.15 K and observed that value of density of SDS in the presence of CTAB in neat water and methanol–water mixture is higher than the density of SDS in the presence of water and methanol–water mixture. Cooley et al. [11] observed CMC of SDS increases with temperature at a given composition. At 0.1 mole fraction of ethylene glycol, the CMC increased from 5.7 mM to 6.7 mM as the temperature increased from 303.15 to 313.15 K after measuring by a conductivity meter (model DDS 307A). Malliaris and Binana [12] measured the conductance of SDS in acetone–water mixtures and found that initially, CMC decreased on adding acetone; maximum depression was seen at 1.14% of acetone and then increased until finally micellar formation was inhibited at acetone concentrations above 25%. From the graph, it was observed that CMC decreased above 30% acetone concentration (v/v).

Here, we studied the effect of acetone and temperature on the micellization of CTAB and SDS by conductivity measurement and calculated the CMC, α , ΔG_m° , ΔS_m° , ΔH_m° , $\Delta_m C_p$ and ΔG_{trans}° . The effect of acetone on micellization behavior was also observed by contact angle measurement. The correlation of ΔG_m° with the solvent parameters and the solvophobic parameter is included.

2 Experimental section

2.1 Materials

In this work, SDS of molecular weight 288.372 g/mol and CTAB of molecular weight 364.45 g/mol were purchased from Loba Chemical Private Limited, India. Acetone was obtained from Fischer Scientific India Pvt. Ltd. The assay percentage range was 99% and was a certified reagent grade solvent. Surfactants were dried for 1 h. Triply distilled water with a specific conductance of $< 0.6 \mu\text{S}/\text{cm}$ at 298.15 K was used. Solutions were prepared in neat water and 0.10 to 0.40 volume fraction of acetone–water. The concentration range of the solutions was $\sim 0.01 \text{ mol L}^{-1}$ at 298.15, 308.15, 318.15 and 323.15 K.

2.2 Electrical conductivity measurements

Conductance measurements were done on a Pye-Unicam PW 9509 conductivity meter at a frequency of 2000 Hz utilizing a dip - type cell with a cell constant of 1.15 cm^{-1} and with an uncertainty of 0.01%. The cell was adjusted utilizing

aqueous KCl solution [13]. To maintain different temperatures, a digital water bath purchased from India was used.

2.3 Contact angles measurements

Contact angles were measured using Kruss-DSA25E, Germany. The contact angles of CTAB and SDS solutions of different concentrations in the acetone–water mixture were determined by the sessile drop method over the borosilicate glass surface and aluminum surface respectively. Different concentrations of CTAB and SDS (above and below CMC) were prepared and for each concentration, the contact angles were measured using DSA software.

3 Results and discussion

3.1 Specific conductance of the SDS and CTAB solutions

The specific conductance study is one of the useful methods to understand the physicochemical properties of the solutions of surfactants. The conductometric plots of SDS and CTAB in water and acetone–water mixtures at 298.15, 308.15, 318.15 and 323.15 K are presented in Figs. 1, 2 and 3 (for CTAB) and in Figs. 4, 5 and 6 (for SDS) respectively. The specific conductance increases with an increase in concentration with a certain inclination. The meeting point of the two straight lines is a CMC. The premicellar and postmicellar slopes were used to calculate α .

From Figs. 1, 2, 3, 4, 5 and 6, it is apparent that the specific conductance shows a sharp increase with concentration, which is due to an increase in the number of ions by unit volume of the solution. The increase in specific conductance with temperature is observed and it is due to the decrease in the viscosity of the solution; that there is an increase in the speed of the ions and hence the increase in α .

Table 1 displays the values of premicellar (S_1) and postmicellar (S_2) slopes drawn from the graphs of specific conductance with the concentration of CTAB and SDS solutions of acetone–water mixtures. It is observed from the data in Table 1 that there is a decrease in the slopes of the S_1 region compared to the S_2 region with the increase in acetone.

The increase in α upon the addition of acetone may be due to a diminished polarity, which rises the repulsion between ionic head groups and diminishes micelle stability, which in turn also decreases the corresponding charge density.

The rising temperature may rise the steric volume of the head in the micelle and hence α is affected [14]. Two forces as coulombic and thermal are responsible

Fig. 1 Concentration dependency of the conductance for CTAB in neat water at 298.15 K (open triangle), 308.15 K (open square), 318.15 K (closed triangle) and 323.15 K (closed square)

Fig. 2 Concentration dependency of the conductance for CTAB in 0.10 volume fraction of acetone at 298.15 K (open triangle), 308.15 K (open square), 318.15 K (closed triangle) and 323.15 K (closed square)

for the increase in α [15]. The former force is assigned to the attraction of the counter ions to the polar head and the second force is temperature-dependent. When

the temperature is increased, the thermal force prevails over the coulombic force and the degree of ionization increases.

