Synthesis of Green Surfactant for Sustainability

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Abstract:

Although surfactants are essential to many businesses, their non-renewable sources and associated ecological effects sometimes raise environmental concerns. To investigate and create effective ways to synthesize eco-friendly surfactants from bio-based, renewable, and eco-friendly materials. Used cooking oil has been considered as an alternative natural feedstock source to lower the price of surfactant. For improved oil recovery in the petroleum industries, ricinoleic acid methyl ester, which is derived from spent cooking oil, was synthesized into sodium methyl ester sulfonate (SMES), a novel surfactant. By testing the surface tension with and without sodium chloride and its thermal stability at reservoir temperature, the performance of SMES was investigated. A crucial factor is the co surfactant/SMES-oil-water system's phase behavior.

Keywords: Green surfactants, cooking oil, sodium methyl ester sulfonate FTIR etc.

Introduction:

To create an ecologically safe and sustainable surfactant for use in diverse industrial applications. Surfactants are widely used in a variety of sectors, including oil recovery, agriculture, personal care, and home cleaning. Conventional surfactants, however, frequently come from non-renewable resources and have the potential to harm the environment. Therefore, boosting sustainability in these businesses depends on the creation of a green surfactant.

Global Market Review:

Due to growing consumer demand for sustainable products, stronger regulations, and more environmental consciousness, the global market for green surfactants has been expanding steadily. The demand for more environmentally friendly substitutes for conventional surfactants made of petrochemicals is what drives the market.

Regional Market Insights: The market for green surfactants is global, with significant growth observed in several regions, including

North America: The region has been at the forefront of sustainability initiatives, with stringent regulations and consumer demand for eco-friendly products driving the market growth for green surfactants.

Europe: European countries have well-established regulations promoting the use of green surfactants and sustainable practices. The region is witnessing increased adoption of eco-friendly surfactants in various industries.

Asia-Pacific: The region offers significant growth potential due to its large population, expanding middle class, and increasing consumer awareness about environmental issues. Countries like China and India are witnessing a rise in demand for green surfactants.

Rest of the World: Other regions, including Latin America, Africa, and the Middle East, are also experiencing a growing interest in green surfactants. The market growth in these regions is driven by increasing environmental concerns and a shift towards sustainable practices.

Comparative Study of Synthetic Surfactant and Green Surfactant:

 Synthetic Surfactants: Typically, synthetic surfactants are produced chemically from petrochemicals. They entail the use of non-renewable fossil fuel sources as production feedstock, including crude oil or natural gas.

 Green Surfactants: Green surfactants come from sources that are sustainable and renewable, such plant-based products, biowaste, or agricultural byproducts. Biotechnological procedures, enzymatic reactions, or green chemistry concepts are frequently used in production techniques.

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SMES Surfactant Reaction:

