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Thermodynamics of Micellization of SDS in the Presence of Promethazine Hydrochloride and Ethanol Medium

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Abstract: ***Micellization of sodium dodecyl sulphate using Conductometric titration technique was employed in this work. The specific conductivity versus surfactant concentration plots were analyzed using Boltzman sigmoid approach for the determination of the critical micelles concentration (CMC) of the SDS in absence and presence of PMZ at different temperature. The thermodynamic parameters of micellization, such as change in the free Gibbs energy (ΔG_m^0), enthalpy (ΔH_m^0), entropy ((ΔS_m^0)), Gibbs energy of transfer ($\Delta G_{m.tr}^0$), enthalpy transfer ($\Delta H_{m.tr}^0$)and entropy transfer (($\Delta S_{m.tr}^0$)) were obtained from the CMC measurement in these study, using the phase separation model of micellization. SDS micelles were micellized and stabilized earlier when PMZ concentrations rose from 0.1 mM to 0.25 mM in aqueous. The obtained values of (ΔG_m^0 were generally negative and varied slightly with temperature which indicates the spontaneous aggregation process. The magnitude of enthalpy transfer ($\Delta H_{m.tr}^0$ was positive in PMZ/H_2O which denote that the transfer of hydrophobic portion from aqueous SDS medium to PMZ/SDS system in water are endothermic in nature. In the presence of PMZ, the reduced CMC values strongly suggest favorable, early aggregation and stabilization of SDS micelles. Overall, SDS micellization is entropically regulated in the presence of PMZ. Negative ΔG_m^0 values for the micellization of SDS in water and in the presence of varying amounts of PMZ and ethanol account for the process spontaneity at all temperature.***

Keywords: Micellization, Surfactant, Critical micelle concentration, Prometizine hydrochloride

1. Introduction

Most pharmaceuticals are composed of hydrophobic organic compounds with distinct molecular structures. Many of these hydrophobic drugs aggregate and adsorb in aqueous solutions similarly to surfactants because they are amphiphilic by nature.

Medication promethazine The phenothiazine family of medicines includes PMZ, a neuroleptic and first-generation antihistamine that is used as a sedative, migraine treatment, and to lessen anxiety, restlessness, and agitation brought on by mental illnesses. Constipation, weariness, dizziness, and sleepiness are possible side effects.

Critical Micelle Concentration is the concentration of surfactant above which the micelles form, and all additional surfactants added to the system go to micelle. Before reaching the CMC, the surface tension changes strongly with concentration of the surfactant.

Thermodynamic parameters are important tools to know the micellization phenomenon, the interactions between the drug and surfactant and therefore the influence of various additives. Also, the drug delivery and release rate are functions of the molecular interaction of a drug with surfactants; thus, these molecular interactions are often explained in terms of thermodynamic parameters, and therefore the values of various thermodynamic parameters are often utilized in drug formulation to realize better drug delivery and drug release rates.

This study aims to determine the thermodynamic parameters-free energy, enthalpy and entropy of the self-aggregation of SDS and to Investigate the thermodynamic properties of transfer for SDS – PMZ mixture on the micellization process.

2. Experimental

Chemicals

The surfactant was used without additional purification after being purchased from Sigma Aldrich at a 98% purity level. Additionally, analytical grade ethanol and PMZ were acquired and used exactly as supplied. The water was deionized with a specific conductivity of 1-3µScm-1 at room temperature using doubly distilled water.

Method

The conductivity meter (Hanna-H15521-02) was calibrated before use by measuring the electrical conductivities of 0.01 N KCl solution (Merck, purity 99%) to give 1413µS cm^{-1} at 298.15K and a thermostatic water bath (Grant GD 120) to maintain the temperature within ±0.1K. All weights measurements were carried out using an electronic weighing balance (Mettler Toledo AB54, ±0.0001g.

