Salt Induced Phase Separation

Get Wet Report

Abhishek Raut

MCEN 5151: Flow Visualization
University of Colorado Boulder
09/25/2023

Context and Purpose

Phase separation and aggregation are fundamental in chemistry and fluid dynamics, making them a focal point in academic and practical research. In particular, salt-induced phase separation is a method commonly employed for solid precipitation and, intriguingly, for liquid separation. This phenomenon is especially pertinent in the pursuit of economical methods for alcohol separation and purification. Salt-induced phase separation operates on the principle of adding salt to a mixture, where the salt interacts with the solvent, disrupting the solubility balance and leading to the aggregation of the solute or the separation of two liquids[1]. In this experiment, conducted as part of the MCEN 5151 Flow Visualization course's 'Get Wet' assignment, the primary objective was to visually capture and analyze the motion of fluids during such a separation process, providing insight into the fluid dynamics at play.

Flow Apparatus

The experimentation phase involved testing multiple combinations of liquids, ultimately leading to the selection of isopropyl alcohol, distilled water, and common salt (NaCl) as the working materials[2]. In the setup, alcohol and water were mixed together in a vial, to which salt was incrementally added. This gradual addition was key to increasing the salt's saturation in the mixture, a critical factor in inducing the phase separation. It was essential to avoid adding excess salt, as undissolved salt could act as contaminants, adversely affecting the clarity of the video capture.

Visualization Technique

Dyeing both liquids beforehand was not feasible, as the dyes would dissolve in both. Therefore, dyes were carefully added to each liquid using a dropper – red for the alcohol and blue for the water. The challenge lay in effectively visualizing the small bubbles forming in the mixture. After experimenting with various lighting techniques, a point source of light was placed as a backlight approximately 60cm behind the vial was placed to simulate rays from infinite distance and help show minute details clearly. The lighting was directly aligned with the center where the liquid interface was expected to form. This setup provided a sufficiently parallel light arrangement, crucial for capturing the fine details of the small bubbles in the mixture.

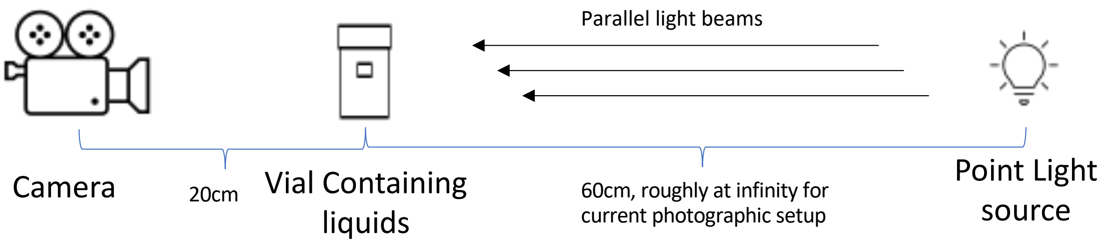

Figure 1 Photographic and Visualization Setup

Photographic Technique

The videography was conducted using a Canon EOS 1500D camera, equipped with a Canon MP-E 65mm f/2.8 1-5x Macro lens, and mounted on a Benro MP80 Macro Head. The camera achieved 4x and 5x macro magnification for the two clips. Given the APS-C sensor size of 22.2mm x 14.8mm, this setup resulted in a frame width of 5.55mm x 3.7mm at 4x magnification and 4.44mm x 2.96mm at 5x magnification. The camera settings were carefully adjusted, with an aperture of f/3.6 providing adequate light while maintaining a reasonable depth of field. The videos were captured at a resolution of 1920x1080p, and a frame rate of 25fps. The challenges included maintaining focus due to the shallow depth of field and the need to precisely reposition the vial for each attempt – a process that took over 30 tries to perfect.
The video can be accessed here: https://youtu.be/2Z24JNafLxQ