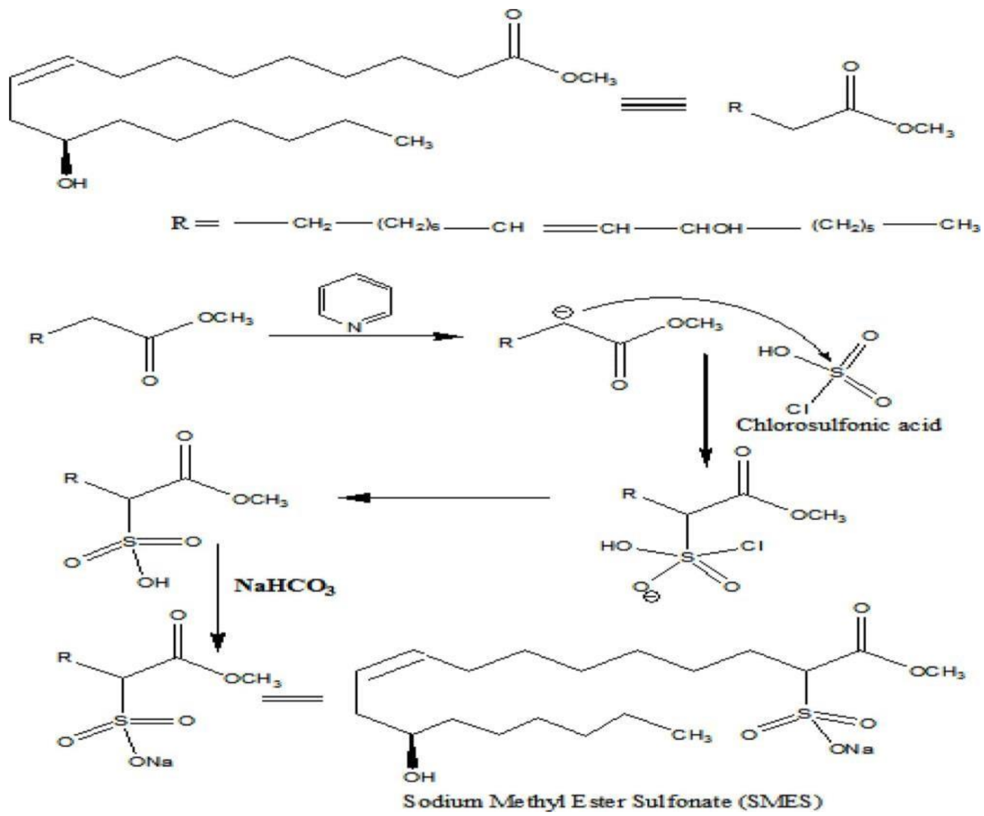

Fig 1.1 Chemical reactions of Sodium Methyl Ester Sulfonate

Sodium Methyl Ester Sulfonate (SMES) Uses and Applications:

- **Detergents and Cleaning Products**: In a wide range of cleaning formulas, including laundry detergents, dishwashing solutions, and all-purpose cleaners, SMES is widely employed as a surfactant. It effectively removes filth, grease, and stains because to its superior cleaning power, emulsification, and foaming qualities.

- **Personal Care Products**: In personal care items including shampoos, body washes, soaps, and facial cleansers, SMES is used. It functions as a mild cleanser that helps to keep the skin and hair's natural moisture balance while removing pollutants.

- **Personal Care Products**: Shampoos, body washes, soaps, and facial cleansers are a few examples of personal care items where SMES is used. While preserving the skin's and hair's natural moisture balance, it functions as a light and gentle cleanser to assist remove pollutants.

- **Industrial Cleaners:** SMES is a component of industrial cleaning formulas used in the automotive, manufacturing, and food processing sectors to clean surfaces of grease, oil, and dirt. It has effective degreasing qualities and is adaptable to different cleaning procedures.

- **Enhanced Oil Recovery (EOR):** SMES is used in methods for increased oil recovery in the oil and gas sector. It aids in lowering the friction at the oil-water interface, improving oil displacement and extraction from reservoirs.

2. Experimental Work:

2.1 Chemicals: Pyridine Used, Cooking Oil, Acetic anhydride, Methyl Ester, Sodium Carbonate, Sodium Bicarbonate, N- butanol etc.

2.2 Synthesis of Sodium Methyl Ester Sulfonate:

A 250 mL round bottom (R.B) flask set in a chilled bath received 15 mL of pyridine. The R.B. flask was then filled with 2.63 g of acetic acid and continuously stirred for 15 minutes at 800 rpm. After stirring for another 30 minutes, 2.60 g of a castor oil methyl ester solution was progressively added to the mixture. When heated to 65 °C, the solution emerged as a clear liquid after being withdrawn from the ice bath. The second step involved saturating the solution with inorganic salt by adding 33 g of aqueous sodium carbonate to 300 mL of distilled water in an ice-cooled bath while stirring continuously at 800 rpm. The ice became saturated as it cooled.

3. Results & Analysis:

3.1 FTIR Spectrophotometer of SMES

Figure shows the infrared spectra of SMES surfactant. The methyl group's (C-H) asymmetrical bending vibration band often correlates to the strong band at 1455 cm-1. The terminal -CH3 group's symmetric and asymmetric C-H stretching modes both manifest simultaneously at 2873 and 2955 cm-1. The adsorbed water is stretched by OH, which causes the broad vibration in SMES with a centre of 3267 cm-1. The vibration of the absorbed water revealed that SMES's hydrophobic surface had turned hydrophilic. The strong peak at 1158 cm-1 indicates the presence of the sulfonate group (S=O) stretching vibration, which shows that this compound must be sodium methyl ester sulfonate. Analysis of all IR absorption bands was done using spectrometric data.