Fig. 3 Concentration dependency of the conductance for CTAB in 0.20 volume fraction of acetone at 298.15 K (open triangle), 308.15 K (open square), 318.15 K (closed triangle) and 323.15 K (closed square)

Fig. 4 Concentration dependency of the conductance for SDS in neat water at 298.15, 308.15, 318.15 and 323.15 K

3.2 Thermodynamics of micellization

After finding the value of cmc, we can ascertain significant thermodynamic parameters as ΔG_m° can be calculated from a pseudo-phase separation model [13, 16]:

$$\Delta G_m^\circ = (2 - \alpha)RT \ln X_{\text{cmc}} \quad (1)$$

The standard heat of micelle formation, ΔH_m° , can be evaluated from the Gibbs–Helmholtz equation [17]:

$$\Delta H_m^\circ = -RT^2(2 - \alpha) \left[\frac{\partial \ln X_{\text{cmc}}}{\partial T} \right]_p \quad (2)$$

The term $\left[\frac{\partial \ln X_{\text{cmc}}}{\partial T} \right]_p$ is evaluated by fitting the graph of $\ln X_{\text{cmc}}$ versus temperature and using the corresponding temperature derivative. ΔS_m° can be calculated using the following equation:

$$T\Delta S_m^\circ = \Delta H_m^\circ - \Delta G_m^\circ \quad (3)$$

Fig. 5 Concentration dependency of the conductance for SDS in 0.10 volume fraction of acetone at 298.15, 308.15, 318.15 and 323.15 K

Fig. 6 Concentration dependency of the conductance for SDS in 0.20 volume fraction of acetone at 298.15, 308.15, 318.15 and 323.15 K

where α = degree of dissociation, X_{cmc} = mole fraction of surfactant at CMC, R = universal gas constant and T = absolute temperature.

Also, the effect of acetone on the aggregation process can be studied using ΔG_{trans}^0 , which is defined by [16]:

$$\Delta G_{trans}^0 = (\Delta G_m^0)_{\text{acetone+water}} - (\Delta G_m^0)_{\text{water}} \quad (4)$$

A linear variation observed between ΔH_m^0 and ΔS_m^0 is calculated with the help of the relation (5).

Table 1 S_1 and S_2 for CTAB and SDS obtained from conductance measurements in neat water and acetone–water mixtures containing 0.0, 0.10 and 0.20 volume fractions of acetone at 298.15, 308.15, 318.15 and 323.15 K

Temperature (K)	Vol. fraction of acetone	CTAB S_1, S_2 (mS cm ⁻¹ M ⁻¹)	SDS S_1, S_2 (mS cm ⁻¹ M ⁻¹)
298.15	0	222, 42.1	86.7, 38.9
	0.1	208, 41.5	60.5, 38.8
	0.2	195, 41.0	52.9, 38.6
308.15	0	182, 41.8	83.9, 38.6
	0.1	172, 41.3	58.8, 38.3
	0.2	163, 40.8	50.5, 37.5
318.15	0	173, 41.5	81.5, 33.3
	0.1	164, 41.0	57.0, 37.6
	0.2	155, 40.4	47.8, 37.4
323.15	0	159, 41.3	79.1, 38.0
	0.1	152, 40.9	54.9, 37.2
	0.2	144, 40.2	46.1, 36.4

$$\Delta S_m^o = \frac{1}{T_c} \Delta H_m^o + \sigma \quad (5)$$

where $\frac{1}{T_c}$ is the slope and σ is the intercept of a linear plot. T_c refers to the solvation part of micellization, the σ measures solute–solvent interaction. The temperature dependence of the hydrophobic impact communicated as $\Delta_m C_p^o$ and determined from the slope of ΔH_m^o versus temperature graph is noted as follows:

$$\Delta_m C_p^o = \frac{\partial \Delta H_m^o}{\partial T} \quad (6)$$

The thermodynamic properties of micellization, such as ΔG_m^o , ΔH_m^o , ΔS_m^o and ΔG_{trans}^o are shown in Tables 2 and 3 for CTAB and SDS respectively in water as well as acetone–water mixtures at 298.15, 308.15, 318.15 and 323.15 K.

