Champagne Bubbles

The context of these images is to visualize the formation of bubbles in champagne, or any carbonated beverage. The purpose of the images captured is to understand how and why these bubbles form in champagne. According to Philip Ball, champagne bubbles “contain carbon dioxide, created in the fermentation process” [1]. Manufactures often dissolve large quantities of carbon dioxide in the liquid product they are trying to sell. As long as the container stays sealed and pressurized, the carbon dioxide remains dissolved in the liquid. Once the pressure is released, meaning the container is opened, the champagne becomes supersaturated, meaning that there is more of it in the liquid than can be contained. The second reference written by Gerard Liger-Belair et al. gives a much more scientifically rigorous explanation for the formation of CO_2 gas bubbles after the cork has been removed. After the initial pour into the glass and the initial fizziness goes away, there is usually a steady formation of bubbles (see Figure 1). According to Philip Ball, the “appearance is triggered or ‘nucleated’ only at certain points on the wall of the glass, where there is perhaps a tiny irregularity such as a scratch” [1]. Gerard Liger-Belair states that “the bubbles are released from the nucleation sites with clockwork regularity” [2]. Or in the case of the experiment here, salt was used as a nucleating agent for the carbon dioxide bubbles to form (see Figure 2). This phenomenon is the same as phenomena responsible for formulating a second phase in alloy solids, or raindrops nucleating in the region of dust particles in wet air.

Figure 1. Champagne No Salt

Figure 2. Champagne with Salt

The experimental essentials and their quantities are as follows: the glass container was filled with only two cups of champagne (the champagne was replaced after salt was dropped into the glass with a fresh 2 cups). Only one-quarter teaspoon of salt was dropped into the champagne (too much salt caused a lot of bubble formation and unfortunately too much confusion in the picture). The experimental setup was not too complicated (see Figure 3 below). The glass used to hold the champagne was three and three-quarters inches in diameter and had a height of four and three-quarters inches.

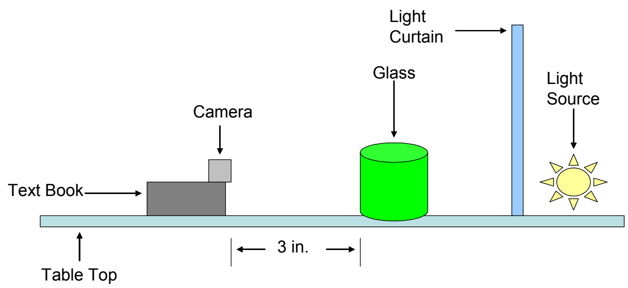

Figure 3. Experimental Setup

A white curtain was hung between the glass, and the two background lighting elements. The lighting elements were just two house hold lamps that had 150 watt light bulbs. The two lamps were offset horizontally by about 45 degrees on either side of the glass. The camera was resting on a book approximately three inches from the glass. Using these parameters, one could also calculate the growth rate of the bubbles as they ascend in the liquid. Using the appropriate mass transfer equations, Gerard Liger-Belair has documented the theoretical equation for the growth rate of the ascending bubbles by in champagne, which is represented by equation 1.

$$k = \frac{dR}{dt} \approx 0.63 \frac{k_B \theta}{P_0} D^{2/3} \left(\frac{2 \alpha \rho g}{9 \eta} \right)^{1/3} \Delta c$$

Equation 1. Bubble Growth Rate [2]

Where R is the bubble radius, k_B is Boltzmann constant, θ is the absolute temperature, P_o is the pressure into the bubble (assumed to be atmospheric), D is the diffusion coefficient of CO_2 molecules dissolved in the liquid, ρ is the density of the liquid, η is the dynamic viscosity, g is the acceleration due to gravity, α is a constant with a value close to 0.75 and Δc is the difference in CO_2 concentrations between a nearby bubble and the liquid bulk [3]. Through researching this I have found that there is actually a lot of documentation on bubble formation and bubble size in champagne because of the common belief that champagne with smaller bubbles will taste better (Some people have too much money).

Photographic Technique

For the image in Figure 1 (No Salt)

- Size of field of view: About 17.8 in^2
- Distance from object to lens: 3 in
- Lens focal length: 8.0mm
- Type of camera: Nikon Coolpix 4300 Digital Camera, (Resolution “HI”, 2272 x 1704 pixels)
- Exposure Specs: Aperture - F 2.8, Shutter Speed – 1/26.7, Focus – AutoFocus
- Photoshop processing: Cropping subject to fit frame

Image in Figure 2 (Salt)

- Size of field of view: About 17.8 in^2
- Distance from object to lens: 3 in
- Lens focal length: 8.0mm
- Type of camera: Nikon Coolpix 4300 Digital Camera, (Resolution “HI”, 2272 x 1704 pixels)
- Exposure Specs: Aperture - F 2.8, Shutter Speed – 1/30.3, Focus – AutoFocus
- Photoshop processing: Cropping subject to fit frame

This image reveals how dissolved carbon dioxide contained in champagne can easily be agitated into a gas phase by a foreign particulate, in this case salt. This phenomenon is the same phenomenon responsible for the formation of a second phase in alloy metals, why pure water freezes at a lower temperature than water that has minerals in it, and how raindrops nucleating in the region of dust particles in wet air. If I could do the experiment over again, I would definitely adjust the shutter speed to get a crisper, more precise location of where the salt grains and bubbles are located. After doing a little research, I believe that with a strobe, a little experimentation with the shutter speed, and a calculation of the speed at which the salt grains drop and the speed at which the bubbles ascend could help enhance the quality of the photo in Figure 2.

References

[1] Ball, Phillip. “Physics: Bottoms Up” **Nature Science Update** Wed. 3/1/2000. http://www.ericweisstein.com/fun/wine/news/000302-8.html.

[2] Liger-Belair, Gerard. Et al. “On the Velocity of Expanding Spherical Gas Bubbles Rising in Line in Supersaturated Hydroalcoholic Solutions: Application to Bubble Trains in Carbonated Beverages” **Langmuir** 2000, 16, pg. 1889-1895. http://pubs.acs.org/cgi-bin/article.cgi/langd5/2000/16/i04/pdf/la990653x.pdf

[3] Liger-Belair, Gerard. Et al. “Diffusion Coefficient of CO_2 Molecules as Determined by ^{13}C NMR in Various Carbonated Beverages” **Journal of Agricultural and Food Chemistry** 2003, 51, pg. 7560-7563. http://pubs.acs.org/journals/jafcau/51/i26/pdf/jf034693p.pdf