

## The interfacial tension at the liquid junction of petrol and Sodium dodecyl sulphate solution

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Submitted: 12/17/2023, revised: 12/24/2023, accepted: 12/28/2023

### Abstract

The precise measurements of petrol interfacial tension (IFT) in the presence of Sodium dodecyl sulphate (SDS) at room temperature by Mansingh Survismeter are reported. The concentration of sodium dodecyl sulphate was varied from above and below the critical micelle concentration (CMC) to cover the minimum and maximum concentrations of the investigated surfactant. Petrol was taken from the dealer in Nepal and used without purification. Therefore, when surfactant is added to the system, the surfactant decreases its free energy, thus decreasing its surface tension.

### Introduction

The behavior of the liquids at the junction layer is a function of interfacial tension. And, interfacial tension is an important parameter to determine the consequences due to the presence of immiscible organic liquids like petroleum and oil that exist as separate entities in the aqueous environment due to their low solubility value [1]. Fortunately, there are various methods to measure values for interfacial tension, such as the Donahue and Bartell method [2], the Fu et al. method [3], and the Ramey and Foroozabadi method [4]. But, instead of those, we chose the Mansingh Survismeter and the formula to calculate interfacial tension in this work. The Mansingh

Survismeter is an easy, effective, and efficient apparatus that requires very little sample to give an accurate result. This is a single apparatus with multiple functionalities that offers the ability to calculate surface tension, interfacial tension, viscosity, and other various liquid behavioral parameters [5].

The interfacial tension is a function of temperature, pressure, and the composition of each phase. With the change of medium that is just above the liquid, the surface tension of the whole system changes. For example, if the medium above the liquid (say, water) is air, then the surface tension value will be higher than for the vapor medium. And, if there is any oily liquid

above the free surface of water, the surface tension value will go further down.

The interfacial tension affects falsifiability and the tendency for the phases to separate. It is an important parameter to test the quality of hydrophobic liquids such as transformer oil and petroleum because the aging of these liquids usually depends on their interfacial tension with water. Moreover, if there is a decrease in interfacial tension caused by dissolved surfactant, the hydrophobic phase can be mobilized after flooding with water. Many commercial cleaning products require surfactant optimization in aqueous solutions [6]. Surfactants are generally used as detergents, wetting agents, emulsifiers, dispersants, and foaming agents. There is a wide use of chemical surfactants in the oil industry to increase oil recovery [7], [8], and [9]. They have amphiphilic structures designed so that the polar head stays in the water and the nonpolar tail stays in the oil phase [7], [10].

As a result, they assist in aligning themselves at the water-oil interface and reducing the interfacial tension (IFT) [11], [12], and [13]. Water interacts with four kinds of surfactants, whose head groups may be charged [7].

Upon dissolving in water, anionic surfactants have negative polar head groups, cationic surfactants have positive polar head groups, and nonionic surfactants do not have any charge. Zwitterionic surfactants, on the other hand, have both positive and negative polar head groups [7],[12].

A surfactant's performance is best when its critical micelle concentration (CMC) is minimized for the greatest reduction of IFT [7], [12]. The IFT value

is not affected by excessive doses of surfactants in CMC [14].

The main problem of the present work is to analyze the variation of interfacial tension with the concentration of SDS in the petrol system using the Mansingh Survisometer. It is a low-cost method for determining the interfacial tension of surfactants in the presence of petrol. No more work has been done, particularly on the measurements of the interfacial tension of SDS in the presence of petrol systems at room temperature by Mansingh Survisometer. The objective of this research is to evaluate the interfacial tension at the liquid-liquid junction of petrol and SDS solution and compare the qualities of petrol.