It is evident from Tables 2 and 3 that the free energy and enthalpy of micelle formation are negative in all cases and that the free energy becomes less negative as the acetone content in the mixture increases, indicating that the micelle formation becomes less spontaneous at higher acetone content. This behavior suggests that micellization becomes less favorable at higher acetone contents.

The entropy of micelle formation of CTAB in water and acetone–water mixture decreases with the addition of acetone, but for that of SDS, it increases. Further, this type of change implies that the driving force for micellization in water–CTAB–acetone and water–SDS–acetone systems under these conditions must be accredited to the enthalpic term. The similar type of behavior of CTAB and SDS was observed in the presence of co-solvents such as DMSO, DMF, DMA, THF, dioxane and acetonitrile [18–22]. Because the entropy of micellization values of

Table 2 CMC, α , ΔG_m^o , ΔH_m^o , ΔS_m^o and ΔG_{trans}^o for the CTAB from specific conductance measurements in neat water and acetone–water mixtures containing 0.10 and 0.20 volume fractions of acetone at 298.15, 308.15, 318.15 and 323.15 K

Temperature (K)	Volume fraction of acetone	CMC [mM]	α	ΔG_m^o [kJ mol ⁻¹]	ΔH_m^o [kJ mol ⁻¹]	ΔS_m^o [J mol ⁻¹ K ⁻¹]	ΔG_{trans}^o [kJ mol ⁻¹]
298.15	0	0.898	0.19	−49.81	−27.36	75.28	–
	0.1	1.50	0.20	−46.57	−39.74	22.92	3.24
	0.2	2.00	0.21	−44.66	−42.54	7.12	5.15
308.15	0	0.998	0.23	−49.80	−28.73	68.40	–
	0.1	1.91	0.24	−45.99	−41.46	14.68	3.81
	0.2	3.30	0.25	−42.87	−44.30	−4.65	6.93
318.15	0	1.25	0.24	−49.78	−30.71	59.93	–
	0.1	4.86	0.25	−45.92	−43.82	6.59	3.86
	0.2	3.90	0.26	−42.85	−46.94	−12.84	6.93
323.15	0	1.35	0.26	−49.61	−31.61	55.70	–
	0.1	3.18	0.27	−44.95	−44.76	0.596	4.66
	0.2	4.38	0.28	−42.82	−47.89	−15.68	6.79

Table 3 CMC, α , ΔG_m° , ΔH_m° , ΔS_m° and ΔG_{trans}° for the SDS from specific conductance measurements in neat water and acetone–water mixtures containing 0.10 and 0.20 volume fractions of acetone at 298.15, 308.15, 318.15 and 323.15 K

Temperature (K)	Volume fraction of acetone	CMC [mM]	α	ΔG_m° [kJ mol ⁻¹]	ΔH_m° [kJ mol ⁻¹]	ΔS_m° [J mol ⁻¹ K ⁻¹]	ΔG_{trans}° [kJ mol ⁻¹]
298.15	0	7.80	0.45	-34.07	-12.53	72.23	–
	0.1	10.3	0.64	-28.69	-6.41	74.72	5.38
	0.2	11.2	0.73	-26.26	-3.94	74.88	7.81
308.15	0	8.60	0.46	-34.59	-13.24	69.31	–
	0.1	10.5	0.65	-29.42	-6.80	73.41	5.17
	0.2	11.5	0.75	-26.62	-3.94	73.58	7.97
318.15	0	9.50	0.47	-35.06	-14.02	66.14	–
	0.1	11.30	0.66	-29.81	-7.16	71.19	5.17
	0.2	12.00	0.78	-26.67	-3.71	74.52	8.39
323.15	0	10.20	0.48	-35.08	-14.38	64.05	–
	0.1	11.9	0.67	-29.86	-7.32	69.76	5.22
	0.2	12.3	0.79	-26.78	-4.23	69.77	8.30

CTAB decreases with the inclusion of acetone, a rise in the orderliness of the water-CTAB-acetone system takes place as the volume of acetone is raised. This is agreeing with strong interactions, such as H-bonding, between acetone and water, which is a well-established fact. It is noted that acetone forms a clathrate of the stoichiometry $\text{CH}_3\text{COCH}_3 \cdot 17\text{H}_2\text{O}$ [23, 24].

The value of ΔG_{trans}° slowly rises with an increase in the volume fraction of acetone in the water. The plot of ΔH_m° and ΔS_m° values displays the joint correlation phenomena of the enthalpy-entropy compensation. When the

enthalpy provides less contribution to ΔG_m° , its counterpart noted as ΔS_m° has higher participation in creating free energy to have a large negative value and vice versa.

