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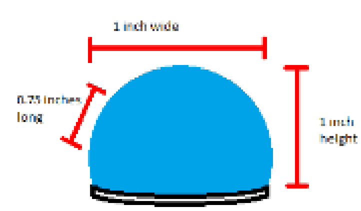
Flow Visualization
Get Wet Project
2/20/12

The image to the right is the original photo of an experiment involving Alka-Seltzer tablet and food dye in the production of bubbles. This type of flow shows the effects of difference in internal and external pressures on a liquid (food coloring) and the creation of bubbles. Surface tension is the force that allows the food coloring to expand as internal pressures increases and the outside pressure remains constant. This reaction when first conducted would stop before larger bubbles could be created because the dye would create a thick film over the tablet preventing it from dissolving the tablet. An Alka-Seltzer tablet is compressed aspirin (acetyl-salicylic acid) and sodium bicarbonate (baking soda) and normally these to react to one another and create carbon dioxide gases. However, in this compressed form the reaction cannot occur and water is normally used to dissolve the tablet and allowing the aspirin to react to the sodium bicarbonate. To increase the dissolving of the tablet more surface area had to be available for the dye to come in contact with.[1] To achieve more surface area the top of the tablet was scraped with a knife to create Alka-Seltzer powder on top of the tablet. By breaking up the tablet into powder increased the surface area and promotes the dissolving of the tablet allowing a reaction between the aspirin and sodium bicarbonate to increase. With the increased carbon dioxide production the larger bubbles seen in the picture were created by the dye creating a film that has a surface tension that can withstand the internal pressures (carbon dioxide production) and the external pressures (atmospheric pressure).



For the purpose of describing this flow only the largest bubble (the one circled in the above picture) will be used. The dimensions of this bubble are 0.75 inches long by 1 inch wide (diameter) by 1 inch in height. It will also be assumed that the bubble did not move during the photo time because it had reached internal and external pressure equilibrium.

The surface tension of the dye depends on the radius of the bubble and the difference in pressure exerted internally and externally, equation is below: [2,3,4]

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1 "Student Science Experiments." *Alka-Seltzer*. Bayer HealthCare LLC, 2012. Web. 21 Feb. 2012. <http://alkaseltzer.com/as/student_experiment.html>.

2 "Air Pressure in Bubbles [Soapbubble.dk]." *Soapbubble.dk*. Creative Commons BY-NC 2.5 DK Licens., 2008. Web. 21 Feb. 2012. <http://www.soapbubble.dk/en/bubbles/airpressure.php>.

3 Bush, John W. M. "Surface Tension Module." *Department of Mathematics, MIT*. MIT. Web. 20 Feb. 2012.

4 Clift, R., John R. Grace, and Martin E. Weber. *Bubbles, Drops, and Particles*. New York: Academic, 1978. Print.

$$\gamma = \ surface\ tension = \Delta P\ x\ R/4 = Pressure\ Difference\ x\ Radius\ of\ Bubble/4$$

During this particular experiment the bubble increased in size until the dye films integrity became compromised. The integrity can become compromised in many different ways and the evaporation of the water content within the dye is the biggest contributing factor. As the water molecules are removed from the dye film the overall strength is lost and as the internal pressure increases caused from carbon dioxide production the surface tension strength is lost. This will cause the bubble to burst at the exact moment the dye film loses enough of its resistance from internal pressure increase.[5] This photo was taken moments before the pressures became equal and can be assumed the internal pressure was still larger than the external pressures. The internal pressure is hypothesized to be 15 psi and the external pressure to be atmospheric pressure at 14.7 psi. Therefore the surface tension is found to be:

$$\gamma = \frac{(15\ psi - 14.7\ psi)\ x\ 0.5\ inches}{4} = 0.0.0375\ lbs/in$$

A dimensionless number to be able to describe the importance of surface tension compared to the gravitational body forces exerted on the bubble is the Eötvös number, also known as the Bond number, Bo:

$$Bo = \frac{\Delta\rho\ x\ g\ x\ R^2}{\gamma} \qquad g = gravity\ (32\ ft/\sec^2)\ \ \Delta\rho = density\ difference\ between\ fluids$$

The gravitational body forces in this case would be the fluid of the dye film onto the carbon dioxide being produced. In this case the dye film is going to be considered to have the same density of water at room temperature (62.30 lb/ft^3)[6] and carbon dioxide density will also be considered at room temperature (0.1150 lb/ft^3).[7] This particular bubble would have a Bond number of:

$$Bo = \frac{\left(62.30\frac{lb}{ft^3} - 0.1150\frac{lb}{ft^3}\right)\ x\ \left(32\frac{ft}{sec^2}\right) x\ (0.5\ inches)^2}{0.0375\frac{lbs}{in}} = 7.67$$

Having a Bond number greater than 1 indicates that the carbon dioxide is unaffected by surface tension effects[8], meaning carbon dioxide production can continue without being inhibited by the dye film. This is why the bubble is able to expand until the integrity of the dye film is compromised from water evaporation and the overall strength of the dye film is decreased.

