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INTERMOLECULAR ACTIVITIES OF CURCUMIN WITH IONIC AND NON - IONIC SURFACTANT MODERATED THROUGH PHYSICOCHEMICAL PROPERTIES

Trikmani Mital Jitendrabhai
Department of Chemistry, Centre of Education, I.I.T.E., Gandhinagar, India

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ABSTRACT

In this study, the effects of curcumin's intermolecular interactions with ionic (CTAB) and non-ionic (SDS) surfactants on important physicochemical characteristics, including density, viscosity, pH, and conductivity at 310.15 K, are examined. The purpose of the study is to comprehend the effects of surfactants on the stability, solubility, and molecular behavior of curcumin in aqueous solutions. Because CTAB is cationic, it establishes significant electrostatic contacts with curcumin, increasing its molecular stability and solubility, according to experimental data. However, SDS stabilizes curcumin through hydrophobic interactions, though not as well as CTAB. Micelle formation is indicated by changes in density and viscosity, which modify molecular packing and the strength of interactions. Variations in pH imply that curcumin's interaction with surfactants influences proton dynamics, especially in solutions containing CTAB. The total physicochemical environment is impacted by ion mobility, which is influenced by surfactant-mediated micelle production, as confirmed by conductivity trends. These results demonstrate how surfactants may increase the bioavailability of curcumin for use in food, medicine, and cosmetics. The study opens the door for improved formulations in drug delivery and related disciplines by highlighting the significance of surfactant selection in improving curcumin's physicochemical properties.

KEYWORDS:- *Curcumin, Surfactant ,CTAB, SDS, Intermolecular Properties*

INTRODUCTION

Curcumin: The main bioactive component of turmeric (Curcuma longa), curcumin, has drawn a lot of interest because of its many therapeutic uses, which include anti-inflammatory, anti-cancer, anti-microbial, and antioxidant effects. Unfortunately, its low bioavailability, quick metabolic breakdown, and poor water solubility limit its practical uses in medications and biomedical research. For curcumin to have more medicinal potential, these restrictions must be removed.

Surfactant: An effective approach for enhancing curcumin's stability and dispersion in aqueous conditions is the use of surfactants, which are amphiphilic molecules that lower surface tension and promote solubilization. In pharmaceutical and industrial formulations, ionic (like cetyltrimethylammonium bromide, or CTAB) and non-ionic (like sodium dodecyl sulfate, or SDS) surfactants are frequently employed to improve the solubility and bioavailability of hydrophobic substances. Their capacity to form micelles improves the physicochemical characteristics of curcumin molecules by encasing them in a microenvironment.

CTAB: A cationic surfactant, CTAB is a member of the family of quaternary ammonium compounds. It is very good at micelle production and electrostatic interactions because it has a positively charged ammonium head group and a lengthy hydrophobic alkyl chain (C16). CTAB is frequently utilized in drug delivery systems, DNA extraction, and nanoparticle creation because of its potent antibacterial, emulsifying, and stabilizing qualities. Above the critical micelle concentration (CMC), CTAB produces micelles in aqueous solutions, encasing hydrophobic compounds such as curcumin and increasing their solubility and bioavailability. Because CTAB is ionic, it can interact with negatively charged biomolecules, changing their physicochemical behavior and molecular structure.

SDS: An anionic surfactant, SDS finds extensive usage in industrial, chemical, and biological processes. It can function as a detergent, emulsifier, and solubilizing agent because of its hydrophobic 12-carbon alkyl tail and negatively charged sulfate head group. Because of its well-known capacity to break down hydrophobic bonds, SDS is an essential part of drug solubilization and protein denaturation. SDS helps hydrophobic molecules disperse when it creates micelles in aqueous solutions, stabilizing them via hydrophobic interactions as opposed to electrostatic forces. SDS provides distinct solubilization methods for substances like curcumin by interacting mostly with non-polar areas of biomolecules, in contrast to CTAB.