Conductometric titration method, involves the titration of a known volume of surfactant ito a fixed volume of water contained in a thermostated water bath to maintain the temperature constant within $\pm 0.1^0$C

The following is the basic idea behind the conductometric titration process: when an ion is substituted during a titration procedure, the electrolytic conductivity of the solution is directly affected by the difference in the ionic conductivities of the two ions.

Additionally, it is evident that the values of ionic conductance differ between anions and cations. Lastly, the conductivity also depends on a chemical reaction occurring in the electrolytic solution.

Theory

This kind of titration is based on the theory that conductivity measurement can be used to identify the end-point associated with the titration process. Just like when a base is added to an acid-base neutralization reaction, the solution's initial conductivity will decrease. This is because the base's cationic component would take the place of the H+ ions.

The concentration of the ionic entities will rise following the achievement of the equivalency point. Consequently, the solution's conductance rises. Plotting the conductance values graphically will thus result in two straight lines with opposite slopes. The equivalency point is where these two lines intersect.

3. Result and Discussion

A plot of specific conductivity against surfactant concentration at different temperature consists of two linear segments with different positive slopes (pre-CMC slope, and post CMC slope), that intercepted at break points (fig 4.1) which corresponds to the formation of micelles (CMC). The break is as a result of the binding of some of the counter-ion to the micellar surface. The CMC values reflects the degree of binding, an increase in binding causes a decrease in value of the CMC, and the extent of the binding can be obtained as follows:

$$\beta = 1 - \alpha$$

$$\alpha = \frac{S_2}{S_1}$$

where α is the degree of counter-ion dissociation, β is the extent of counter ion binding, S_2, is the post micellar slope, and S_1 is the pre-micellar slope (1). The conductivity measurement has been reported (2) to be one of the straight forward techniques for the determination of the critical micelle concentration (CMC) of the ionic surfactants and other micellar parameters such as degree of micellar ionization. This is due to high sensitivity and reproducibility. This methods has also been reported to be a better diagnostic tool for the measurement of CMC of ionic surfactant (6)

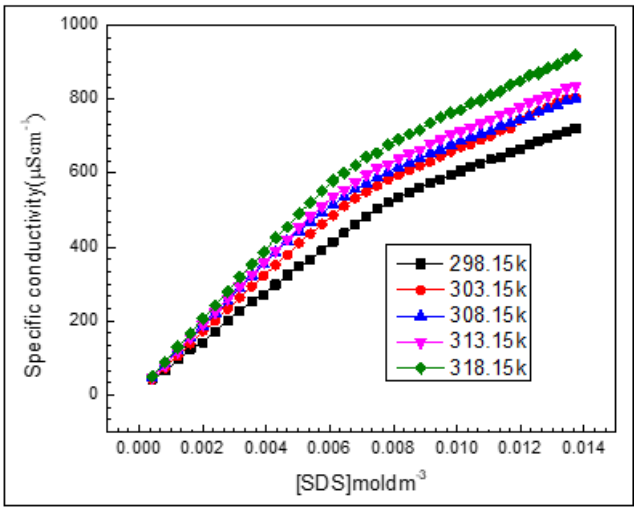

Figure 4.1: A typical plot of specific conductivity versus concentration of SDS in the presence of PMZ at different Temperature

The spontaneity or non-spontaneity of micellization are often measured from the values of micellization, which may be executed using the pseudo-phase partition model (3,4,5) through the subsequent relation:

$$\Delta G_m^0 = (1+\beta)RT \ln \chi_{cmc} \quad \text{.....4.2}$$

In Equation (4.2), represents the mole fraction of CMC regarding the employed surfactant, while R and T elicit their usual meanings. The enthalpy of micellization for pure SDS alongside PMZ-mediated micellization of SDS were estimated utilizing the next equation:

$$\Delta H_m^0 = -(1+\beta)RT^2(\partial \ln \chi_{cmc})/\partial T \quad \text{.....4.3}$$

The alteration of χ_{cmc} , which is temperature dependent, is shown to be a parabolic arc by relation.

