Hydrogen Bubble Formation

Group Members: Eric Stahl, Jade Jauquet, Vien Nguyen
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Background

The primary purpose of this project was to generate hydrogen bubbles by performing electrolysis reaction of water. A brief background on electrolysis reaction is discussed before introducing the details of experimental set up.

In any electrolysis reaction, there needs to be a cathode and an anode end in order to produce electricity. During the electrolysis reaction, the water is actually splitting into hydrogen and oxygen molecules (1). When the current is applied to the electrolysis unit, the electrons on the cathode end will combine with the water, causing each water molecule to release one hydrogen atom. These hydrogen atoms are combined to form hydrogen bubbles and leaving negatively charged ions of hydroxyl group (OH^-) behind (2). Equation 1 represents this chemical reaction.

$$2H^+ + 2e \rightarrow H_2 \qquad (1)$$

Since hydroxyl groups are negatively charged, they are repelled by the cathode end and then migrated towards the anode end to undergo a different reaction. The hydroxyl group converts to the oxygen bubbles at the anode end according to the following equation (2).

$$2OH^- \rightarrow \frac{1}{2}O_2 + H_2O + 2e \qquad (2)$$

Figure 1 below represents a simple diagram of the electrolysis system. This figure also shows where the hydrogen bubble formation occurs in the system. It is important to add salt to the electrolysis system because salts are electrolytes, and these electrolytes are required to initiate the electrolysis reaction (2). Once the current is no longer presented in the electrolysis system, the hydrogen atom and hydroxyl atom can recombine to form water. With these basic knowledge on hydrogen bubble formation, the following section is going to describe the experimental details.

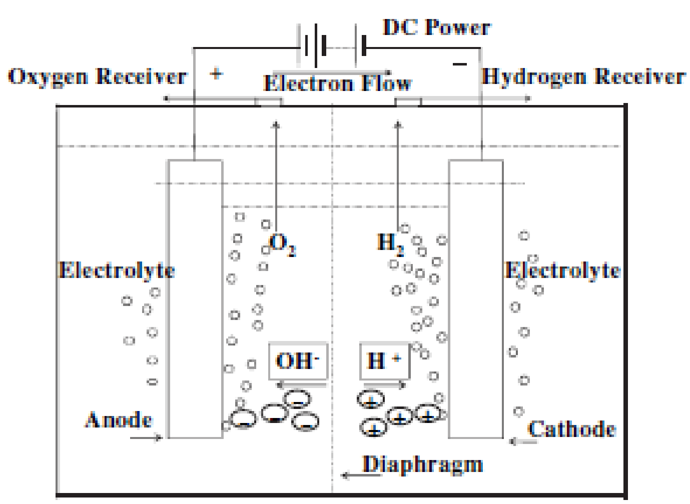

Figure 1: A schematic illustration of a basic water electrolysis system (2)

Experimental Set Up

Our experimental set up consisted of platinum wire which represents the cathode end, a piece of metal sheet (anode end), DC power supply, sodium chloride as electrolytes, and water. The electrolysis reaction was carried out in a fish tank. The distance between the anode and cathode ends was about 1 foot. We also used a water pumping system in order to examine how the flow would disturb the rising of hydrogen bubbles. Figure 2 below shows the basic set up of our experiment.