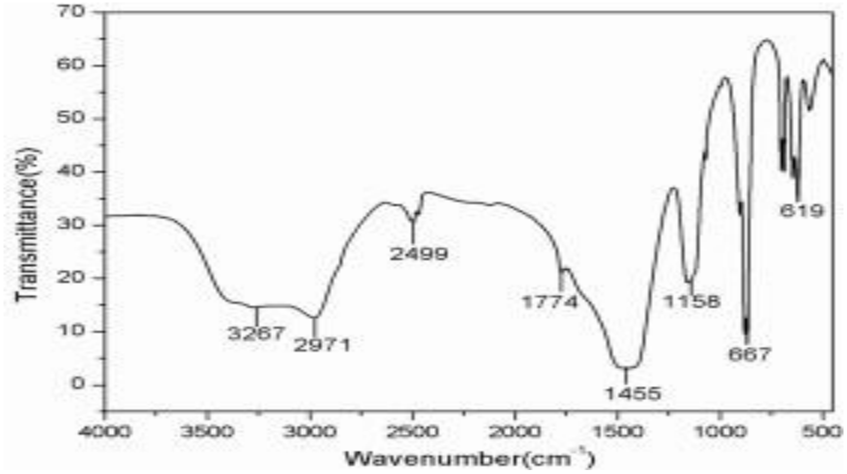

Figure: Infrared spectrum of sodium methyl ester sulfonate

Measurement of Surface Tension:

Surface tension of SMES surfactant solutions at various concentrations is depicted in Figure A. The surface tension plots against concentration yielded the critical micelle concentration (CMC) of this surfactant as the intercept between the decreasing slope and the constant horizontal line. Surface tension readings gradually drop with increasing SMES surfactant concentration until the critical micelle concentration, at which point a minimum surface tension value of 38.4 mN/m was reported. For concentrations greater than the CMC, the surface tension values remained constant. Figure shows the impact of NaCl concentration on the SMES surfactant solution's surface tension at constant surfactant concentration (CMC). Surface tension is greatly reduced when NaCl concentration rises. A decrease in surface tension was observed

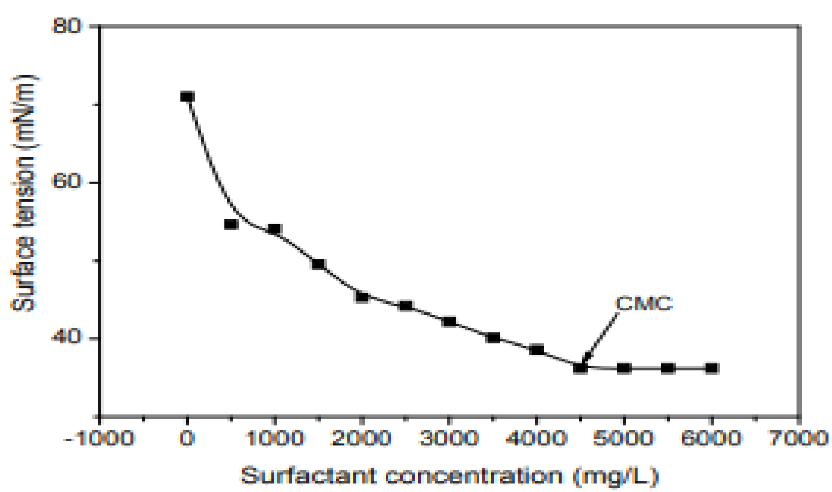

Figure Surface Tension Analysis

Figure shows the results of the SMES surfactant's thermal analysis. Three phases of mass reduction were noticed. The loss of weakly bound water molecules is represented by the first section, which experiences a mass loss of 4.4% from ambient to 100°C. The second zone, from 100 to 150 degrees Celsius, experienced a dramatic loss of mass of 27.6%, showing that SMES molecules begin to break down at higher temperatures. The residual SMES surfactant components were thermally stable up to 500°C, but the third degradation zone between 150 and 500 °C exhibits a complex thermal disintegration that may be caused by the addition of the sulfonate group with mass loss of 2.93%. However, the SMES surfactant should keep an average of 85.91% given that typical reservoir temperatures range from 50 to 120 degrees Celsius.

