Get Wet

"Isolation"

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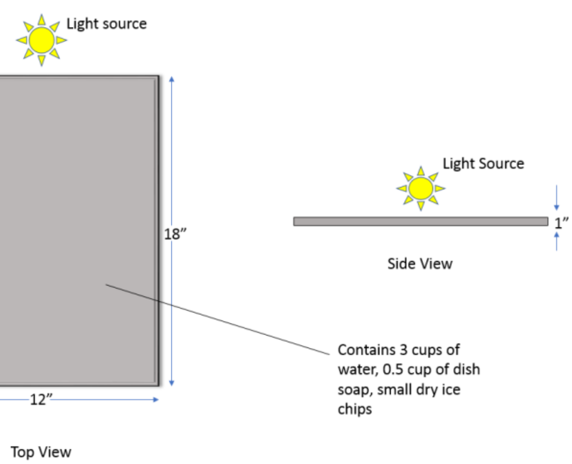
I. Context and Purpose

I originally intended this image to be an exploration of the effects of dry ice, but ultimately I found this image also served as an adventure in learning about manual camera settings and several unintended physical phenomena. I was trying to capture the sublimation of the carbon dioxide from the dry ice. This is essentially the very cold carbon dioxide gas condensing the water vapor in the air into little liquid water droplets, causing the vapor we typically associate with dry ice. I was indeed successful in capturing this, but I also managed to capture the prismatic effects of thin-film interference of the bubble, the hydrophilic and hydrophobic nature of soapy water, and the rapid increase in pressure within the bubble.

II. Experimental Setup and Description of Physical Phenomena

In order to create the effects exemplified in the image, I used a 12" by 18" by 1" metal baking sheet and mixed 3 cups of water with a half cup of Dawn Ultra dish soap. I purchased 1 pound of dry ice from a local grocery store and used a rolling pin to carefully break it into smaller pieces. The ideal size for each piece of dry ice was no larger than 1" in any direction, but wide chips with a short height worked best for creating bubbles. I then used tongs to stir dry ice and soapy water mixture. Typically, if the dry ice was momentarily submerged in the soapy water mixture, a bubble would immediately form. This is why it was conducive to have smaller chips of dry ice rather than large chunks. Please see below for safety considerations and an image of this set-up.



The flow of the vapor was caused by the sublimation of the dry ice. Sublimation is when a material instantly changes states from solid to gas. As previously mentioned, the cold, gaseous carbon dioxide from the dry ice instantly condenses the gaseous water vapor in the air due to humidity and creates tiny water droplets, which is the vapor that we see. Eventually, this sublimation will cause a build-up of pressure, causing the bubble to pop.

Bubbles form because of the surface tension due to the properties of soapy water. Soap molecules have a hydrophilic and hydrophobic side[1]. A bubble is formed when a layer of water is sandwiched between two layers of soap. The surface tension of soapy water is about γ= 0.025 N/m, and we can calculate the pressure caused by the sublimation process of the steam using the following equation[2]:

$$P_i - P_o = 4\gamma/r$$

Where P_i is the internal pressure and P_o is the external pressure and r is the radius of the bubble. The radius of the bubble was about 1.5cm, and assuming atmospheric pressure is 0.826 kg/cm^2 in Boulder, CO, for the external pressure, we can solve for the internal pressure within the bubble caused by the vaporization of carbon dioxide:

$$P_i - 0.826 = 4(0.025)/1.5$$

$$P_i = 0.893 \text{ [kg/cm}^2\text{]}$$

Finally, the prismatic rainbow effect that we see on the bubble is due to thin-film interference[3]. Essentially, light enters the film, which is comprised of soap-water-soap layers, and passes through the first layer of soap, but reflects off of the bottom layer of soap, and bounces off of the top layer again. Essentially these light waves interfere constructively with one another. When the internal reflection happens inside the thin film, since the film has a thickness close to the wavelength of light, bands of individual colors are easily identifiable within the film as they are reflected within the layer.

Safety considerations: if you choose to recreate this experiment and handle dry ice, take extreme caution as it can cause second degree burns on the skin. Only handle with tongs while wearing gloves. Perform your experiment in a well-ventilated area and never, under any circumstances, seal dry ice in a container. The aforementioned sublimation process causes a build-up in pressure, as demonstrated in this lab, and this could cause serious injury.

