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Freezing Time: An Observation of Super Cooled Water Freezing with a High Speed Camera

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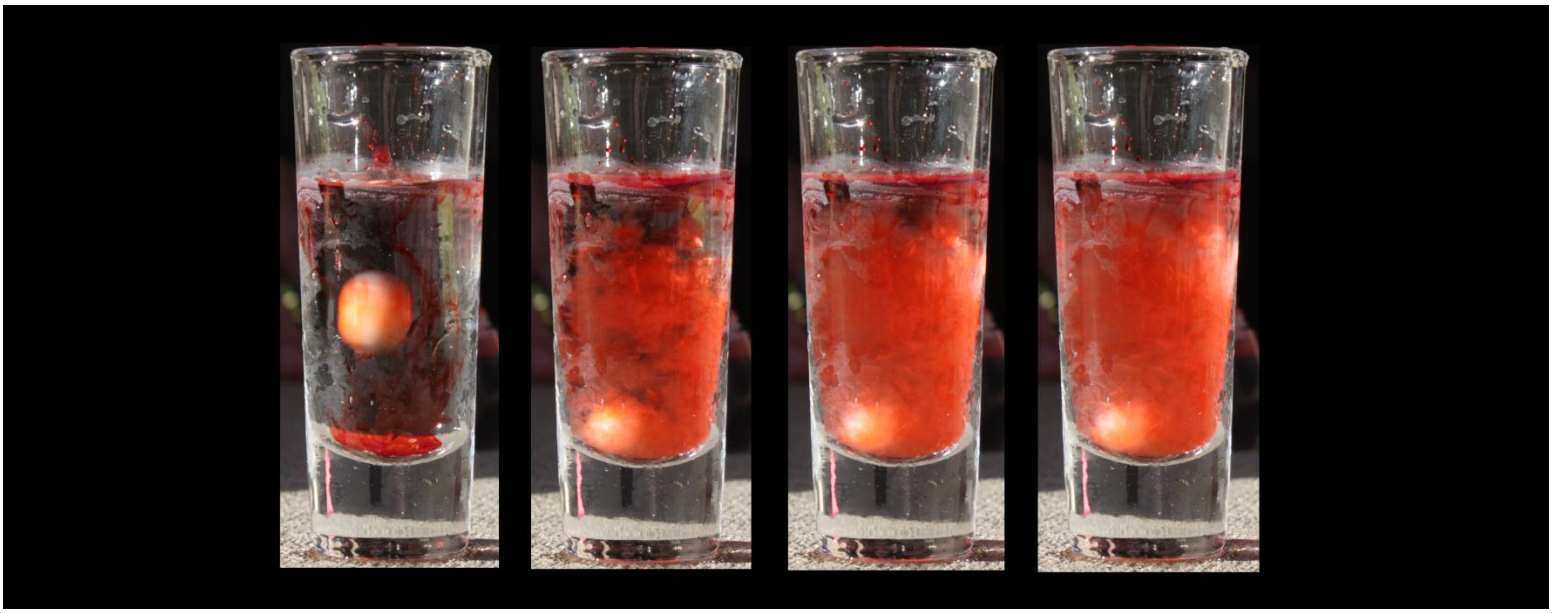

Introduction

To know exactly what is meant by the term "Supercooled", the term must be defined before introducing the entire project. Supercooling, or more commonly referred to as undercooling, is the lowering of the temperature of a liquid beyond the freezing temperature and still maintaining a liquid form.[1] Looking to the title, it can be seen that water was the liquid used for this experiment. Water's freezing temperature under a pressure of one atmosphere is approximately zero degrees Celsius. It is known that most water freezes at this temperature, so a specific type of water was needed in order for this phenomenon to occur in an experimental environment. Liquids freeze at their freezing temperature when there are imperfections present that imposed an ordering of the liquids atoms which cause the atoms to arrange themselves in a crystalline structure. [1] This process is commonly referred to as nucleation. Without these imperfections, it becomes more difficult for nucleation to occur in the respective liquid. Common imperfections in regular tap water consist of various types of minerals and chemicals which were presented to the water either naturally or through filtration processes. In order for the undercooling of water to occur, a type of water with very few imperfections was needed. Distilled and deionized water was used for this experiment. The following provides an explanation of the experimental setup so that the reader can enjoy the experiment for themselves.