Measurement of Dynamic Light Scattering (DLS)

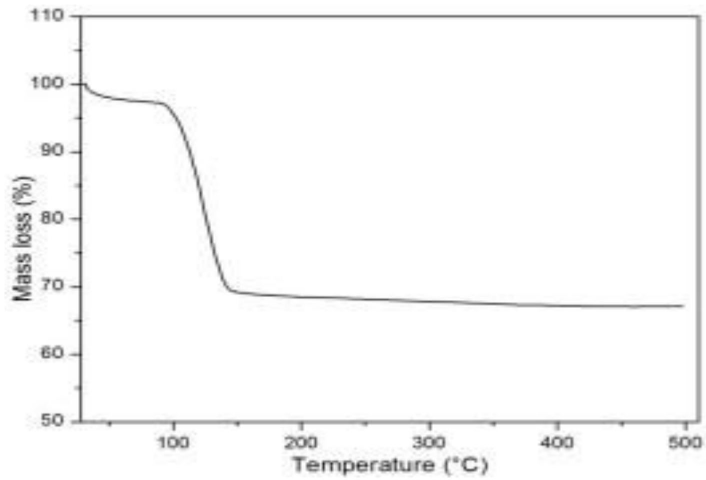

Figure: Thermal stability curve for SMES surfactant

Figure demonstrates that when the concentration of SMES surfactant increases, so does the hydrodynamic diameter. The molecular aggregation causes the hydrodynamic diameter to grow. The particle size increases concurrently with the increase in SMES surfactant concentration because the rate of diffusion is faster for small particles.

For SMES surfactant solutions the apparent micelle sizes exhibit an increasing trend with increasing concentration of SMES surfactant According to Figure 5, the hydrodynamic diameter increases linearly with surfactant, indicating that the micelles are in the zone of net repulsion.

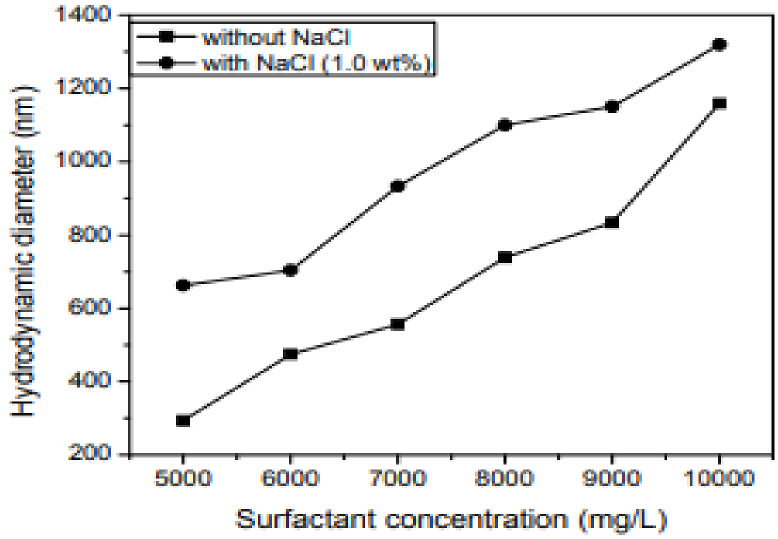

Figure: Particle size analysis of SMES surfactant in presence and absence of sodium chloride

Pseudoternary Phase Diagram:

A pseudoternary phase diagram for combinations of oil, co surfactant/surfactant, and water at different ratios is shown in Figure 6. Co-surfactant/surfactant can be used to create any type of dispersion, including standard water in oil and oil in water micro emulsions, discontinuous and transitional liquid crystalline structures, and structures with a high swelling capacity. Oil, co surfactant/surfactant, and water combine to generate a sizable micro emulsion region (Winsor IV+ Solid). The transition from an oil-in-water micro emulsion near the water apex to a water-in-oil micro emulsion near the n-heptane apex through a discontinuous structure is seen as a single phase region (Winsor IV). The huge area of the surfactant-created oil-in-water micro emulsion is the result of the surfactant's high molecular packing ratio in the two phase region