Physico-chemical properties: A substance's basic behavior in different settings is defined by its physicochemical qualities, which also affect how well it dissolves and interacts with other molecules. awareness the formulation, bioavailability, and functional uses of bioactive substances like curcumin requires an awareness of these characteristics. Density, viscosity, pH, and conductivity are important physicochemical parameters that reveal information on molecule interactions and stability in various solvent systems. The constrained water solubility of curcumin, a hydrophobic polyphenol, makes it difficult to utilize in culinary, cosmetic, and medicinal formulations. These physicochemical characteristics can be considerably altered by adding surfactants such as sodium dodecyl sulfate (SDS) and cetyltrimethylammonium bromide (CTAB), which improve curcumin's stability and dispersibility.

MATERIAL AND METHOD

Material: Curcumin, CTAB, SDS, Acetone, Distilled water were used as received.

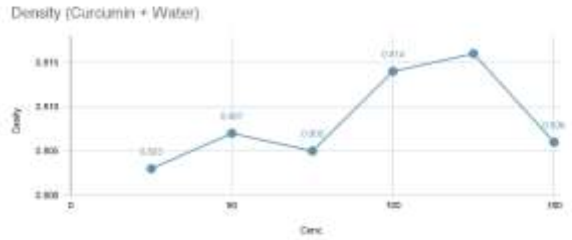
Method: The solutions with different concentrations of curcumin ranged from 25 to 150 Micromolar separately prepared in distilled water and CTAB, SDS. Prepared miscible solutions were stirred for 15 minutes to obtain a homogeneous solution. Further physicochemical properties measured at predetermined temperature at 310.15K for determination of interacting stability. The physicochemical properties such as density, PH, conductance, viscosity and which confirms the molecular interaction activities of curcumin with CTAB and SDS at 310.15K temperature.

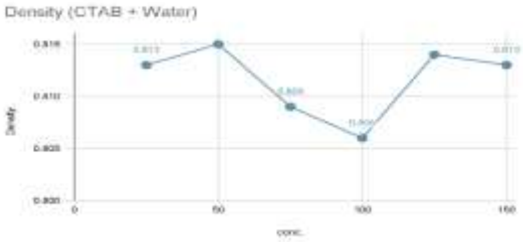
RESULT AND DISCUSSION

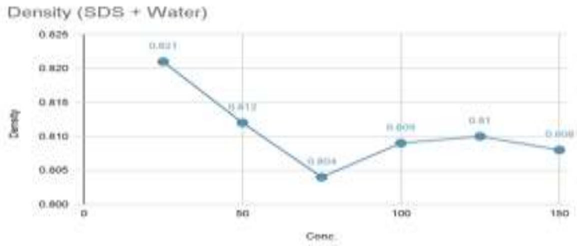
Table 1: Micro molar/L(M), density (10^{-4} g cm^{-3}), viscosity(10^{-4} mPa.s), pH (pH, 10^{-2}), and Conductance (Cond, 10^{-1}, mho), at 310.15 K.

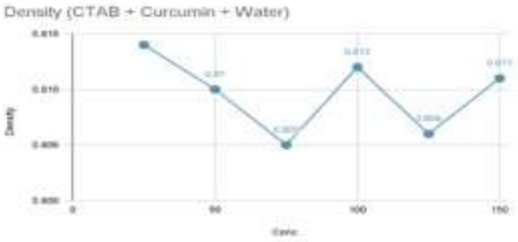
μM	ρ	η	pH	Cond
Curcumin + water				
25	0.803	0.0794	6.532	7.1
50	0.807	0.0818	6.726	9.9
75	0.805	0.0803	6.642	9.0
100	0.814	0.0795	6.703	10.4
125	0.816	0.0817	6.413	4.7
150	0.806	0.0794	6.437	4.0
CTAB + Water				
25	0.813	0.0817	8.865	18.5
50	0.815	0.0799	7.607	36.6
75	0.809	0.0810	7.453	39.4
100	0.806	0.0787	7.039	32.8
125	0.814	0.0815	7.053	37.0
150	0.813	0.0811	6.943	30.3
SDS + Water				
25	0.821	0.0815	6.756	8.2
50	0.812	0.0796	6.628	13.5
75	0.804	0.0798	6.537	15.9
100	0.809	0.0793	6.586	18.9
125	0.810	0.0818	6.364	22.4
150	0.808	0.0785	6.243	19.2
CTAB+ Curcumin + Water				
25	0.814	0.0798	6.387	12.0
50	0.810	0.0801	6.351	10.5
75	0.805	0.0823	6.329	15.7
100	0.812	0.0813	6.268	23.7
125	0.806	0.0790	6.201	21.3
150	0.811	0.0798	6.162	24.4
SDS + Curcumin+ Water				
25	0.814	0.0791	6.502	11.8
50	0.812	0.0816	6.575	10.2
75	0.804	0.0771	6.412	12.9
100	0.814	0.0784	6.151	13.6
125	0.799	0.0780	6.196	15.8
150	0.805	0.0803	6.348	25.2