The linear variation (Figs. 7 and 9) for ΔH_m° with ΔS_m° gives T_c and another linear variation (Figs. 8 and 10) for ΔH_m° with T gives $\Delta_m C_p^\circ$. The T_c values obtained for water, 0.1 and 0.2 volume fractions of acetone measured at 298.15, 308.15, 318.15 and 323.15 K, respectively.

The values of T_c , σ and $\Delta_m C_p^\circ$ for CTAB and SDS are given in Table 4 for the acetone–water system.

Fig. 7 Plot of ΔH_m° versus ΔS_m° (CTAB)

Fig. 8 Plot of ΔH_m° versus T (CTAB) **Fig. 9** Plot of ΔH_m° versus ΔS_m° (SDS)

The $\Delta_m C_p^\circ$ value decreases for neat water, 0.1 and 0.2 volume fraction of acetone.

3.3 Correlation of ΔG_m° with solvent parameters

We have correlated ΔG_m° with dielectric constant (D), viscosity(η_0), Reichardt's parameter (E_T) [25], the

Hildebrand parameter (δ) [26–28], and the Gordon parameter (G) [29]. Since aggregation exists of molecular association, the fluidity, polarity and solvent structure are anticipated to impress the process [30]. Here, we used the acetone–water mixture to see the influence of CTAB and SDS on the ΔG_m° values.

Fig. 10 Plot of ΔH_m^0 versus T (SDS)

Table 4 Values of T_c , σ and $\Delta_m C_p^0$ for CTAB and SDS in the acetone–water mixture

Compensation parameters	CTAB			SDS		
	Water	0.1 acetone	0.2 acetone	Water	0.1 acetone	0.2 acetone
T_c (K)	4.54	4.29	4.25	-0.198	-0.032	-0.013
σ	-43.8	-45.1	-43.9	9674.0	2789.0	9674.0
$\Delta_m C_p^0$ (J mol ⁻¹ K ⁻¹)	-173	-205	-220	-74.4	-31.0	-5.05

Fig. 11 Plot of ΔG_m^0 versus 1/D at 298.15 K (CTAB)

Fig. 12 Plot of ΔG_m^0 versus ρ at 298.15 K(CTAB) **Fig. 13** Plot of ΔG_m^0 versus η_0 at 298.15 K(CTAB)

In Figs. 11, 12, 13, 14, 15 and 16, the dependence of ΔG_m^0 (CTAB) and in Figs. 17, 18, 19, 20, 21 and 22, the dependence of ΔG_m^0 (SDS) on the solvent parameters, E_T , η_0 , D , G , ρ and δ of the acetone–water mixture are presented. The E_T , η_0 , ρ and D were used from the literature [31–37], G values were calculated by us (Table 5) and δ values were evaluated with

the empirical relationship given elsewhere [38, 39] between δ and D :

$$\delta = 0.45D + 18.5 \quad (7)$$

For CTAB and SDS, the curves were concave down decreasing for the relation of ΔG_m^0 with E_T and δ , while

Fig. 14 Plot of ΔG_m^0 versus E_T at 298.15 K(CTAB) **Fig. 15** Plot of ΔG_m^0 versus G at 298.15 K(CTAB)

curves were concave down increasing for the relation of ΔG_m^0 with D and η_0 in the acetone–water mixture. But the relation of ΔG_m^0 with ρ for CTAB is convex while for SDS is concave down decreasing. Even though few chemists [40, 41] noticed the linear relationship between ΔG_m^0 and

G for some surfactants in mixed aqua-organic solvents, the points in the graphs were widely scattered for witnessing poor correlations, but the curve for CTAB and SDS in the acetone–water system is convex.

Fig. 16 Plot of ΔG_m^0 versus δ at 298.15 K (CTAB)

Fig. 17 Plot of ΔG_m^0 versus ρ (SDS)

3.4 Correlation of ΔG_m^0 with the Solvophobic Parameter

From the theory of solute–solvent interactions, the interaction of alkyl chains with solvents can be marked by the

solvophobicity of hydrocarbons [42]. The solvophobic power of hydrocarbons can be explained by their solvophobic parameter, S_p , calculated by the Gibbs energies of transfer of hydrocarbons from the gas into a given solvent [42].

Fig. 18 Plot of ΔG_m^0 versus $1/D$ (SDS) **Fig. 19** Plot of ΔG_m^0 versus η_0 (SDS)

It can be seen from Figs. 23 and 24 that the ΔG_m^0 values decrease with increasing S_p values in the acetone–water mixture. This indicates that the ΔG_m^0 values depend strongly on the solvophobic power of hydrocarbons in water–acetone mixtures.

