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Assisted by Grace Baccellieri

Flow Visualization Fall 2020

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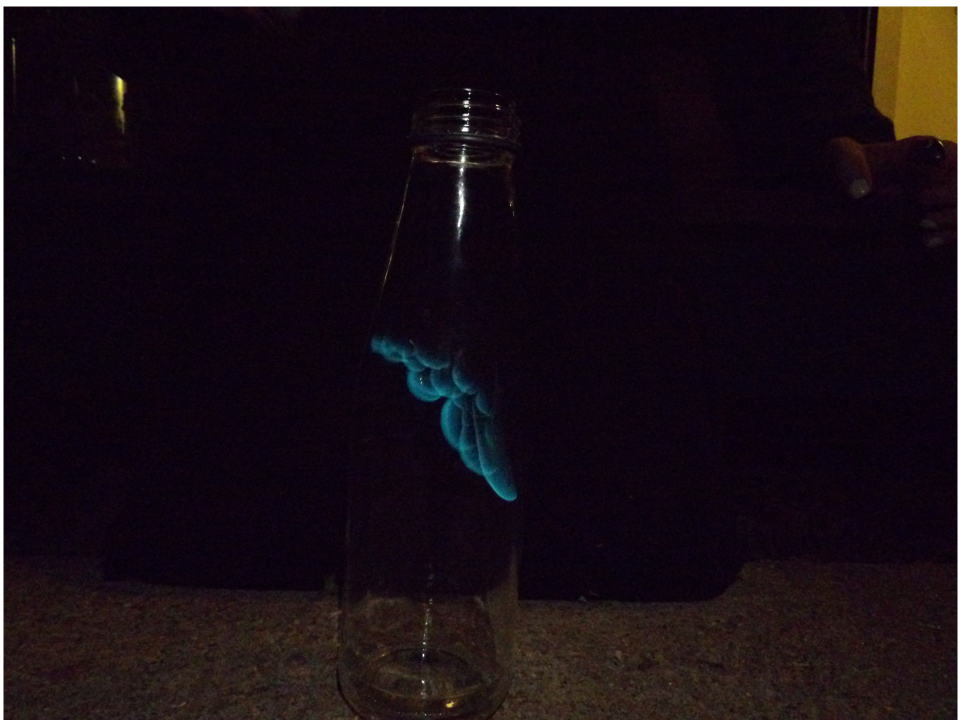
Image-Video 2



This image was submitted for our Flow Visualization assignment “image-video 2”. For my second assignment I decided to capture the flow of cellular flames. I took multiple images attempting to capture the phenomena (one example in figure 1) however I think this one best demonstrates the shape of the travelling flames while also being the most aesthetically pleasing. I could not express the shape of the flame single handedly so my roommate, Grace Baccellieri, helped me in order to produce my image.