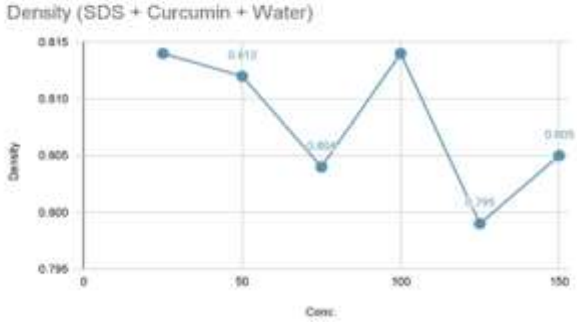
The table provides a comprehensive analysis of the physicochemical properties—density (ρ), viscosity (η), pH, and conductivity (Cond)—of various solutions containing curcumin, CTAB (Cetyltrimethylammonium bromide), SDS (Sodium dodecyl sulfate), and their combinations with water. These measurements, conducted at varying concentrations, reveal the complex interactions between the solutes and water.







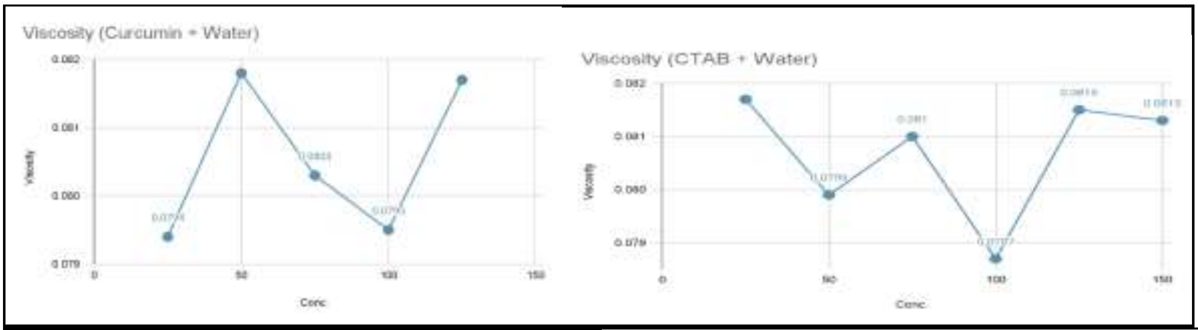


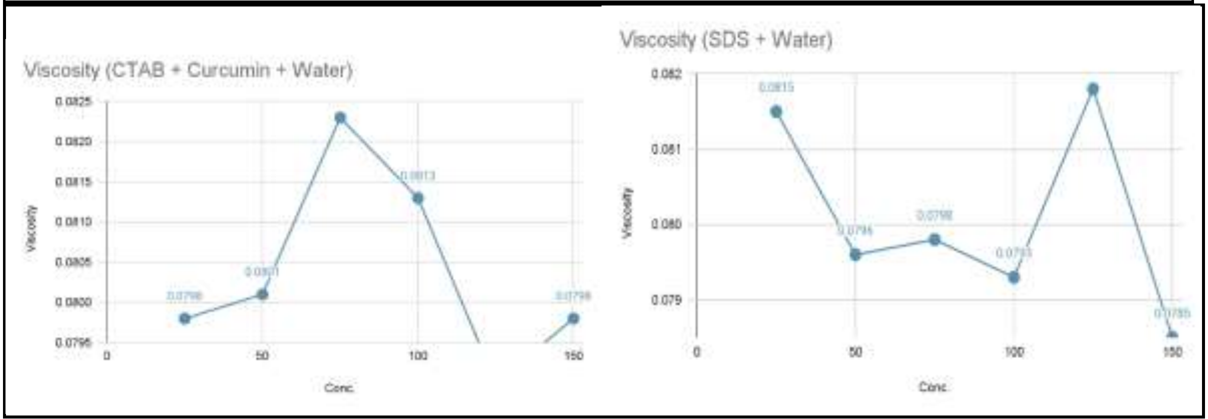


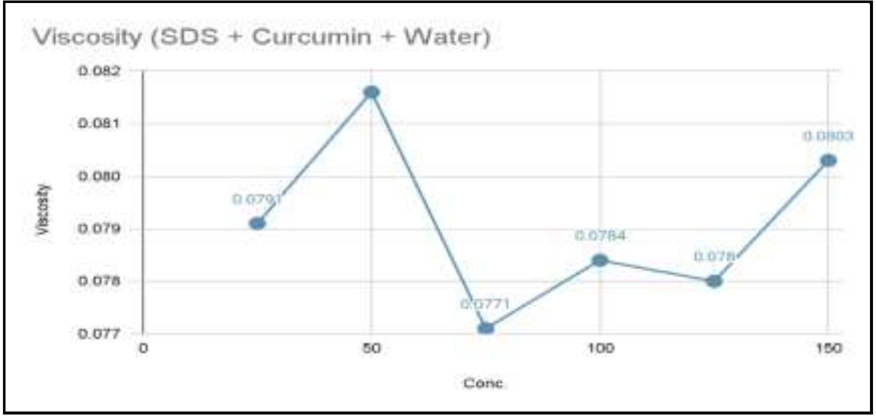
Density: Curcumin's density values with water, CTAB, and SDS change according to concentration. Nonlinear intermolecular interactions are indicated by the density's uneven variation with increasing concentration in all circumstances. In general, curcumin in SDS and CTAB solutions exhibits a higher density than curcumin in water, indicating a stronger surfactant-mediated interaction.

Stronger solute-solvent interactions are indicated by an increase in density at specific concentrations, which is probably caused by micelle production in surfactant solutions. Changes in molecular preparing, aggregation, or solubility behaviour brought on by the presence of surfactants may be reflected in variations in density.

The density data show that curcumin's intermolecular interactions are influenced by surfactants such as CTAB and SDS. These interactions appear to be more stable than those of curcumin in water, indicating that curcumin and surfactants have a better mechanism for solubilisation and association. These results demonstrate how surfactants might moderate curcumin's physical characteristics, potentially enhancing its use in aqueous solutions.



