Team Second Report

MCEN 4151

Flow Visualization

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Team 10

This image, yet, subtle, explores the science of carbonation. This image was submitted for the Flow Visualization (Spring 2018) Team Second Assignment. I chose to go a different direction from my team. The intent of the image is to show the details of carbonated water, and its effervescence. The image has been desaturated and colors on the bubbles near the middle of the image to add an artistic element. The image is below in Figure 1.

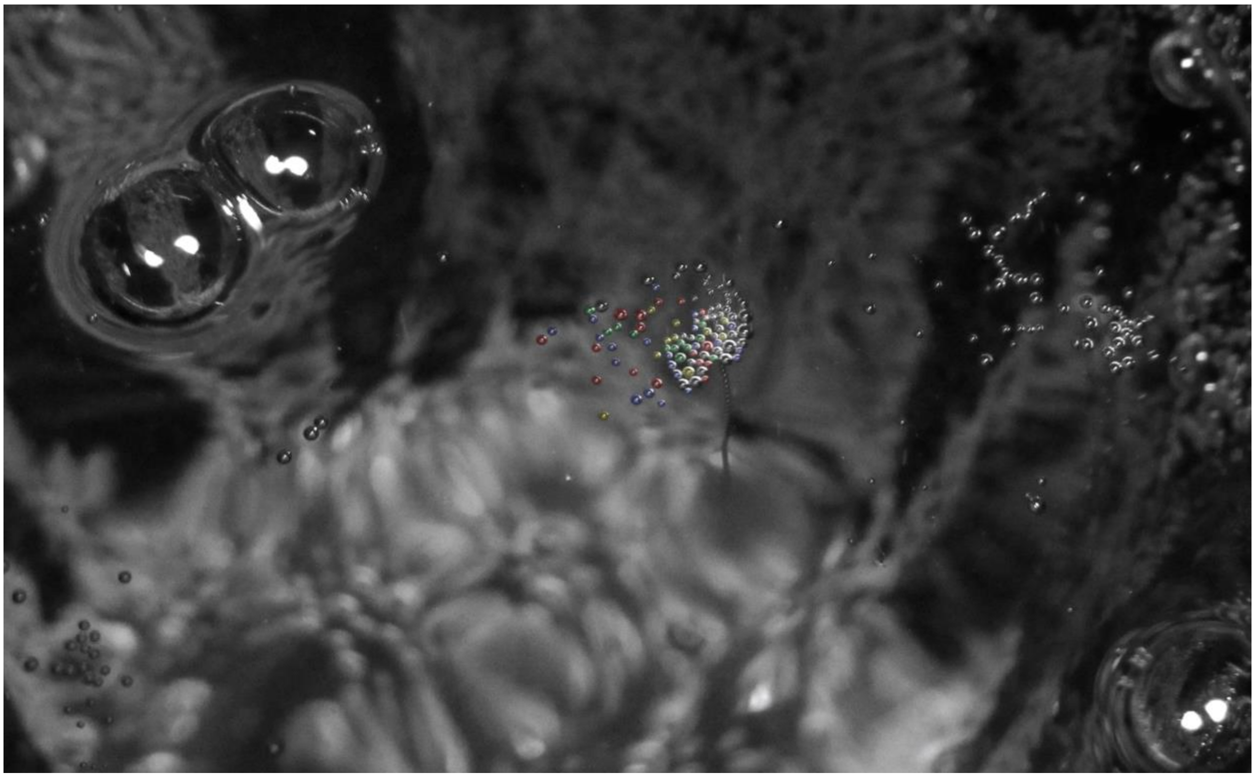


Figure 1: Image submitted

The image in Figure 1 was created by pouring carbonated water (specifically, Orange flavored New York Seltzer) in to a small 6 fl. oz. cup. After the cup was filled, I agitated the fluid, slightly, by tapping the outside of the cup to detach bubbles from the side and cause them to rise to the surface.