III. Visualization Technique and Lighting

In order to visualize this flow, I found it was necessary to using a dark room with a dark background. At times, the vapor was difficult to capture, so I used the white light from my phone's flashlight feature to cast light from the right side of the bubble with all else

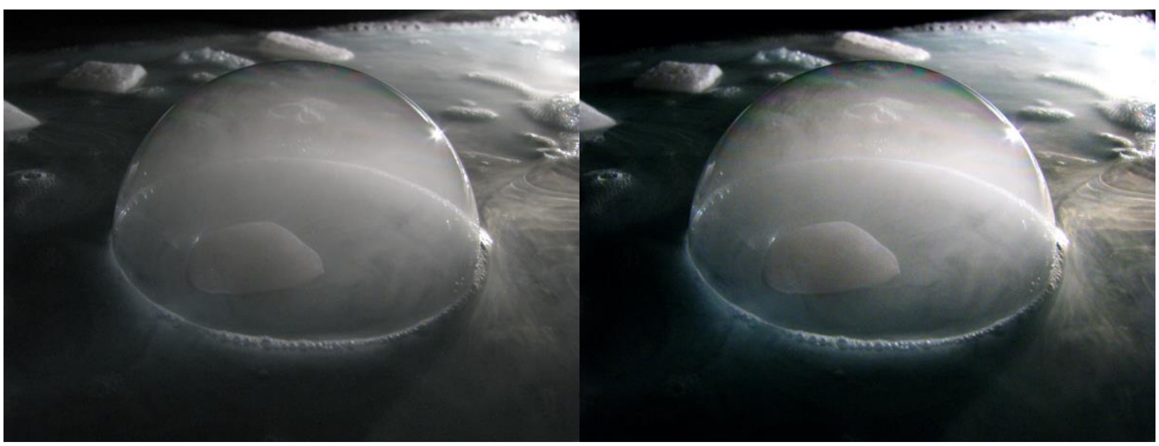
[1] Bradbury, Goodman, Murphy, 2008
[2] The University of Tennessee, Dept. of Physics and Astronomy
[3] Fitzpatrick (2007)

extremely dark. I feel that this was effective in capturing the vapor and the thin film interference due to the light incident to both the vapor and the bubble.

IV. Photographic Technique

This was my first experience photographing using manual settings and I learned quite a bit through trial and error. Using my Canon PowerShot S5 IS, I took my final image about two inches away from the subject with a focal length of 6mm (the shortest for my camera) and using the Macro setting in order to capture as much detail as possible. I found that this produced higher quality, more focused images than using zoom features. I chose an exposure of 1/30 second so that I could capture a still image with as little motion blur as possible since the vapor was obviously moving continuously. I also used an F-Stop of f/5, an aperature of 2.875, and ISO-400 to create optimal exposure settings. I chose these settings because I really wanted to capture the bright, illuminated vapor and gleam of the bubble while still eliminating any graininess and overexposure. I struggled for a while with images that were either too dark or too grainy, but finally found that this combination was successful for my lighting setup. My original image was 3264 by 2448 pixels with 180dpi resolution.

In post-processing, I bumped up the contrast and the color saturation because I wanted to highlight the important physical phenomena that I captured: the sublimation and the thin-film interference. See below for the original image and final, edited image, respectively:



V. Final Thoughts and Future Improvements

Overall, I really enjoyed this experiment and the outcome. My inspiration was derived from my freshman year, when some of my friends and I were playing with some leftover dry ice and decided to pour soap on it. I learned so much about thin-film interference through this process, even though I originally intended to only explore the flow effects of dry ice. I titled my image “Isolation” because I feel as if it calls into question the overall scale of the subject. Although the bubble was only about an inch and a half in diameter, I think this image makes it look very large, like an isolated dome in the middle of the Arctic Ocean. In the future, I hope to better understand the capabilities of my camera and become familiar with the ways that I can make my images better by adjusting settings. I also hope to accurately capture and represent physics and flow with my photography.

VI. References

Bradbury L, Goodman J, Murphy J (2008) http://www.appstate.edu/~goodmanjm/rcoe/hwr/science/dry_ice/dry_ice.html

Fitzpatrick, R (2007) http://farside.ph.utexas.edu/teaching/302l/lectures/node152.html

The University of Tennessee, Department of Physics and Astronomy (date unknown) http://labman.phys.utk.edu/phys221core/modules/m7/surface_tension.html