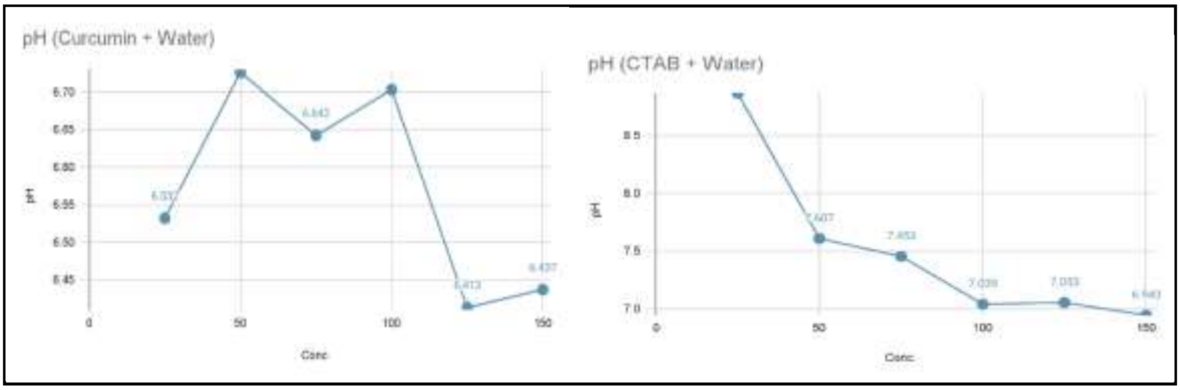


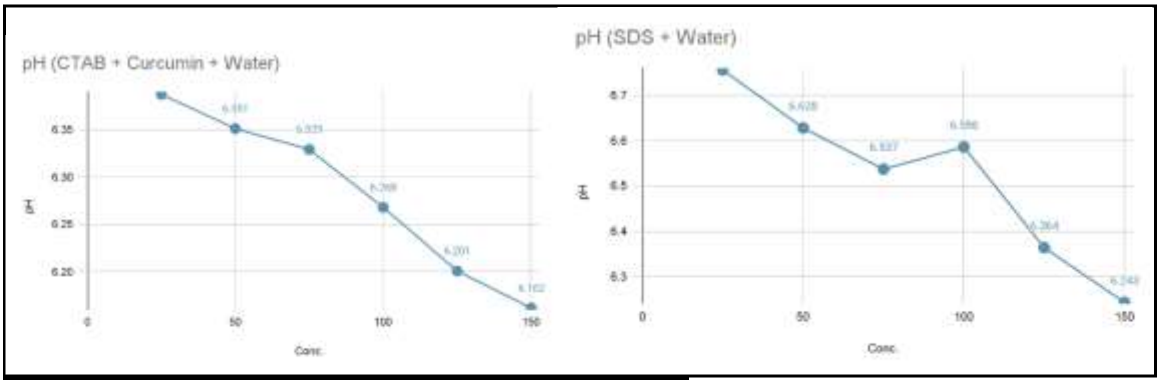


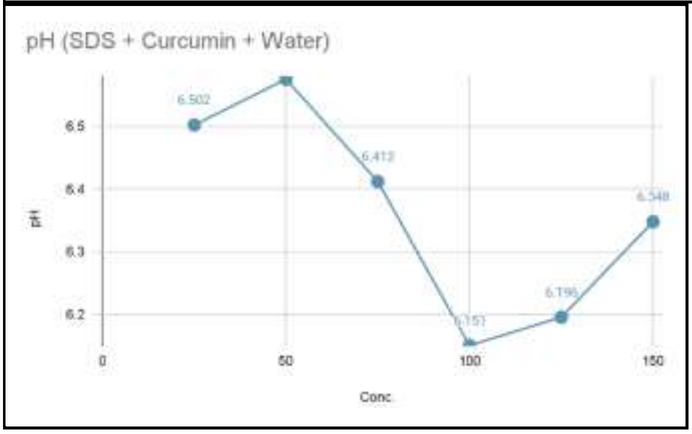
Viscosity: Curcumin's viscosity in water, ionic surfactant (CTAB), and non-ionic surfactant (SDS) solutions shows that the medium affects the intermolecular interactions. Because of solute-solvent interactions and micelle production, surfactants have a significant effect on viscosity. In pure water, the viscosity exhibited small variations as curcumin concentration increased, indicating weak intermolecular interactions.

In general, CTAB (ionic surfactant) exhibited higher viscosity values than SDS and water, suggesting stronger intermolecular pressures that are probably caused by curcumin's electrostatic interactions with CTAB's charged micelles. Compared to water, SDS (non-ionic surfactant) showed a slight increase in viscosity, indicating that hydrophobic interactions predominate over electrostatic forces.

The viscosities of surfactant solutions showed complicated interactions when curcumin was added: At higher curcumin concentrations, CTAB's viscosity exhibited a decreasing trend as the curcumin concentration increased, suggesting micelle disruption or reduced structural connections. Curcumin stabilized micellar structures, as evidenced by the viscosity of SDS, which varied slightly but generally increased at greater concentrations.