## Materials and Methods

SDS was purchased from Sigma Aldrich Company, USA. It was recrystallised for purification. There was a minimum in the surface tension-concentration plot. The presence of highly surface-active dodecyl alcohol molecules is responsible for the minimum in the plot of  $\gamma$  against  $\log c$  for sodium dodecyl sulphate[15]. Dodecyl alcohol may be existed as a contaminant in the given sample of sodium dodecyl sulphate or it may be formed by hydrolysis in the sodium dodecyl sulphate solution. The CMC of sodium dodecyl sulphate is defined as the concentration of sodium dodecyl sulphate that corresponds to the lowest in the plot of  $\gamma$  versus  $\log c$  and the CMC of SDS in water was found to be [8.31 mM] at 298.15 K by surface tension method. This value agrees well with the CMC values found for

sodium dodecyl sulphate from surface tension measurement[16] by Niraula et al. in 2018.

The petrol used was purchased from a Nepalese government-certified retailer whose concentration was not changed. A drop of petrol was taken on filter paper and tested for purity. Petrol was clean and purely volatile fuel and consequently, oil vaporized from the filter paper more easily and quickly without leaving any traces or patches [17].

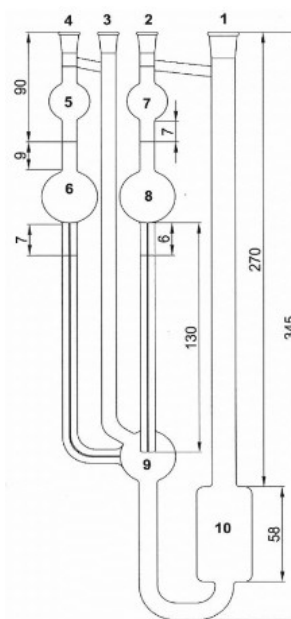
The density of petrol was found  $0.721 \text{ Kg/m}^3$  from using Anton Paar Density meter DMA 4200 M, Switzerland at 298.15 K. If the temperature of petrol is increased, the kinetic energy of the particles increases thereby causing an increase in volume and a corresponding decrease in density  $0.719 \text{ Kg/m}^3$  as shown in the literature at 299.15 K [17].

Millipore water of  $0.055 \mu\text{S/cm}$  conductance at 298.15 K was used from the research laboratory of the School of Chemical Sciences, Central University of Gujarat, Gandhinagar, India.

$0.01 \text{ mol.L}^{-1}$  SDS was dissolved in a 100ml volumetric flask with Millipore water and the volume make-up of the SDS solution was done after 24h at a constant temperature of 298.15 K in a thermostat. From the stock solution of  $0.01 \text{ mol.L}^{-1}$  SDS, the rest lower concentration solutions of SDS were prepared in 30 ml vials.

Petrol was kept in a tight concentration at room temperature. The interfacial tensions at the interface of SDS solutions with concentrations ranging from 0 to  $0.01 \text{ mol/L}$  and petrol were

calculated using Mansingh Survisometer (Scheme 1).



*Scheme 1: Survisometer representations are 10: Reservoir 9: Carburetor 6 for viscous flows 5, 7: buffer 8: dropwise flow Limbs are categorized from 9 to 3 for pressure from 10 to 1: overhead pressure sockets from 1, 2, 3, 4 for blocking pressure from 10 to 8 surface tension capillaries from 10 to 9 Hyphenating bends [18].*

Methanol was used as the calibration solution for the Mansingh Survisometer. The experimental data obtained for the surface tension of methanol was  $22.29 \text{ mN/m}$ , which was matched with the literature value of  $22.28 \text{ mN/m}$  [19].

## Results and Discussion

In the oil and petroleum industry, surfactants are introduced into the oil reservoir to improve Enhanced oil recovery (EOR) application[20].

The surfactant will work at the lowest interfacial tension and therefore it is necessary to consider the concentration of surfactant higher than CMC

[21]. For SDS, the value of CMC at 298 K is  $8 \times 10^{-3}$  mol/L [22].

Whenever a surfactant is introduced into the system, surfactant starts to aggregate and finally transform into micelles when the concentration reaches CMC and therefore again will decrease the surface energy (surface tension) by lowering the chances that the hydrophobic parts of the surfactant molecule make contact with water [23]. At CMC, any further addition of a surfactant or any surface-active compounds in the system will just increase the number of micelles and therefore the decrease in surface tension will be expected to become steady[24].