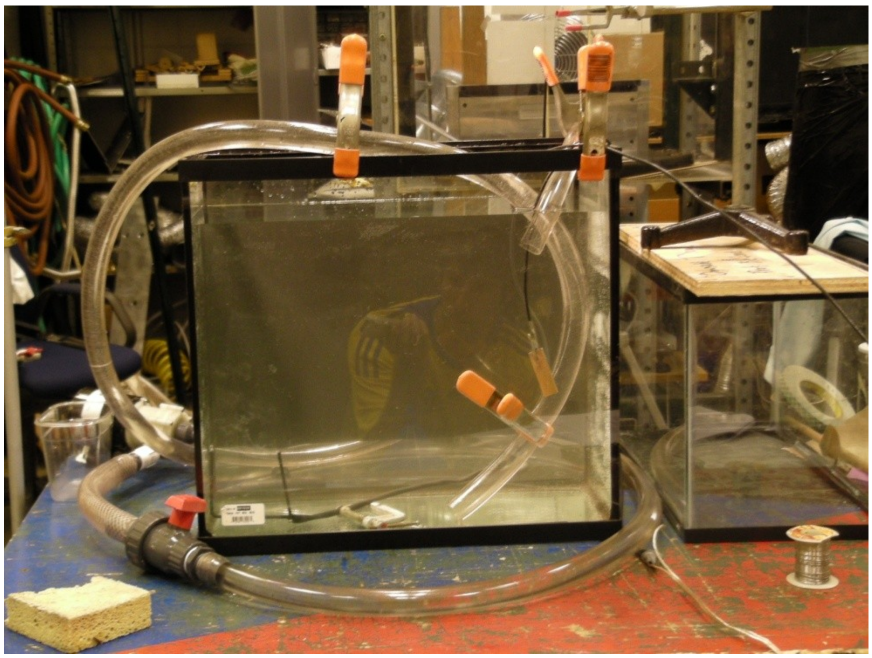

Figure 2: Experiment Set Up

Discussion

Hydrogen bubbles are created by electrolyzing water. A complete circuit was created in the tank by using a platinum wire acting as the cathode and a copper plate acting as an anode. Salt is added to increase the conductivity of the water which is desired to create visible hydrogen bubbles. The images were produced by varying the voltage levels of the circuit. The voltage was varied based on the photographer preference but was in the range of 0-40 Volts. Any voltage above 1 Volt produced small hydrogen bubbles that were formed at the cathode because the hydroxide ion is stripped from the H20 molecule leaving the remaining visible hydrogen ions (3). The speed of the bubbles was approximately 0.2ft/sec. At higher voltages the speed of the bubbles approached 0.5ft/sec.

Once the hydrogen bubbles were formed, they started to rise to the top surface of the water. The primary reasons for this behavior are due to the buoyancy force and the difference in density. The density of hydrogen gas is approximately 0.0899 kg/m^3 which is 10,000 times smaller than the density of water and this is why the bubbles could continue to rise in water (4).

Visualization Technique

We used hydrogen bubbles to track the flow of the water as it circulated around the tank. The bubbles them self provided no flow, they were only a means of seeing the flow of water throughout the tank. A small water pump was set up to circulate water around the tank. This was used during some of the filming, but a number of photos and video clips were taken while the pump was off. During these times the flow observed was the rise of hydrogen bubbles through the water, and how they interacted with the water. Horizontal movement of the flow was observed using selective lighting, as described below. Because a true flow phenomenon was not being tested, this would be the best part of our project, seeing how light can be used to best show a flow.

By using the light very specifically it allowed us to see how the bubbles were moving in 3D space, with relation to the camera. When the light was flooding the tank all the bubbles were rising to the top, however when we limited the amount of light we were able to see how the bubbles were moving forward and backward, right and left as well as how they were going up.

Photographic Technique

The camera we used was a Canon 7D with a 28-135mm lens on it. The average ISO was 3200 and the average f/stop was 5.6. For the still photos the shutter speed was 1/60th of a second, the shutter speed for the video was also 1/60th of a second. The video was captured in a compressed H.263 HD, and the photos were captured as 5184x3456 raw files. The light used was a single 500 wt light shined through the side of the fish tank. For most of the shots and the video's this was the lighting used. However for the part of the video that showed the different layering of the rising bubbles the light was shined through a then slit in a piece of black paper. This caused the light to only hit the bubbles within the plane of light. As the paper was moved back and forth it showed the different horizontal movement the flow had as the bubbles raised through the water.

Conclusion

The reason we chose to photograph hydrogen bubbles is because it has an interesting look. The hydrogen bubbles in water closely resemble smoke in air at times, while keeping some properties of air bubbles in water. This creates an interesting effect that can be quite beautiful at times. Having additional cathodes in the water could have added another dynamic to the concept. The team feels that we have properly demonstrated the visual appeal of this interesting flow visualization technique.

Works Cited

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