

This is the first assignment and is intended to introduce the concept of Flow Visualization. The intent of this image was to visualize the interaction between liquid and gas. For this image, solid Carbon-Dioxide (also known as Dry Ice) was placed in a tank of liquid water. The Dry Ice sublimates and CO₂ gas bubbles are formed around the solid, release, and head toward the surface of the water. The original intent of the image was to visualize the CO₂ gas on the surface of the water, however, it proved much more difficult to get the correct lighting than anticipated so the focus of the photograph turned to the bubbles of CO₂.

The flow was set-up according to Figure 1. A piece of Dry Ice approximately 7 cm in diameter was placed in a tank containing liquid water.

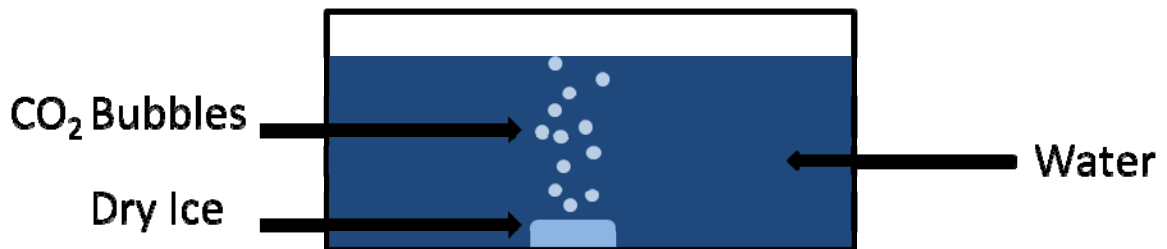


Figure 1: Flow Set-Up

The reason that Dry Ice sublimates can be explained using Figure 2. Although not measured directly, the pressure of the water at the bottom of the tank can be calculated by determining the force of air and water acting upon the surface of the Ice and finally divide by the area of the Ice.

Assuming that the water depth is 0.4 m, the area of the ice is 0.005 m², the air pressure is 101.3 kPa, and the density of water is 1000 Kg/m³, the pressure acting on the Dry Ice is 105.3 kPa according to $P_{Ice} = P_{air} + \rho_{water} gh$ Equation 1 [1].

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From the phase diagram in Figure 2 it can be determined that at a pressure of 1 atm (about 101 kPa), the CO₂ changes phase directly from solid to gas.

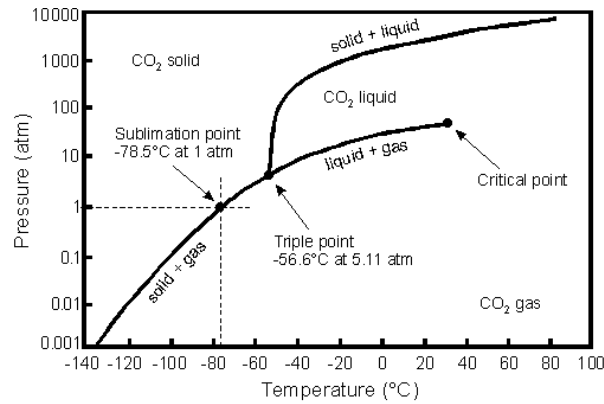


Figure 2: Carbon Dioxide Phase Diagram [2]

As the solid CO₂ sublimates, it forms bubbles which contain both CO₂ and water vapor (seen as the fog inside the bubbles in Figure 3).

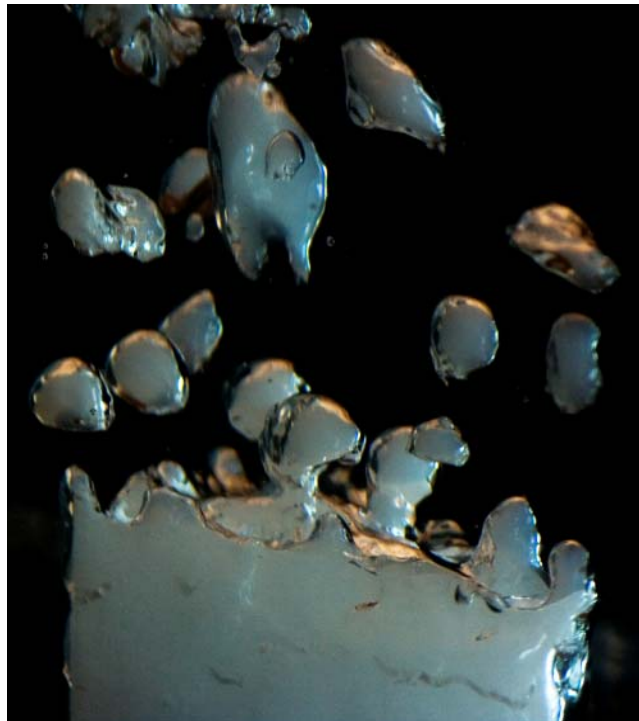


Figure 3: CO₂ Bubbles form from Dry Ice

To visualize this phenomenon, a fish tank was used to hold the volume of water. The camera was positioned above the plane of the ice at a slight downward angle in order to photograph the top of the ice as well as the fluid around it. Two different lighting set-ups were experimented with. The first was two fluorescent bulbs placed directly above the tank. With this set-up the shutter speed required to remove motion blur produced a drastically underexposed image. To remedy this, a compact florescent bulb was placed on the side of the tank and directed at the ice.

The camera used for this photograph was a Canon Digital Rebel XT with a 28-200 mm 1:3.5-5.6 lens. The image was taken at a focal length of 200 mm with an ISO setting of 400, a shutter speed of 1/800 of a second, and an aperture value of 5.6. The unedited picture was 3456 x 2304 pixels, and the final picture is 2046 x 2304 pixels. The distance across the wide axis of the final image is approximately 8 cm and the distance from the object to the lens was about 80 cm. The image was cropped in Photoshop and the contrast of the photograph was increased using "Curves."

This image shows the complexity of the CO₂ sublimation in water. The most interesting quality of this picture is the bubble which have not yet separated from the surface of the Dry Ice. This picture successfully displays the complexities of the gas/liquid interactions. In the future, more light should be used in order to either decrease the ISO setting (reduce the noise in the picture) or increase the shutter speed (further reduce motion blur).

References

[1] Pressure Calculation, <http://hyperphysics.phy-astr.gsu.edu/HBASE/pflu.html>

[2] Carbon Dioxide Phase Diagram

http://scifun.chem.wisc.edu/chemweek/CO2/CO2_phase_diagram.gif