3.5 Contact angles

Surfactants play an important role in the wetting of low-energy solid surfaces, and the contact angle can successfully reflect the wetting ability. For a perfect, homogeneous solid surface, the great plan of the force balance

Fig. 20 Plot of ΔG_m^0 versus δ (SDS) **Fig. 21** Plot of ΔG_m^0 versus G (SDS)

on the contact line predicts the contact angle (θ) with respect to the interfacial energy densities of the three interfaces of the system [43]. The Young–Dupre condition [Eq. (8)] depicts this equalization. It can be determined by limiting the mechanical energy of the system for different varieties of the contact zones of the solid, fluid, and vapor stages [44–46].

$$\cos \theta = \frac{(\gamma_{sg} - \gamma_{sl})}{\gamma_{lg}} \quad (8)$$

The Young–Dupre equation speaks to the association of the tiny contact angle to the interfacial tensions acting on the contact line and emerging from the molecular and

Fig. 22 Plot of ΔG_m^0 versus E_T (SDS)

Table 5 Various Physicochemical parameters of the mixed solvents (acetone–water) at 298.15 K

Volume fraction of acetone	1/D	η_o (mPa s)	E_T (kcal mol ⁻¹)	G (J m ⁻³)	ρ (kg m ⁻³)	δ	S_p
0	0.0127	0.893	63.10	2.740	997.100	53.84	1.00
0.1	0.0135	1.007	61.66	1.537	987.582	51.87	0.919
0.2	0.0144	1.205	60.15	1.450	977.136	49.66	0.818

Fig. 23 Plot of ΔG_m^0 versus S_p (CTAB)

Fig. 24 Plot of ΔG_m^0 versus S_p (SDS)

infinitesimal structure and science of the interfaces. Here, θ is the contact angle, γ_{sg} , γ_{lg} and γ_{sl} are the surface tensions at the interfaces of solid/gas, liquid/gas and solid/liquid, respectively.

Starkweather et al. [47] made two solutions of oil/SDS in water, one is below CMC (8 mM) and another is above CMC (20 mM) to study the change in contact angle on stainless

steel and optical glass surfaces, and they observed that increasing the surfactant concentration causes a decrease in the oil/surfactant solution interfacial tension for solutions of SDS resulted in a decrease in the change in the contact angle, but 20 mM SDS did not yield an optimum but only a decrease in the change in the contact angle as the pH increased.

Fig. 25 Plot of contact angle versus Log C (CTAB)

Fig. 26 Plot of contact angle versus Log C (SDS)

In this study, the contact angle and surface free energy of CTAB and SDS in acetone–water mixed solvent media (containing water, 0.10 and 0.20 volume fractions of acetone) were measured on the Borosilicate glass surface and aluminum surface respectively at 298.15 K. Based on Figs. 25 and 26, the CA increases with decreases in the concentration of CTAB and SDS for different volumes fraction of acetone. Similar results were observed by Menezes et al. [37].

4 Conclusion

The exploratory outcomes for the conductance of CTAB and SDS in pure water and acetone–water mixtures have been introduced as a component of surfactant concentration.

The conductance was observed increase with increasing surfactant concentration while values were likewise observed to be diminished with an increase in acetone content in the mixed solvent media. The values of the pre-CMC slope (S_1) and post-CMC slope (S_2) gives an appropriate view in regards to the solution nature of CTAB and SDS. The CMC and α were observed to increase for both CTAB and SDS up to 0.20 volume fraction of acetone. After 0.20 volume fraction, no CMC was observed. The free energies and enthalpy of micelle development were observed to

be negative for both CTAB and DTAB but enthalpy goes on decreasing with increasing volume fraction of acetone for CTAB in a given mixed-solvent media which is contrary to the enthalpy of micellization for SDS with increasing the volume fraction of acetone. The entropy of micellization increases for SDS whereas decreases for CTAB with the increase in the volume fraction of acetone. It can be seen that ΔG_m^0 values in the acetone–water mixture do not show a straight forward linear correlation with the different studied solvent parameters i.e. D , E_T , G , η_0 , ρ and δ . The standard free energy of micellization values decrease with increasing S_p values in the acetone-water mixtures indicating strongly dependent on the solvophobic power of hydrocarbons in water-acetone mixtures.

Also, the contact angles increased with a decrease in the concentration of CTAB and SDS in pure water, 0.10 and 0.20 volume fraction of acetone for different concentrations.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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