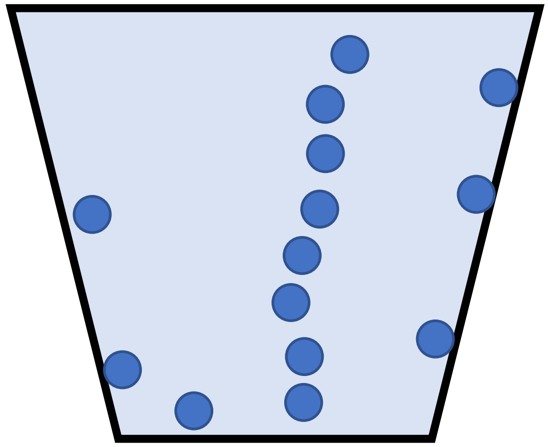


Figure 2: Schematic of cup with bubbles (nucleating at sides and bottom)

A schematic of the flow setup is shown in the diagram above. The primary flow intended to be focused on by this image is the stream of bubbles emanating from the bottom of the cup and accumulating at the surface near the center of this image (color-added). Carbonation is the result of dissolved carbon dioxide (at high pressure) that is pumped into a pressure vessel (such as an aluminum soda can).

Each bubble is approximately 1-2 millimeters in diameter, and as can be seen, there is a stream of bubbles, a chain, that stretch from the surface, all the way to the bottom. The forces acting on this bubble-flow are primarily the buoyant force (which due to the difference in densities between the air and the water, causes the bubbles to rise). Gravity would be the other force primarily acting on the bubbles. Bubbles become visible on the sides and bottom of the cup/glass that a carbonated beverage is contained in when preexisting, microscopic cavities in the sides of the container allow for their formation. These places, known as *nucleation sites*, allow for pockets of dissolved carbon dioxide to bond together and create a bubble. When the buoyant force caused by the bubble exceed the magnitude of the intermolecular forces bonding the bubble to the side of the container, the bubble detaches.

A useful number for analyzing and understanding carbonated liquids is the Henry's Law. Henry's law states "that the concentration of dissolved gas in a solution is proportional to its partial pressure in the vapor phase" (Liger-Belair, et. al.). We can calculate the Henry's law constant, which represents the ration of aqueous-phase concentration of the dissolved carbon dioxide in the water to its partial pressure in the gas-phase. The equation below (from Liger-Belair, et. al.) is one way to calculate the Henry's law constant (of volatility), k_H, for carbon dioxide:

$$k_H = k_{298K} exp\left[-\frac{\Delta H_{diss}}{R}\left(\frac{1}{T} - \frac{1}{298K}\right)\right]$$

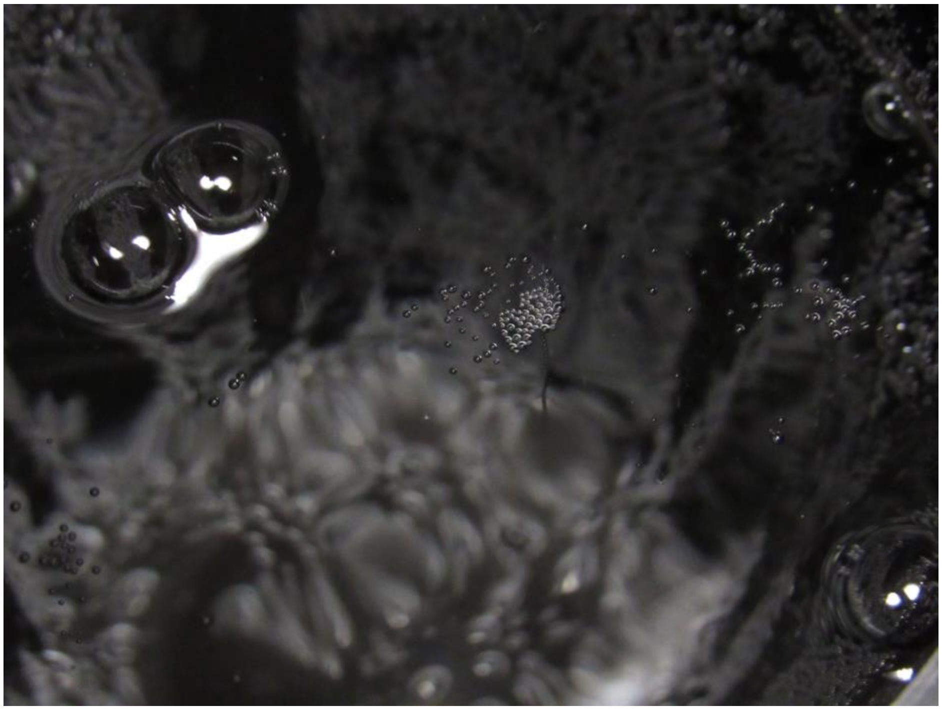
where, T is the temperature in Kelvin, R is the ideal gas constant, and k_{298K} is the Henry's law constant at 298K = 1.21×10^{-5} kg m^{-3} ps^{-1}. $\Delta H_{diss} \approx -24{,}800$ J/mol (the dissolution enthalpy of carbon dioxide molecules, but for champagne, not water, provided by Liger-Belair, et. al. but has been used for the purposes of determining the Henry's law constant for this flow visualization experiment). k_H for this experiment was calculated to be 1.462×10^{-5} kg m^{-3} ps^{-1}.