Image Setup/Procedure

As discussed earlier, distilled and deionized water was used for this experiment because of the significantly less amount of imperfections in the water. In order to drop the liquid below its freezing temperature, a reliable cooling source was needed. The cooling source needs to drop the temperature low enough so that the liquid can undercool, but not so low that the liquid eventually freezes. When the temperature of the liquid is dropped far enough beyond the freezing point, nucleation will occur and the liquid will rapidly freeze into solid form.[2] This is most commonly referred to as recalescence. A salt-water ice bath was used as the cooling source because of its ability to maintain a low temperature and be easily monitored. Salt lowers the freezing temperature of water. This provided a uniform subfreezing temperature for the distilled water. For most of the supercooled crystallization experiment trials, shot glasses were used. The shot glasses were covered so that no impurities would be introduced to the distilled water while sitting in the open salt-water ice bath. The glasses sat in the ice bath for approximately 15 to 25

minutes depending on the temperature of the salt-water bath and the size of the shot glass. Fig.1 presents a visual representation of the experimental setup.

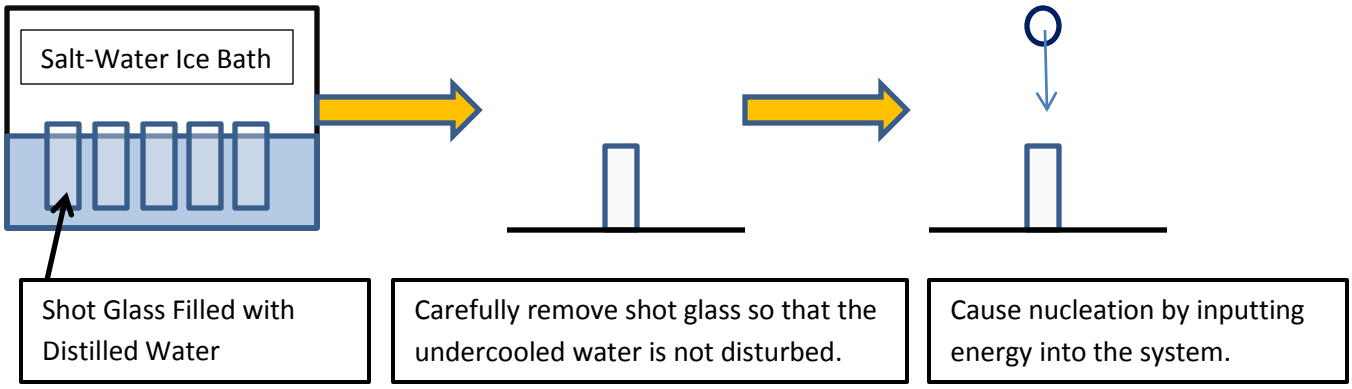

Figure 1: Visual representation of the experimental setup and procedure.

In order to determine if the distilled water is cold enough to induce rapid crystallization, it is suggested that a shot glass filled with tap water is placed in the saltwater ice bath. When the tap water freezes wait about five minutes then remove the distilled water samples. In order to cause crystallization in the distilled water, an abrupt input of energy needs to be imposed on the water. The best way to do this is to disturb the distilled water by moving the glass. The disturbance in this image was introduced to the water by dropping a marble into the shot glass. The distilled water crystallized at a very rapid rate as seen in the image.

Discussion

For this project, two of the team members, Daniella and Scott, used a high speed camera to capture the crystallization process. They filmed the phenomenon happening over a period of two seconds at a frame-rate of 1000 frames per second. The crystallization is better represented visually by this method of filming. After taking multiple pictures and carrying out the experiment numerous times, it can be noticed that the rate of crystallization was different for all the trials. According to experimentally derived literature, the greater the under cooling of water, the greater the velocity of crystallization.[2] This was definitely noticed in one trial where it took the water over eight seconds to fully crystallize in the shot glass. This obviously means for that trial that the water was barely under the freezing temperature of zero degrees Celsius. It should be noted that a substantial amount of energy is needed in order to onset the crystallization of the distilled water. Food coloring was dropped into the shot glass around three feet above the

surface of the water and no crystallization occurred. This experiment is very easy to carry out and almost takes no time unless it is planned to use a high speed camera to capture the phenomenon.

Camera Setup

Camera – Canon EOS DIGITAL REBEL XSi
Distance from focus to lens – Roughly 2 Feet
Focal Length – 35mm
Exposure Time – 1/800 seconds
Aperture – Not Sure
Sensitivity – Not Sure
Image dimensions – 5000 x 1948
Field of View – Approximately 3 Feet
Flash – No Flash

Image Processing

Four images shot roughly 0.2 seconds apart in time were cropped of their originally setting and inlayed on a black background together. The time sequence is in order from left to right.

References

[1] Undercooling of a Liquid, http://www.webcitation.org/5mjJauR7S

[2] Boris Weinberg, The Crystallization of Undercooled Water, Phys. Rev. (Series 1)27,509-510(1908)