$$\ln \chi_{cmc} = A + AB + CT^2 \quad \text{.....4.4}$$

where the constants A, B and C are obtained from the regression assessment of method of least squares. Figure 4.6 showed the plot of the polynomial fitting arc of vs. T, which was subsequently exploited to measure of the currently studied system. The estimated constant values attained from equation 4.4 and 4.6 were exploited accordingly to measure the values of through the following relation (7.8).

$$\Delta H_m^0 = -(1+\beta)RT^2[B + 2CT] \quad \text{.....4.5}$$

The calculated and values were then utilized to calculate the entropy ( )under similar conditions, using the following equation:

$$\Delta S_m^0 = (\Delta H_m^0 - \Delta G_m^0)/T \quad \text{.....4.6}$$

All the thermodynamic parameters evaluated within the current study are summarized in Table 4.10- 4.18. The ΔG_m^0 values for all systems (SDS + PMZ) in aqueous as well as in ethanol media were negative, which shows that the micellization phenomena are thermodynamically spontaneous (9,11). The observed ΔG_m^0 value of SDS alone was found to be above those of the SDS + PMZ mixed system both in aqueous and ethanol media, which signifies that pure SDS undergoes micellization more spontaneously than the SDS + PMZ mixture.

The negative ΔG_m^0 for the micellization of individual SDS in aqueous medium is raised because the temperature elevates, indicating that the association phenomena are additionally more spontaneous at the upper studied temperatures; therefore, CMC is increased at higher temperature (Table 4.1-4.4). However, for the SDS + PMZ mixture in H_2O, the negative values of ΔG_m^0 decreased initially with temperature, reach a maximum, and then dwindle with the successive upsurge of the temperature (table 4.14-4.16), Unlike table 4.11-4.13 that drops with increased in temperature. In ethanol media, the negativity of ΔG_m^0 within the surfactant and PMZ mixture decrease initially with increasing temperature; after a particular temperature, their values start to increase with the subsequent increase in temperature, with few exceptions (Table 4.16). In the aqueous system, the estimated value of ΔH_m^0 SDS alone was found to be positive at subordinate

temperature; however, on elevating the temperature, the value became negative, which signifies that micellization of SDS in aqueous medium is endothermic and exothermic at lower and higher temperature, respectively.

In the case of SDS alone, this type of variation of ΔH_m^0 can also be found in the literature (12) .The ΔH_m^0 values for the SDS and SDS + PMZ mixed systems in the presence of ethanol were found to be positive and negative at lower and elevated temperature, respectively, in almost all cases (Table 4.15-4.18); this implies that micellization of SDS/SDS + PMZ is endothermic and exothermic at lower and elevated temperature, respectively. The ΔH_m^0 value is the outcome of different types of interactions, e.g. hydrophobic also as hydrophilic interactions, counterion binding and hydration of the polar head groups of the surfactants. Negative values of ΔH_m^0 arise when hydration of the hydrophilic portion (head groups) of the surfactant dominates the disruption of the H_2O structure around the hydrophobic chains of the monomeric surfactant and vice versa. The attained ΔS_m^0 value for SDS alone was positive in H_2O and declined as the temperature increased; this implies that SDS molecules are arranged in a more orderly fashion at higher temperatures, and therefore micellization is favored and CMC is lowered (Table 4.10). The ΔS_m^0 value for SDS + PMZ was positive at the lower and better employed PMZ concentrations and negative at the intermediate concentration. Again, in ethanol solution, at a lower selected temperature, the ΔS_m^0 value for the surfactant alone was found to be positive in all cases for SDS in ethanol solution.

The positive ΔS_m^0 values in the presence of ethanol increases to a maximum and decreases as temperature increases (except for 10% and 15% v/v ethanol). The ΔS_m^0 values for the SDS + PMZ mixed system in the presence of ethanol were found to be positive in almost all cases.