Photographic technique used:

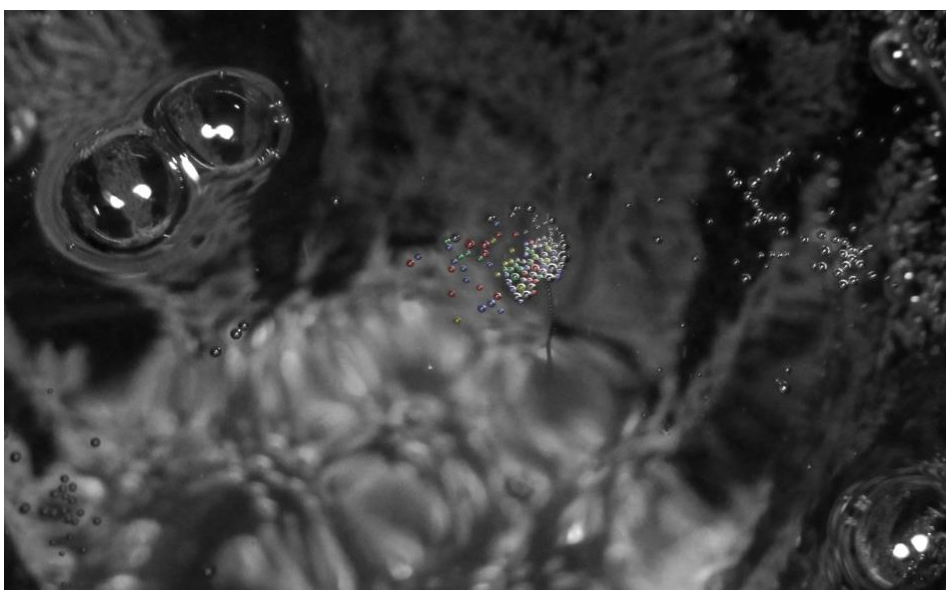
- The size of the field of view is about 1"x2".
- Distance from surface to lens is about 3 inches.
- Camera used: Canon PowerShot SX530 HS
- Final image height: 3000 × 1849px
- ISO: 1600, F/4.5, with auto white-balance
- Cropped, desaturated, and color added in Photoshop CS2
- Default camera flash used.

I like how this image reveals the carbonation and nucleation effects of the sparkling water. Overall, I think the physics shown is pretty clear. Perhaps in the future, an image such as this one could benefit from additional cropping.

Comparison between original and submitted image is shown on the next page.



Original image



Edited/submitted image

Work Consulted

1. Liger-Belair, Gérard, et al. “Modeling the Kinetics of Bubble Nucleation in Champagne and Carbonated Beverages.” *The Journal of Physical Chemistry B*, vol. 110, no. 42, 12 Aug. 2006, pp. 21145–21151., doi:10.1021/jp0640427.