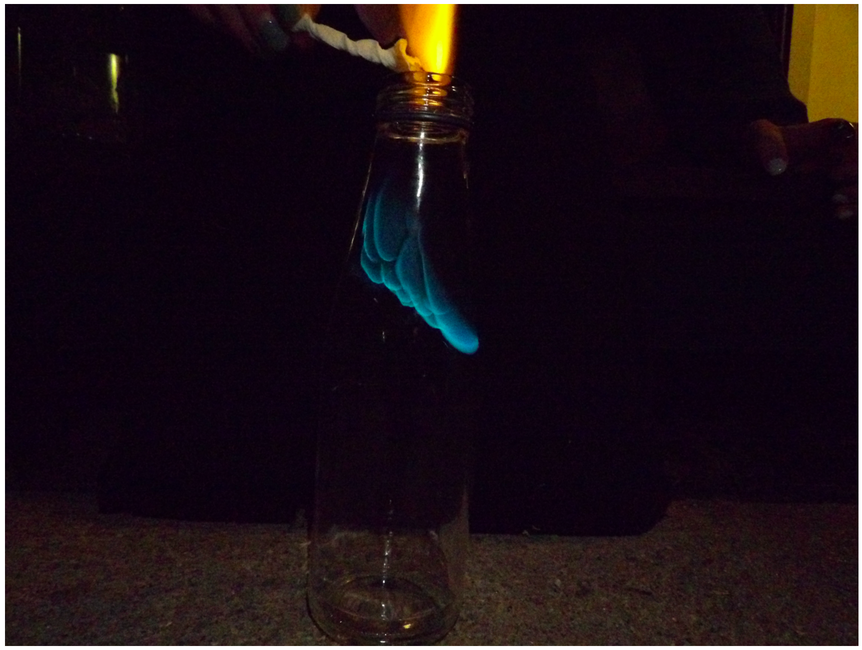


Figure 1

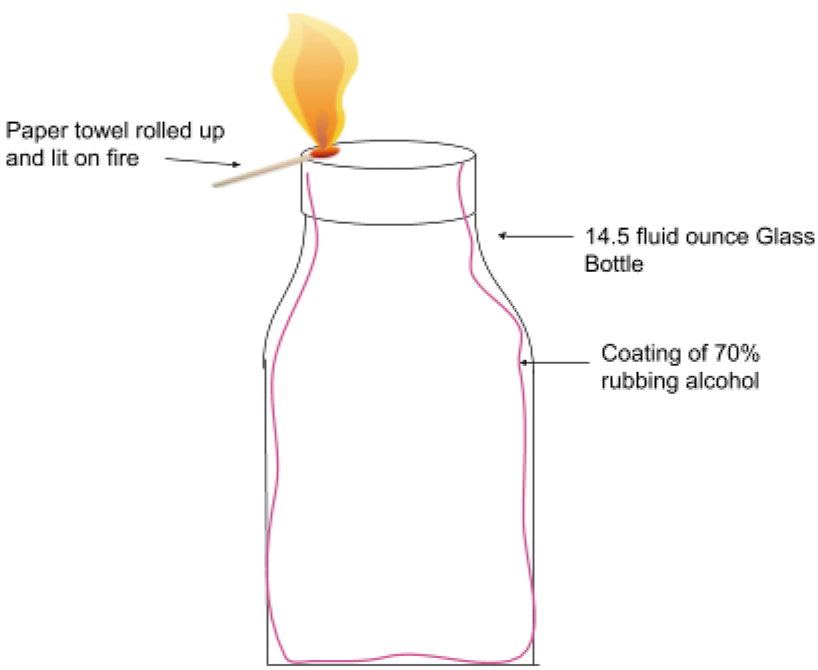


Figure 2

My apparatus is illustrated in figure 2, a detailed explanation is as follows. To produce a cellular flame I used 70% isopropyl rubbing alcohol, a 14.5 fluid ounce glass bottle that got narrower near the mouth, and a small controlled flame. Coating the inner walls of the glass bottle with 70% isopropyl rubbing alcohol makes an extremely flammable layer within the bottle. When the flame approaches the mouth of the bottle the rubbing alcohol combusts. The flame then travels down through the bottle as the walls covered in rubbing alcohol ignite.

Rubbing alcohol evaporates very easily, so it will change from a liquid to a gas at room temperature. Since the molecules in the rubbing alcohol evaporate so easily the small amount of rubbing alcohol used to coat the inner walls of the bottle will expand to a gas combining with the already present oxygen in the bottle creating a combustible environment. Once heat is introduced to the mouth of the bottle the gases in the bottle quickly catch flame and molecules fight to escape the bottle. The complete combustion of the isopropyl rubbing alcohol is $(CH_3)_2CHOH(g) + \frac{9}{2}O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$. According to the ideal gas law, $PV=nRT$ (where P is pressure, V is volume, n is the number of moles, R is the universal gas constant, and T is temperature), when gases are heated they increase in pressure and volume. So, when the heat from the paper towel rolled up and lit on fire meets the combustible gases the pressure increases in the bottle and molecules rush to escape out of the mouth of the bottle as the flame travels downwards (The Sci Guys, 2015). This particular experiment helps to demonstrate the phenomena of cellular flames because cellular flames can only occur “when a sufficiently light reactant of the combustible mixture is present in a low concentration” (Sivashinsky, 1977). The cellular flames seen in this image are unstable.

To produce the image seen above I used an empty 14.5 fluid ounce empty teavana bottle from Starbucks, approximately 1 teaspoon of 70% isopropyl rubbing alcohol manufactured by

Ready in Case, and a paper towel rolled up and lit on fire. After coating the inner walls of the bottle with a thin layer of the rubbing alcohol I set the bottle in front of a cookie sheet with a black shirt draped over it in order to create a black background on my porch. Next, my roommate, Grace Baccellieri, took the ignited paper towel and touched it to the brim of the bottle causing the gases to combust. The exact image I submitted for the assignment was taken at night so there was no natural lighting with a flashlight directed towards the bottle from the right side. The flash on my camera could not capture the cellular flames.

The original image was taken with about 6 inches between the lens and the bottle, this resulted in the whole bottle being in the field of view and in focus. I did have to turn the ISO on my camera up to 3200 in order to best capture the flame in the darkness. Before submission, I edited the photo in darktable so the crop was focused only on the flame, not on the whole apparatus. I also increased the vibrance of the image, softened the image, and worked to denoise the image.

My final image does capture the physics and phenomena of cellular flames in an interesting way. I love how you can follow the movement of the flames in the image and how as you scan the image from left to right the flames begin to elongate creating a fascinating shape. What I wish I could improve in the image is the clarity by capturing a less grainy version of this picture. Continuing research on the flow and physics behind this image has inspired me to consider using different percentages of concentration in the rubbing alcohol and changing the focus of my camera when working with flames.

References

The Sci Guys , director. *The Sci Guys: Science at Home- SE3-EP3: Whoosh Bottle*. 10 Feb. 2015, www.youtube.com/watch?v=xhAV2xbQOSo.

Sivashinsky, G I. "Diffusional-Thermal Theory of Cellular Flames ." *Combustion Science and Technology*, vol. 15, no. 3-4, 1977, pp. 137–145., doi:10.1080/00102207708946779.