The attained ΔS_m^0 values for the SDS + PMZ mixture decreased as the temperature was elevated, signifying more ordered SDS + PMZ systems at elevated temperature. Positive values of ΔS_m^0 arise when the hydrophobic portion of the drug transfers from the aqueous vicinity to the micelle interior (12). It is well known that the H-bonding of water molecules in the immediate vicinity of a hydrophobic portion is stronger than that of normal water, i.e. the H_2O molecules within the immediate vicinity of a hydrophobic moiety attract one another more strongly than normal H_2O molecules; due to tightening of the H_2O structure (13), the interior torsional vibration of the hydrophobic chain is reduced.

Taken together, the magnitudes of ΔH_m^0 and ΔS_m^0 indicate that micellization of pure SDS is entropically controlled at lower temperature and both entropically and enthalpically controlled at greater temperature in H_2O/ethanol solution. In the aqueous system, the magnitudes of ΔH_m^0 and ΔS_m^0 for the SDS + PMZ mixed system indicate that micellization is entropically governed at both lower and higher drug concentrations, but enthalpically governed at the intermediate concentration of the drug. The ΔH_m^0 and ΔS_m^0 values for the SDS + PMZ mixed system in the presence of ethanol elicits that micellization is governed by entropy at lower temperature but becomes governed by both enthalpy and entropy at elevated temperature. It is reported that positive enthalpy and entropy values of a system reveal the presence of hydrophobic bonding, while negative enthalpy and entropy values are indicative of both hydrogen bonding and electrostatic interactions (14). Other researchers have reported the presence of hydrophobic interactions between the surfactant and solutes based on negative enthalpies and positive entropies (15) Thus, the binding forces between SDS and PMZ involve hydrophobic interactions as well as electrostatic interactions such as hydrogen bonding and ion dipole interactions.

The following equations were used to calculate various thermodynamic transfer parameters, such as free energy of transfer, enthalpy of transfer, and entropy of transfer, during the micellization of SDS/SDS + PMZ mixes in various solvents.

$$\Delta G_{m,tr}^0 = \Delta G_m^0(aq.additive) - \Delta G_m^0(aq)$$
$$\Delta H_{m,tr}^0 = \Delta H_m^0(aq.additive) - \Delta H_m^0(aq)$$
$$\Delta S_{m,tr}^0 = \Delta S_m^0(aq.additive) - \Delta S_m^0(aq)$$

Table 4.10-4.18 lists all of the measured $\Delta G_{m.tr}^0$, $\Delta H_{m.tr}^0$, and $\Delta S_{m.tr}^0$ values for all of the solvents used. The amplitude of $\Delta G_{m.tr}^0$ was found to be positive in the aqueous medium in the presence of PMZ, indicating that micelle production is less spontaneous in the presence of PMZ. The $\Delta H_{m.tr}^0$ and $\Delta S_{m.tr}^0$values in water were positive for lower and higher drug concentrations, respectively, and negative at an intermediate drug concentration. The $\Delta G_{m.tr}^0$ values for SDS alone were negative in the presence of ethanol at all temperatures tested, showing that micelle production is more spontaneous in the presence of ethanol. The $\Delta H_{m.tr}^0$ and $\Delta S_{m.tr}^0$ values for SDS + PMZ were positive at all temperatures and PMZ concentrations used., except at a very high concentration of PMZ which $\Delta H_{m.tr}^0$ values were negative.

Table 4.1: Critical micelle concentration (CMC) and degree of counter ion binding (β) of SDS in the absence of PMZ at different temperature

Surfactant	T/K	CMC (mM)	χ_{cmc} (mM)	$\ln \chi_{cmc}$	β	$\bar{\beta}$
SDS + H_2O	298.15	8.32	0.130	-8.946	0.589	
	303.15	7.90	0.124	-8.991	0.576	0.58
	308.15	7.10	0.113	-9.085	0.568	
	313.15	8.50	0.133	-8.927	0.555	
	318.15	8.90	0.138	-8.880	0.539	

Table 4.2: Critical micelle concentration (CMC) and degree of counter ion binding (β) of SDS in the presence 0.1mMkg^{-1} of PMZ at different temperature.

