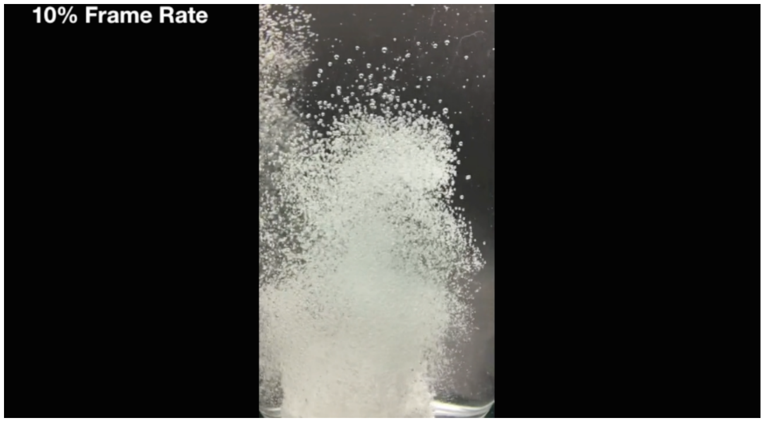



Final Group Project 3 Video: Effervescence created by Alka-Seltzer tablet and water, still from video located at https://vimeo.com/147673312

# 1 Purpose

This visualization is a part of the third Flow Visualization project, in which our group worked with a slow-motion camera to visualize various bubble-like phenomena. Due to the time commitment associated with working with the Olympus I-Speed camera, this project was created using an iPhone 6s and it's slow-motion capabilities. Our initial approach was to capture the reaction of a soap film when water droplets are dropped onto it's surface, but since the I-Speed proved to be more time consuming than we had initially thought, I changed the direction that I wanted to go with this project. My approach to this project was to visualize the reaction of an Alka-seltzer cold tablet as it was dropped into water and to visualize what happens during this reaction process, called effervescence. The lighting setup was achieved thanks to the help of my teammates Vincent Staverovsky and Yasmin Mazloom, with a special thanks to Yasmin for allowing us to use her studio as a facility for filming.

# 2 Flow Apparatus

The apparatus used to achieve the visualization was simply a glass cup filled with tap water at room temperature, which the tablet was then dropped into. The full reaction was allowed to progress from beginning to end where the entirety of the process was filmed. Otherwise, the physical setup consisted of several lights, specifically 3 40-watt fluorescent bulbs and 2 150-watt tungsten bulbs. The approximate placement of the lights is shown in the images below, essentially surrounding where the glass was placed. The glass of water was placed on top of a stack of 3 books and the iPhone was placed leaning against the edge of those books so that it could stand in place while recording with a direct, close-up view of the process.

Lighting placement for filming, with Olympus I-Speed from initial attempts, and approximate locations of lights shown

As mentioned previously, an Alka-seltzer tablet was the method by which the effervescent phenomena was created. This occurs by the method of a release of gas into the water once the tablet has been dropped into it. In general, antacids contain alkaline ions that neutralize the acidity of the stomach. This "alkalinity" directly defines the capacity for an aqueous solution to neutralize an acid, and is sometimes incorrectly classified as a measure of the basicity of a solution, which is not a true description of this measurement. It does not measure the same quantity as the pH (or basicity), though it is the stoichiometric sum of the bases in a solution. The antacid consists of baking soda for neutralizing the acidity (also known as sodium bicarbonate) and aspirin as a pain reliever, and produces $CO_2$ bubbles and water after the reaction. The chemical equation for this reaction is shown below. [1] It can be seen that the right-hand side of the equation is completely neutral, which is the overall purpose of the antacid.