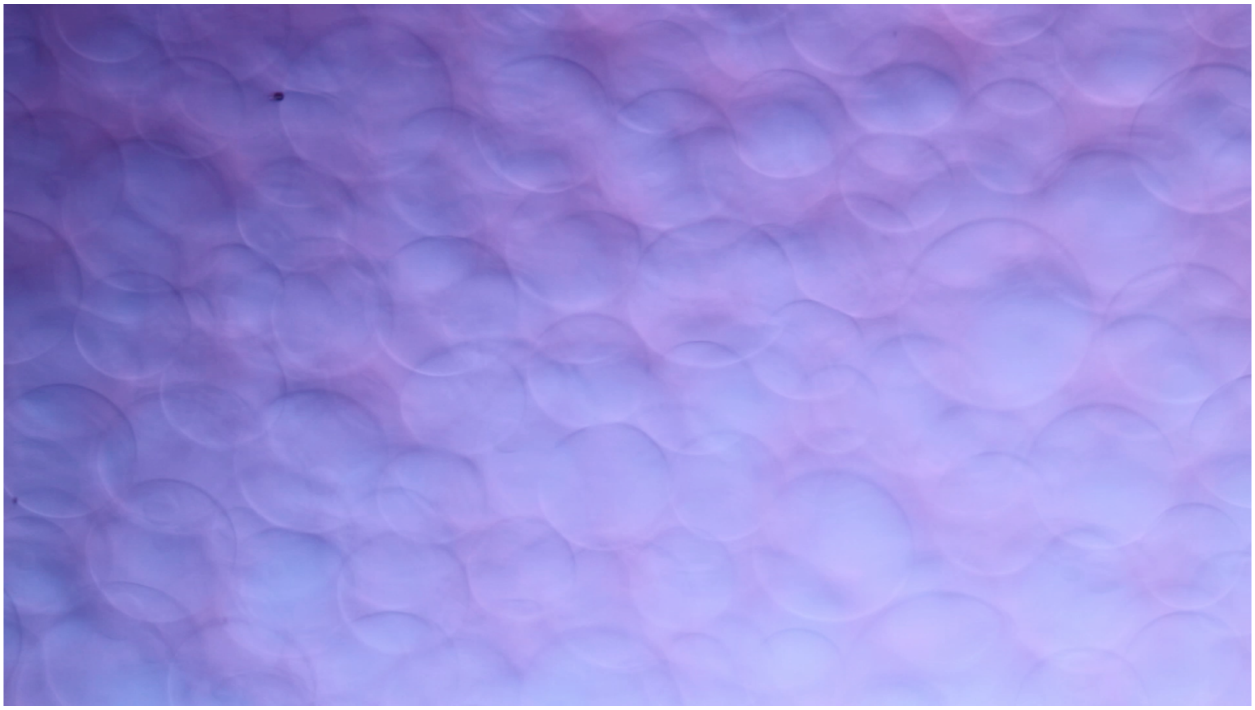

Figure 2 Salting out Video

Video Analysis

The analysis of the captured video revealed the dynamic process of salt-induced phase separation. Small bubbles of isopropyl alcohol and water formed, displaying chaotic yet directional movement – upwards for alcohol and downwards for water – due to density differences. These bubbles then coalesced into larger ones, eventually leading to the formation of two distinct liquid layers[3]. Calculating the size of the bubbles was possible by examining their respective pixel sizes. At 4x magnification, with a resolution of 1920x1080 pixels and a frame width of 5.55mm x 3.7mm, the bubble sizes were measured to be approximately 146 pixels horizontally and vertically.
The diameter calculations were as follows:

- Horizontal Diameter: $\frac{146 \text{ pixels}}{1920 \text{ pixels}} \times 5.55 \text{ mm} = \ 0.42203 \text{ mm}$

- Vertical Diameter: $\frac{146 \text{ pixels}}{1080 \text{ pixels}} \times 3.7 \text{ mm} = 0.500185 \text{ mm}$

Thus, the bubble diameters ranged from approximately 0.422 to 0.5 micrometers. The video successfully captured not only the separation of the two liquids in motion but also met the aesthetic requirements of the assignment.

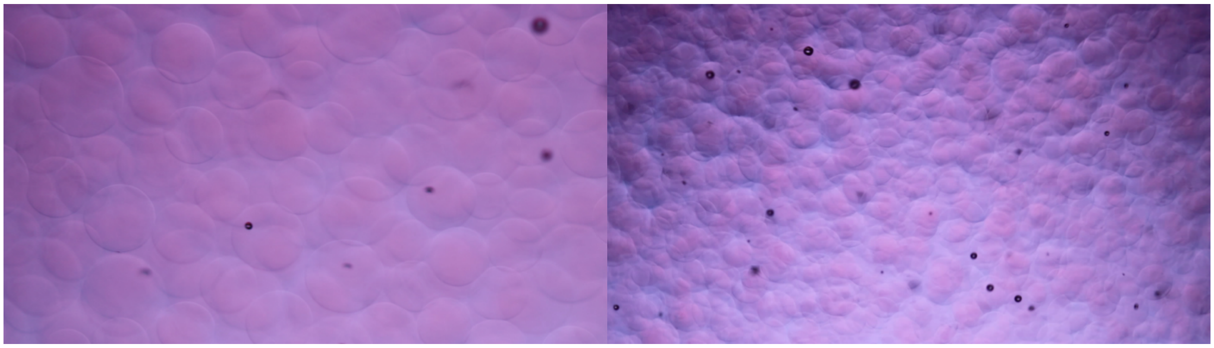

Figure 3&4 Clip snapshots at 5x and 4x macro to measure bubble diameter

Further Work

In the realm of salt-induced phase separation and fluid dynamics, future research avenues present numerous opportunities for advancement. One key area is the exploration of various combinations of solvents and salts, aiming to understand the nuanced impacts of different chemical properties on the separation process. Additionally, molecular dynamics simulations could offer profound insights into the microscopic interactions occurring during phase separation, particularly under diverse temperature and pressure settings. Another promising field is the application of this process in industrial contexts, such as wastewater treatment and biofuel production, with a parallel focus on assessing the environmental implications of these applications. This multifaceted approach not only deepens our understanding of phase separation but also opens doors to practical, real-world implementations and improvements.

References

[1] T. L. Donaldson, “Phase separation of organics/water mixtures using salts,” *Biotechnol Bioeng Symp U. S.*, vol. 14, Jan. 1984, Accessed: Nov. 26, 2023. [Online]. Available: https://www.osti.gov/biblio/5766986

[2] J. C. Card and L. M. Farrell, “Separation of alcohol-water mixtures using salts,” Oak Ridge National Lab. (ORNL), Oak Ridge, TN (United States), ORNL/MIT-338, Apr. 1982. doi: 10.2172/5250443.

[3] J. Eggers, J. R. Lister, and H. A. Stone, “Coalescence of liquid drops,” *J. Fluid Mech.*, vol. 401, pp. 293–310, Dec. 1999, doi: 10.1017/S002211209900662X.