Surfactant	T/K	CMC (mM)	χ_{cmc} (mM)	ln χ_{cmc}	β	$\bar{\beta}$
SDS + 0.1(mM) PMZ	298.15	7.29	0.131	-8.939	0.585	
	303.15	7.20	0.130	-8.951	0.578	0.594
	308.15	7.21	0.125	-8.965	0.565	
	313.15	7.25	0.130	-8.944	0.575	
	318.15	7.59	0.137	-8.899	0.671	

Table 4.3: Critical micelle concentration (CMC) and degree of counter ion binding (β) of SDS in the presence 0.15mMkg^{-1} of PMZ at different temperature

Surfactant	T/K	CMC (mM)	χ_{cmc} (mM)	ln χ_{cmc}	β	$\bar{\beta}$
SDS + 0.15(mM) PMZ	298.15	7.01	0.126	-8.978	0.512	
	303.15	6.73	0.121	-9.019	0.534	0.577
	308.15	6.22	0.112	-9.098	0.642	
	313.15	6.92	0.124	-8.994	0.584	
	318.15	7.43	0.134	-8.920	0.615	

Table 4.4: Critical micelle concentration (CMC) and degree of counter ion binding (β) of SDS in the presence 0.20mMkg^{-1} of PMZ at different temperature

Surfactant	T/K	CMC (mM)	χ_{cmc} (mM)	ln χ_{cmc}	β	$\bar{\beta}$
SDS + 0.20(mM) PMZ	298.15	6.62	0.119	-9.035	0.589	
	303.15	6.57	0.118	-9.043	0.581	0.584
	308.15	5.83	0.105	-9.162	0.550	
	313.15	6.81	0.123	-9.007	0.599	
	318.15	7.41	0.133	-8.923	0.601	

Table 4.10: Variation of (ΔG_m^0 , ΔH_m^0, ΔS_m^0, $\Delta G_{m.tr}^0$, and $\Delta H_{m.tr}^0$ values of SDS in Aqueous medium at different Temperature

SDS + H_2O						
T/K	(ΔG_m^0, KJmol^{-1}	ΔH_m^0, KJmol^{-1}	ΔS_m^0, Jmol^{-1}K^{-1}	$\Delta G_{m.tr}^0$, KJmol^{-1}	$\Delta H_{m.tr}^0$, KJmol^{-1}	$\Delta S_{m.tr}^0$, Jmol^{-1} K^{-1}
298.15	-34.14	6.00	98.04	-	-	-
303.15	-34.15	6.26	97.14	-	-	-
308.15	-34.50	6.51	97.31	-	-	-
313.15	-34.71	-6.78	93.75	-	-	-
318.15	-34.73	-7.08	91.37	-	-	-

Table 4.11: Variation of (ΔG_m^0 , ΔH_m^0, ΔS_m^0, $\Delta G_{m.tr}^0$, and $\Delta H_{m.tr}^0$ values of SDS in Aqueous Solution of 0.10mM PMZ with Temperature

SDS + 0.10mM PMZ						
T/K	(ΔG_m^0, KJmol^{-1}	ΔH_m^0, KJmol^{-1}	ΔS_m^0, Jmol^{-1}K^{-1}	$\Delta G_{m.tr}^0$, KJmol^{-1}	$\Delta H_{m.tr}^0$, KJmol^{-1}	$\Delta S_{m.tr}^0$, Jmol^{-1} K^{-1}
298.15	-35.12	1.05	114.26	70.36	7.06	212.30
303.15	-35.60	1.09	113.86	71.31	7.35	211.00
308.15	-35.95	1.11	113.04	72.44	7.62	210.35
313.15	-36.68	1.16	113.43	72.82	7.94	207.18
318.15	-39.33	1.27	-119.64	75.48	-8.34	211.02

Table 4.12: Variation of (ΔG_m^0 , ΔH_m^0, ΔS_m^0, $\Delta G_{m.tr}^0$, and $\Delta H_{m.tr}^0$ values of SDS in Aqueous Solution of 0.15mM PMZ with Temperature

