A multicomponent model for the dilatational viscoelasticity of soluble non-ionic surfactant mixtures

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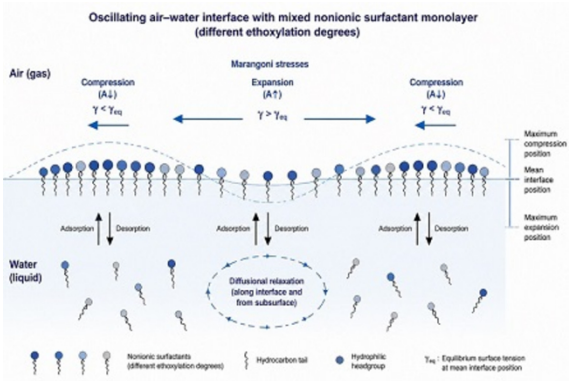
A multicomponent model is developed for the complex dilatational viscoelastic modulus of fluid interfaces stabilized by mixtures of n soluble non-ionic surfactants [2,7]. The formulation couples the diffusion-controlled exchange of each surfactant species with the composition dependence of the interfacial equation of state and adsorption isotherms, yielding an analytical expression for the complex modulus in terms of equilibrium surface concentrations, diffusion coefficients, and the corresponding thermodynamic derivatives [1,6-7]. The model recovers, as limiting cases, the classical Lucassen-van den Tempel description for a single surfactant and the established binary-mixture formulations reported by Jiang et al. and Joos, thereby supporting its internal consistency [1-3,7]. The approach is applied to literature data for ethoxylated alcohol systems, with particular emphasis on the ternary mixture C10EO5/C12EO5/C14EO8 [4-5,7]. Two thermodynamic closures are examined, Langmuir and a reorientation model that accounts for interfacial compressibility and molecular reorientation [4,6-7]. The Langmuir model overestimates the experimental modulus, whereas the reorientation model provides better agreement [4-7]. These results indicate that the predictive performance of a multicomponent dynamic model depends strongly on the physical realism of the thermodynamic submodel used to represent the interfacial layer [4,6,7]. This model provides a rigorous basis for the analysis and design of multicomponent surfactant formulations with tailored interfacial rheology in foams, emulsions, and related dispersed systems [2,7]



Schematic representation of cases of expansion and contraction of the surface

References:

[1] Lucassen, J.; Van Den Tempel, M. Dynamic Measurements of Dilational Properties of a Liquid Interface. *Chem. Eng. Sci.* **1972** , *27* (6), 1283-1291. https://doi.org/10.1016/0009-2509(72)80104-0

[2] Garrett, P. R.; Joos, P. Dynamic Dilational Surface Properties of Submicellar Multicomponent Surfactant Solutions. Part 1. Theoretical. *J. Chem. Soc., Faraday Trans. 1* **1976** , *72* , 2161-2173. https://doi.org/10.1039/F19767202161

[3] Jiang, Q.; Valentini, J. E.; Chiew, Y. C. Theoretical Models for Dynamic Dilational Surface Properties of Binary Surfactant Mixtures. *J. Colloid Interface Sci.* **1995** , *174* (1), 268-271. https://doi.org/10.1006/jcis.1995.1391

[4] Miller, R.; Aksenenko, E. V.; Liggieri, L.; Ravera, F.; Ferrari, M.; Fainerman, V. B. Effect of the Reorientation of Oxyethylated Alcohol Molecules within the Surface Layer on Equilibrium and Dynamic Surface Pressure. *Langmuir* **1999** , *15* (4), 1328-1336. https://doi.org/10.1021/la980956b

[5] Fainerman, V. B.; Aksenenko, E. V.; Petkov, J. T.; Miller, R. Adsorption Layer Characteristics of Multi-Component Surfactants Solutions. *Soft Matter* **2010** , *6* (19), 4694-4700. https://doi.org/10.1039/C0SM00235F

[6] Rosales-Anzola, S. D.; Urbina-Villalba, G. Methodological Approach to Selecting State Equations and Adsorption Isotherms. *J. Appl. Sci. Eng.* **2024** , *28* (3), 451-458. https://doi.org/10.6180/jase.202503_28(3).0003

[7] Rosales-Anzola, S. D. Generalized Theoretical Framework for the Dilatational Viscoelasticity of Multicomponent Surfactant Mixtures. Ind. Eng. Chem. Res. 2025, 64 (49), 23433-23449. https://doi.org/10.1021/acs.iecr.5c03651

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