$$3\,HCO_3^- + 3\,H^+ \longrightarrow 3\,H_2O + 3\,CO_2$$

The general physical process that is occuring is the diffusion of the baking soda tablet into the water in the form of $CO_2$ bubbles. Diffusion is described as a net movement of molecules from a region of high concentration to a region of low concentration, as described by Fick's Law which is shown in the equation below. [2] The equation is stating that the flux, $J$, of a system containing two separate types of molecules will tend in the direction of the negative gradient of the concentration, $\frac{-\partial \phi}{\partial x}$. This means that if a large concentration of one molecule is contained within a system of molecules of a different type, the diffusion will occur in the direction from high concentration to low concentration. They are related by the diffusivity, $D$, describing the rate at which this mixing occurs. The diffusivity of $CO_2$ in water is $D = 0.0016mm^2/s$ as compared to $CO_2$ in air which is 10,000 times that. [3]

$$J = -D\frac{\partial \phi}{\partial x}$$

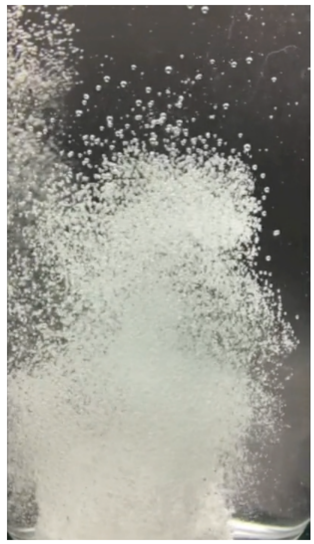
Initially, the reaction of the Alka-Seltzer tablet is occurring very rapidly and relatively large bubbles are forming from the antacid, and it can be seen through the progression of the video that the average bubble size then decreases and seems to approach a constant size over time. This can be attributed to the very fast rate of diffusion that is occurring in the beginning, which eventually reaches a steady state in the end of the video where the bubbles appear to be of uniform size. Another characteristic of the diffusion of the $CO_2$ bubbles into the water is that there are almost equal amounts of bubbles flowing upwards in the water as there are bubbles falling down in the water. This is still an effect of the diffusion of the $CO_2$ into the water, where less buoyant bubbles are displacing the more buoyant ones as the system approaches steady state.

# 3 Visualization Technique

The technique used to capture this image is known as the seeded boundary method and index of refraction technique. Since the water is clear, the white tablet and the emerging $CO_2$ bubbles are distinguishable once the tablet is dropped into the liquid. It is also an index of refraction technique since the video relies on the reflection of the light once it has passed through the liquid and reflected off of the surface of the bubbles to become visible.

## 4 Photographic Techniques

The glass cup was approximately 1 inch away from the camera lens while the video was filmed. Not as much metadata was readily available as compared to what is usually gathered from my point and shoot camera, as I was only able to gather the original size of the video which was 303x540 pixels, while the final video was 720x1280 pixels. Also, the frame rate that the iPhone 6s camera is capable of recording at is 240 fps, which was used on the iPhone during recording, and iMove was used to further slow down the playback rate of the video. The playback rate was manipulated to include moments of slow-motion (10%), regular (100%), and high-speed (400%) playback of the reaction. No color alterations or cropping were made to the original video, the video was actually increased in pixel size to include room for captions describing the playback frame rates that were being played. The original frame size is shown below.



Original video size still

## 5 Video Thoughts

This video reveals one of several physical phenomena that is not clearly visible with the naked eye. I decided to do this as my flow visualization out of curiosity after making an effervescent vitamin-C drink one day, and am happy with the results of the video and that I now know what causes this to happen. Having a prior interest in this phenomena ultimately increased my enthusiasm and interest in the topic, though I had hoped that our group had more success using the Olympus I-Speed camera and the project that we had initially set out to do. With that being said, we explored a range of topics and viewed them in slow motion which was a great experience for me. In the future I might explore different types of antacids and liquids to observe any variation in diffusion occurring in different mediums.

## References


[1] Rowland, Teisha. *Facilitator/Educator Guide: Plop, Plop, Fizz Fast: The Effect of Temperature on Reaction Time.* Science Buddies. `http://www.sciencebuddies.org/science-fair-projects/Classroom_Activity_Educator_Temperature_Reaction_Time.shtml` Accessed on: Dec. 11, 2015.

[2] *Fick's Laws of Diffusion.* Wikipedia. `https://en.wikipedia.org/wiki/Fick%27s_laws_of_diffusion`. Accessed on: Dec. 15, 2015.

[3] *Mass diffusivity.* Wikipedia. `https://en.wikipedia.org/wiki/Mass_diffusivity`. Accessed on: Dec. 15, 2015.