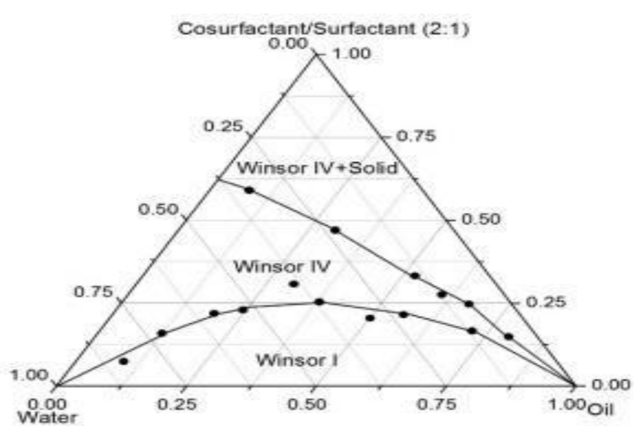

Figure Schematic representation of the pseudoternary phase diagram formed by co surfactant/ surfactant, oil and water mixtures at various compositions (mass fraction)

Conductivity Measurement:

In a constant volume of water, the electrical conductivity of a micro emulsion containing various mass ratios of n-heptanes: (n- hexanol/SMES) was determined. So, with a tiny amount of Na+ ions, Figure 7 clearly shows an increase in conductivity when the surfactant starts to combine. This outcome is comparable to the percolation of surfactant aggregation in an isotropic region, where water droplets quickly cluster to produce an open structure for the effective transport of Na+ ions by transitory fusion and mass shifts. Water molecules are the only factor that influences the percentage of miceller head groups that are neutralized by ions. These findings are consistent with the measurement of conductivity, which rises as miceller ionization increases

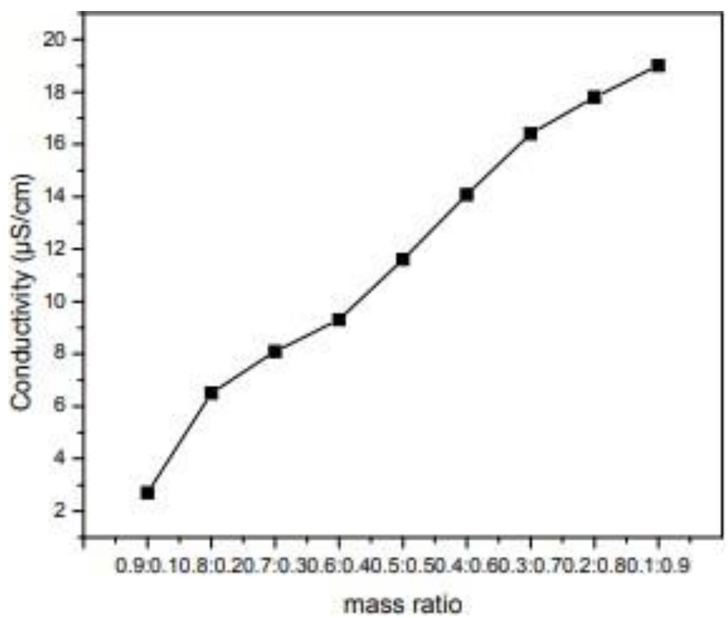

Figure: Conductivity with different mass ratios of n-Heptane: (n-Hexanol/SMES surfactant)

Conclusion:

For use as a surfactant in increased oil recovery, sodium methyl ester sulfonate was created in the current study using castor oil that was not intended for human consumption. Castor oil is a cheap, renewable, and natural feedstock, and the surfactant made from it has excellent surface-active characteristics. The surface tension of the surfactant solution is reduced to 38.4 mN/m and 27.6 mN/m, respectively, at the CMC, according to the plot of surface tension at different concentrations of the surfactant solution. When the sodium methyl ester sulfonate is heated to reservoir temperature, a 14.1% mass loss is seen, although the material exhibits good thermal stability. The sulfonate group (S=O) was confirmed by FTIR spectra at 1158 cm-1, indicating that this substance must be sodium methyl ester sulfonate. The micro's conductivity.

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