The following results are obtained from the experimental work. Figure 1 gives the variation of density with concentration.

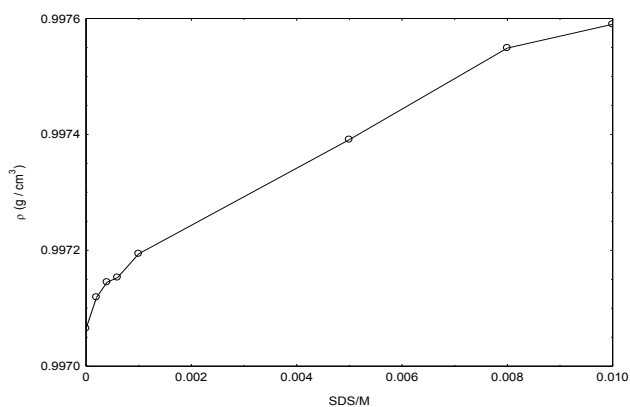


Figure 1: Plot of Density versus Concentration of SDS

This is the variation in density value above and below the CMC of SDS at 298.15 K. As the concentration of SDS increases, the density also increases. Such type of trend was also seen in the literature[25].

Figure 2 gives the variation of Pendant drop (PND) with concentration of SDS.

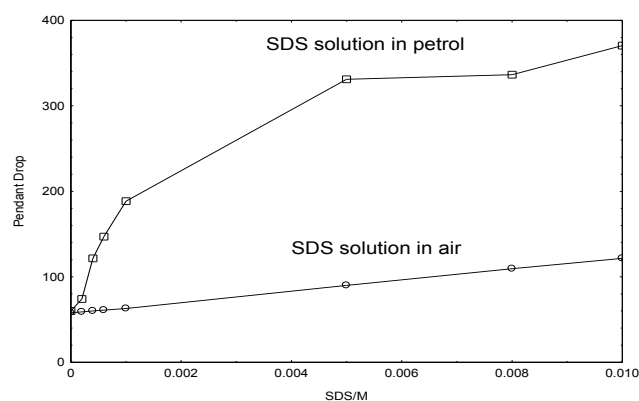


Figure 2: Plot of Pendant drop (PND) versus concentration of SDS

Pendant drop methods rely on drop shape adjustment at constant T and P conditions when gravity and surface forces are in equilibrium. The *pendant* methods are utilized to measure interfacial tension [26].

Increases PDN in petrol is for mutual solubilization. Structuredness of petrol is weakened so that it tends to be solubilized in H<sub>2</sub>O. SDS solution in air follows the straight line equation having slope which indicates the hydrophobicity.

Figure 3 gives the variation of surface tension with concentration of SDS.

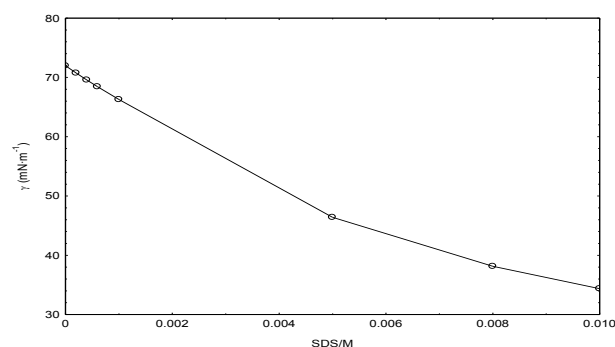


Figure 3: Plot of Surface tension versus Concentration of SDS

This is the variation of surface tension above and below the CMC of SDS at 298.15 K. As the concentration of SDS decreases, the surface tension increases. Such type of trend was found in the literature[27].