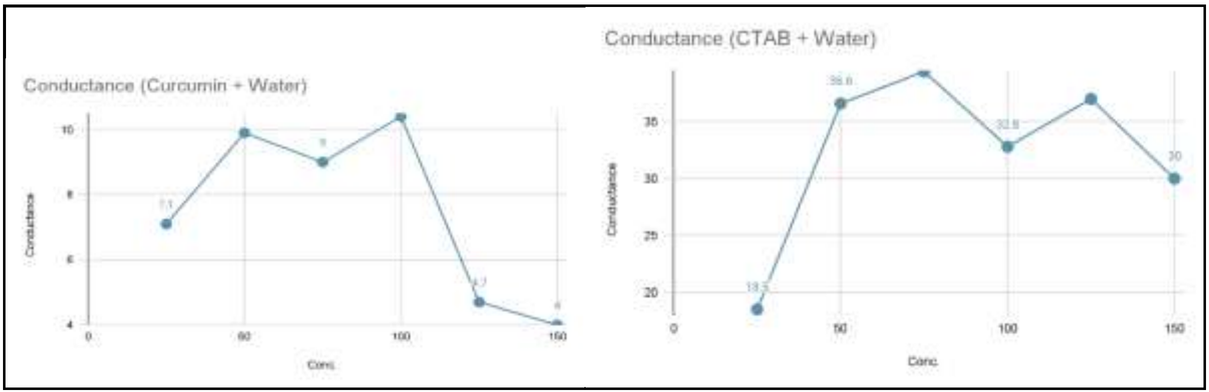


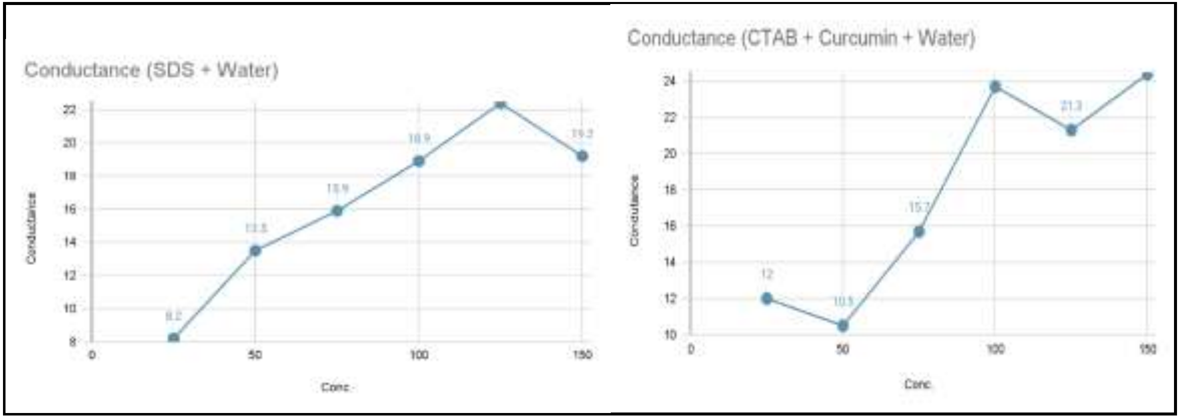


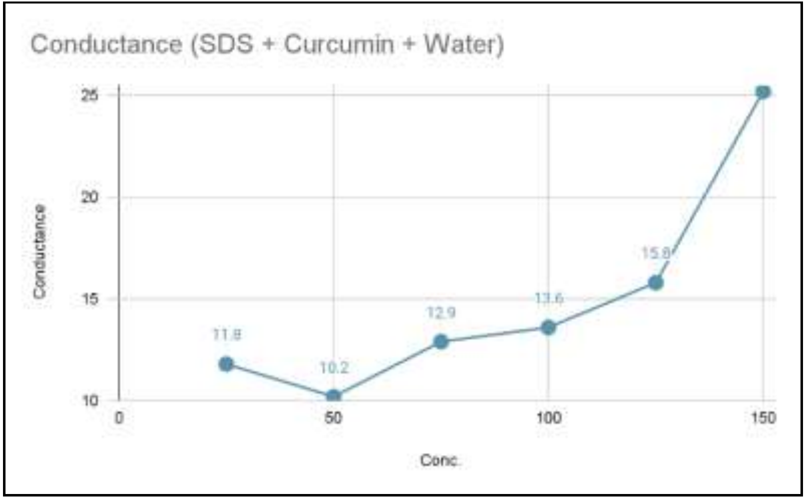
pH: The pH of water increases slightly as curcumin concentration rises, suggesting that there is little interaction between the curcumin molecules and the water. As concentration rises, there is a little potential towards stabilization or slight changes, but overall, the pH of CTAB and SDS surfactants remains acidic.

When CTAB is added, the pH rises noticeably more than when water or SDS is used, indicating that CTAB has a greater effect on the solution's proton concentration. SDS has little effect on changing the hydrogen ion concentration in the curcumin solution, as evidenced by the small pH shifts it exhibits with increasing concentrations.

Curcumin interacts differently with each surfactant when combined with CTAB or SDS, as evidenced by the slow pH shifts. This implies that curcumin and these surfactants have particular molecular interactions. Curcumin solutions maintain an acidic pH range under all circumstances, demonstrating their stability in acidic environments and interactions that are impacted by the kind and quantity of surfactants present.