SDS + 0.15mM PMZ						
T/K	(ΔG_m^0, KJmol^{-1}	ΔH_m^0, KJmol^{-1}	ΔS_m^0, Jmol^{-1}K^{-1}	$\Delta G_{m.tr}^0$, KJmol^{-1}	$\Delta H_{m.tr}^0$, KJmol^{-1}	$\Delta S_{m.tr}^0$, Jmol^{-1} K^{-1}
298.15	-33.65	2.68	103.87	1.59	3.32	5.82
303.15	-34.87	2.81	105.74	0.84	3.45	8.60
308.15	-38.27	3.11	114.10	1.78	3.39	16.79
313.15	-37.09	-3.09	108.55	0.95	3.68	14.75
318.15	-36.10	-3.26	109.52	1.96	3.82	18.14

Table 4.13: Variation of (ΔG_m^0 , ΔH_m^0, ΔS_m^0, $\Delta G_{m.tr}^0$, and $\Delta H_{m.tr}^0$ values of SDS in Aqueous Solution of 0.20mM PMZ with Temperature

SDS + 0.2mM PMZ						
T/K	(ΔG_m^0, KJmol^{-1}	ΔH_m^0, KJmol^{-1}	ΔS_m^0, Jmol^{-1}K^{-1}	$\Delta G_{m.tr}^0$, KJmol^{-1}	$\Delta H_{m.tr}^0$, KJmol^{-1}	$\Delta S_{m.tr}^0$, Jmol^{-1} K^{-1}
298.15	-35.59	3.05	109.12	0.35	2.95	11.08
303.15	-36.03	3.14	108.50	0.32	3.12	11.36
308.15	-36.38	3.18	107.75	-0.11	3.33	10.44
313.15	-37.50	-3.39	108.95	1.36	3.39	15.17
318.15	-37.79	-3.51	107.76	1.64	3.58	-16.38

Table 4.14: Variation of (ΔG_m^0 , ΔH_m^0, ΔS_m^0, $\Delta G_{m.tr}^0$, and $\Delta H_{m.tr}^0$ values of SDS in Aqueous Solution of 0.25mM PMZ with Temperature

SDS + 0.25mM PMZ						
T/K	(ΔG_m^0, KJmol^{-1}	ΔH_m^0, KJmol^{-1}	ΔS_m^0, Jmol^{-1}K^{-1}	$\Delta G_{m.tr}^0$, KJmol^{-1}	$\Delta H_{m.tr}^0$, KJmol^{-1}	$\Delta S_{m.tr}^0$, Jmol^{-1} K^{-1}
298.15	-35.16	3.22	107.12	0.08	2.78	9.07
303.15	-37.53	3.46	112.37	1.81	-2.80	15.23
308.15	-37.36	3.49	109.91	0.87	-3.01	12.59
313.15	-38.24	-3.73	110.21	2.09	-3.05	16.46
318.15	-37.49	-3.72	106.16	1.35	-3.36	14.79

Table 4.15: Variation of (ΔG_m^0 , ΔH_m^0, ΔS_m^0, $\Delta G_{m.tr}^0$, and $\Delta H_{m.tr}^0$ values of SDS in Aqueous Solution of 0.1mM PMZ +5% Ethanol with Temperature

SDS + 0.1(mM) PMZ+5% Ethanol						
T/K	(ΔG_m^0, KJmol^{-1}	ΔH_m^0, KJmol^{-1}	ΔS_m^0, Jmol^{-1}K^{-1}	$\Delta G_{m.tr}^0$, KJmol^{-1}	$\Delta H_{m.tr}^0$, KJmol^{-1}	$\Delta S_{m.tr}^0$, Jmol^{-1} K^{-1}
298.15	-35.47	1.12	115.17	-0.24	4.87	17.12
303.15	-36.36	1.18	116.03	-0.64	5.08	18.88
308.15	-37.80	1.23	118.67	-1.31	5.27	21.36
313.15	-39.12	1.28	120.82	-2.98	5.50	27.07
318.15	-37.93	-1.27	115.23	-1.79	5.80	23.86