The interfacial tension can be calculated from the equation given in the literature [28]:

$$\gamma_{IFT} = \left( \left( \frac{n_{HDL \text{ in air}}}{n_{HDL \text{ in LDL}}} \right) \left( \frac{\rho_{HDL} - \rho_{LDL}}{\rho_{HDL}} \right) \right) \gamma_{HDL} \quad (1)$$

where  $\gamma_{IFT}$  = interfacial tension between low-and high-density liquids,  $n_{HDL \text{ in air}}$  and  $n_{HDL \text{ in LDL}}$  = number of drops of high-density liquid in air and low-density liquid, the  $\rho_{HDL}$  and  $\rho_{LDL}$  = densities of high and low-density liquids and  $\gamma_{HDL}$  = the surface tension of high-density liquid.

Figure 4 gives the variation of Interfacial tension with concentration of SDS.

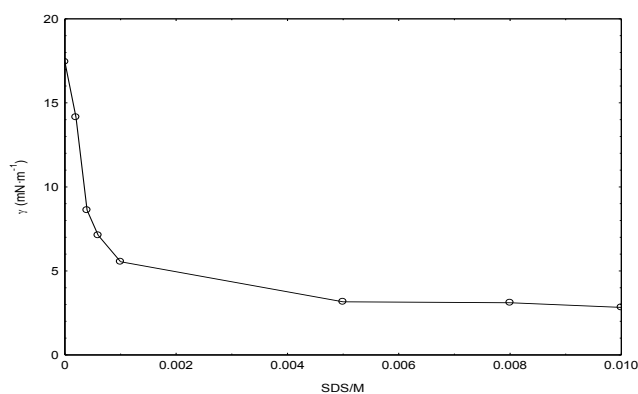


Figure 4: Plot of Interfacial tension versus Concentration of SDS

IFT is maximum at the lowest concentration level and minimum at the highest concentration level. The interfacial tension is dependent on the concentration of the SDS.

However, one limitation is that we could not have visibility on certain concentrations of SDS in the

presence of petrol while measuring interfacial tension. This is the limitation of our study.

IFT data was used to calculate Gibbs free energy [5] as in the equation (2)

$$\Delta G = -nRT \ln(\%IFT) \quad (2)$$

where R = gas constant, n = number of moles, T = temperature in Kelvin, and IFT = interfacial tension. Here, n=1, R=8.314 J/mol/K, and T=298.15 K.

Figure 5 gives the variation of Gibbs free energy with concentration of SDS.

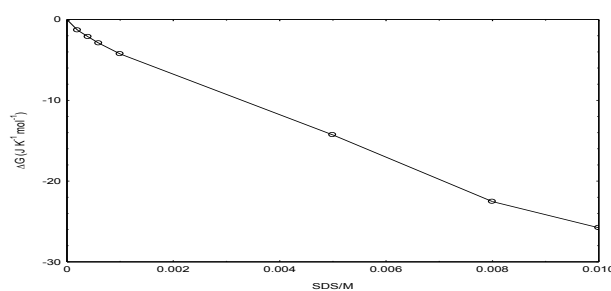


Figure 5: Plot of Gibbs free energy versus Concentration of SDS

It is noticed that the Gibbs free energy is found to be negative in all cases and becomes less negative in the lowest concentration of SDS, indicating that the formation of micelles becomes less favorable as the concentration of SDS decreases. Hence the interfacial tension is dependent on the concentration of the SDS in the study of interfacial tension at the liquids junction of petrol and SDS solution.

## Conclusion

It can be concluded that when surfactant is introduced into the system, the surfactant decreases the surface tension of the system by

decreasing the system's free energy. Meaning, that surfactant either reduces the energy of the interface or restricts the hydrophobic parts of the surfactant molecule from contact with water. The IFT process is driven by a chemical process contrary to upthrust force as per Archimedes's theory. This proves that the hydrophobic-hydrophilic interactions are not only competing or dominant optimism forces but enhancing mutual

solubility with increasing PDN on increasing surfactant concentration.

### Acknowledgement

One of the authors Ajaya Bhattarai would like grateful to the Centre for co-operation in Science and Technology among developing societies (ccstds), Chennai-600 025, India for the fellowship to carry out this work.

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