Conductance: When compared to pure water, curcumin solutions with surfactants (CTAB and SDS) exhibit greater conductance, suggesting that the surfactants have improved ionic dissociation or interaction. Because CTAB is cationic and more effective at promoting ionic movement, it often exhibits the highest conductance values among the systems.

Conductance for SDS and pure water rises with curcumin concentration until it reaches a certain level, after which it falls, indicating a reduced ionic dissociation or molecular aggregation. Strong ionic interactions continue to affect the conductance of CTAB even at increasing concentrations, as seen by the comparatively constant pattern with little changes.

When curcumin is added to CTAB and SDS solutions, the conductance is lower than in systems that just include surfactants. Curcumin's attachment to surfactant micelles, which prevents ions from moving freely, may be the cause of this drop. These findings suggest that curcumin considerably changes the conductance behavior when it interacts with ionic and nonionic surfactants. This demonstrates how curcumin can change ionic environments, which can be used in systems that improve solubility and deliver drugs based on surfactants.

CONCLUSION

The intermolecular interactions between Curcumin and two surfactants- CTAB and SDS through their effect on physicochemical properties at 310.15 K. By the study, surfactants have a major impact on the molecular behavior of curcumin in solution: Curcumin's positively charged micelles allow CTAB to establish stronger electrostatic contacts with it. Curcumin's molecular stability in solution is improved by these interactions, which makes it more appropriate for systems that need stability and solubility.Curcumin and SDS interact mostly through hydrophobic interactions. Through micelle production, SDS stabilizes curcumin partially, though less effectively than CTAB. Curcumin and the surfactants combine to produce significant changes in important physicochemical properties such as density, viscosity, pH, conductance. Curcumin solutions' densities in water, CTAB, and SDS vary nonlinearly with concentration. Stronger molecular packing and solute-solvent interactions were indicated by the higher density values of solutions containing CTAB and SDS as compared to water. Micelle production in surfactant solutions is responsible for increased density at particular concentrations, indicating the stabilizing function of surfactants in curcumin solutions. The viscosity of curcumin in CTAB solutions was higher than that of SDS or water, indicating stronger intermolecular forces made possible by ionic interactions. The development and stabilization of micellar structures were indicated by an ongoing growth in viscosity observed in SDS solutions. While SDS causes minor viscosity changes as a result of hydrophobic contacts, CTAB's ionic nature facilitates stronger molecular interactions.

The pH of curcumin solutions remained acidic in every instance, and when mixed with CTAB, the pH increased significantly in comparison to SDS or water. Weaker protonix interactions are suggested by SDS solutions with little pH changes. The pH changes highlight interactions particular to surfactants, with CTAB enhancing changes in proton concentration more dramatically. Higher conductance than water was seen in solutions containing surfactants (CTAB and SDS), suggesting improved ionic dissociation and mobility of molecules. Because CTAB is cationic and encourages strong ionic interactions, it has the highest conductivity. Higher quantities of curcumin caused a modest drop in conductance, which may indicate that micelle saturation has reduced ionic mobility. Curcumin's capacity to change the ionic environment in surfactant systems, promoting improved solubility and structural organization, is demonstrated by the conductance behavior. Curcumin's capacity to change the ionic environment in surfactant systems, promoting improved solubility and structural organization, is demonstrated by the conductance behavior. Curcumin is more soluble and stable in aqueous settings when micelle production is facilitated by both surfactants.While SDS stabilizes curcumin through anionic hydrophobic forces, CTAB's charged micelles form strong ionic contacts with curcumin. Curcumin's physicochemical properties are shaped differently by the diverse interaction patterns that CTAB and SDS display with it. Curcumin's bioavailability in medication formulations can be increased by stabilizing it with surfactants. To create aqueous curcumin-based drug delivery systems, the improved solubility offered by CTAB and SDS is essential. The unique interaction behaviors point to possible applications in food, cosmetic, and medicinal goods where compatibility between surfactants and curcumin is necessary. Interactions between surfactants and curcumin offer a technique to make stable nanoemulsions for precise medication delivery. In aqueous conditions, curcumin's solubility, stability, and molecular interactions are improved by CTAB and SDS. SDS provides moderate stabilization through hydrophobic contacts, but CTAB's charged micelles have greater ionic interactions. These results highlight how crucial it is to choose the right surfactants when using curcumin in applications for the best possible solubility and stability.

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