Table 4.16: Variation of (ΔG_m^0, ΔH_m^0, ΔS_m^0, $\Delta G_{m.tr}^0$, and $\Delta H_{m.tr}^0$ values of SDS in Aqueous Solution of 0.1mM PMZ + 10% Ethanol with Temperature

SDS + 0.1(mM) PMZ+10% Ethanol						
T/K	(ΔG_m^0, KJmol^{-1}	ΔH_m^0, KJmol^{-1}	ΔS_m^0, Jmol^{-1}K^{-1}	$\Delta G_{m.tr}^0$, KJmol^{-1}	$\Delta H_{m.tr}^0$, KJmol^{-1}	$\Delta S_{m.tr}^0$, Jmol^{-1} K^{-1}
298.15	-38.11	3.73	115.30	-2.87	2.27	-17.25
303.15	-39.28	3.87	116.81	-3.57	2.39	-19.67
308.15	-36.13	3.58	105.65	-0.36	2.93	8.34
313.15	-40.33	4.11	115.64	-4.19	2.67	-21.89
318.15	-35.61	3.71	100.25	0.54	3.37	-8.88

Table 4.17: Variation of (ΔG_m^0, ΔH_m^0, ΔS_m^0, $\Delta G_{m.tr}^0$, and $\Delta H_{m.tr}^0$ values of SDS in Aqueous Solution of 0.1mM PMZ + 15% Ethanol with Temperature

SDS + 0.1(mM) PMZ+15% Ethanol						
T/K	(ΔG_m^0, KJmol^{-1}	ΔH_m^0, KJmol^{-1}	ΔS_m^0, Jmol^{-1}K^{-1}	$\Delta G_{m.tr}^0$, KJmol^{-1}	$\Delta H_{m.tr}^0$, KJmol^{-1}	$\Delta S_{m.tr}^0$, Jmol^{-1} K^{-1}
298.15	-34.61	3.38	104.76	-0.63	2.63	6.71
303.15	-36.27	3.57	107.85	-0.55	2.69	10.71
308.15	-37.25	3.72	108.81	-0.76	2.79	11.49
313.15	-36.48	3.80	104.37	-0.34	2.99	10.62
318.15	-37.54	-4.00	105.42	-1.39	3.08	14.05

Table 4.18: Variation of (ΔG_m^0, ΔH_m^0, ΔS_m^0, $\Delta G_{m.tr}^0$, and $\Delta H_{m.tr}^0$ values of SDS in Aqueous Solution of 0.1mM PMZ + 20 % Ethanol with Temperature

SDS + 0.1(mM) PMZ+20% Ethanol						
T/K	(ΔG_m^0, KJmol^{-1}	ΔH_m^0, KJmol^{-1}	ΔS_m^0, Jmol^{-1}K^{-1}	$\Delta G_{m.tr}^0$, KJmol^{-1}	$\Delta H_{m.tr}^0$, KJmol^{-1}	$\Delta S_{m.tr}^0$, Jmol^{-1} K^{-1}
298.15	-32.97	1.71	104.84	-2.27	4.29	6.79
303.15	-34.96	1.84	109.26	-0.75	4.42	12.11
308.15	-36.66	1.96	112.64	-0.17	4.55	15.32
313.15	-38.62	2.09	116.63	-2.48	4.68	22.88
318.15	-37.29	2.08	110.65	-1.14	4.99	19.28

Conclusively, In both aqueous ethanol solutions and water, the effect of the PMZ drug on SDS CMC values at different temperatures is not linear. This is due to the intricate interactions between surfactants and PMZ drug molecules caused by altering solvent polarity.

Negative ΔG_m^0 values for the micellization of SDS in water and in the presence of varying amounts of PMZ and ethanol account for the process spontaneity at all temperature

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