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[5] Boys, C. V. *Soap Bubbles, Their Colours and the Forces Which Mold Them;*. New York: Dover Publications, 1958. Print.

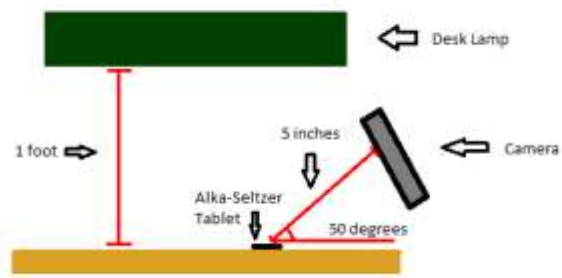
[6] "Water - Density and Specific Weight." *Engineering ToolBox*. Web. 21 Feb. 2012. <http://www.engineeringtoolbox.com/water-density-specific-weight-d_595.html>.

[7] "Gases - Densities." *Engineering ToolBox*. Web. 21 Feb. 2012. <http://www.engineeringtoolbox.com/gas-density-d_158.html>.

[8] Escobedo, Joel, and Ali Mansoori. "Surface Tension." *University of Illinois Chicago*. University of Illinois, May 1996. Web. 21 Feb. 2012.

The visualization technique to capture this flow was the use of dye instead of water was used to create a greater contrast between the background and the bubble. All materials were bought at the local grocery store, which include Alka-Seltzer tablets, generic food coloring, and plan white paper for the background. The Alka-Seltzer tablet was roughed on the upper surface with a knife and then placed onto a plain white piece of computer paper. Computer paper was used to allow a very vivid contrast between the blue food coloring and the background. The white shadow effect is along the bubbles closets to the computer paper, really shows how reflective the surface of the dye really well. Four drops of blue food coloring was then dropped onto the powder.

The camera lens was approximately 5 inches away from the tablet at a 50 degree angle. The light source was a desk lamp directly above and parallel with the Alka-Seltzer tablet's top surface and approximately one foot away. The lamp is a fluorescent 13 W bulb. The flash on the camera was disabled to prevent glare on the bubbles surface. The size of the field of view was approximately an area of 24 in^2.



The camera I used is a Pentax Optio WS80 digital camera with a focal length of 13 mm. This picture had a shutter speed value of 1/100 of a second and an Aperture Value of 4208673/1000000. The ISO setting is 320.

Original Image:

Width: 36428 pixels
Height: 2736 Pixels

Final Image:

Width: 3648 pixels
Height: 2736 pixels

In Photoshop the image was manipulated in the following ways:

- Color Balance:
  - Highlights:
    - Cyan-Red: -40
    - Yellow-blue: 38
  - Midtones:
    - Yellow-blue: 32
  - Shadows:
    - Yellow-blue: 30
- Levels Presets:
  - Increase contrast 1

These setting lightened the image and gave it a more unique color and allow the shadows and light glares all appear blue. It also helped drown out some of the reflectiveness of the surface so the camera and lamp didn't appear in the image as well.

I like how the image came out king of alien looking and if looked close enough other bubbles can be seen inside of the exterior bubbles. This caused the bubbles to have swirls of different shades of blue and was cool. However, this type of flow was very hard to explain and not a lot of it could really be seen because of how dark the blue dye was. If I had to repeat this problem I would try to either dilute the dye or use a lighter color to try and observe the chemical reaction of the aspirin and sodium bicarbonate. I also would have researched the equipment and steps necessary to calculate exactly what the internal pressure was inside of the bubbles. My really question is I guess I still don't fully understand this type of flow fully because it has so many different things going on. There was a chemical reaction and expanding carbon dioxide gas and a dye that combined with the powder created this blue film that allowed enough surface tension to create such large bubbles. There are lots of different forces acting from all sides as well because of the close vicinity of other expanding bubbles. It would have also been nice to calculate the rate of carbon dioxide production. My initial intent was just to create a unique image and I put less emphasis on the flow. To further the idea I would want to get more exact measurements and get a clearer visual of the exact forces and flows involved with this creation of bubbles.