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MCEN 4151: Flow Visualization
30 November 2016

Team Second – 2016 Report

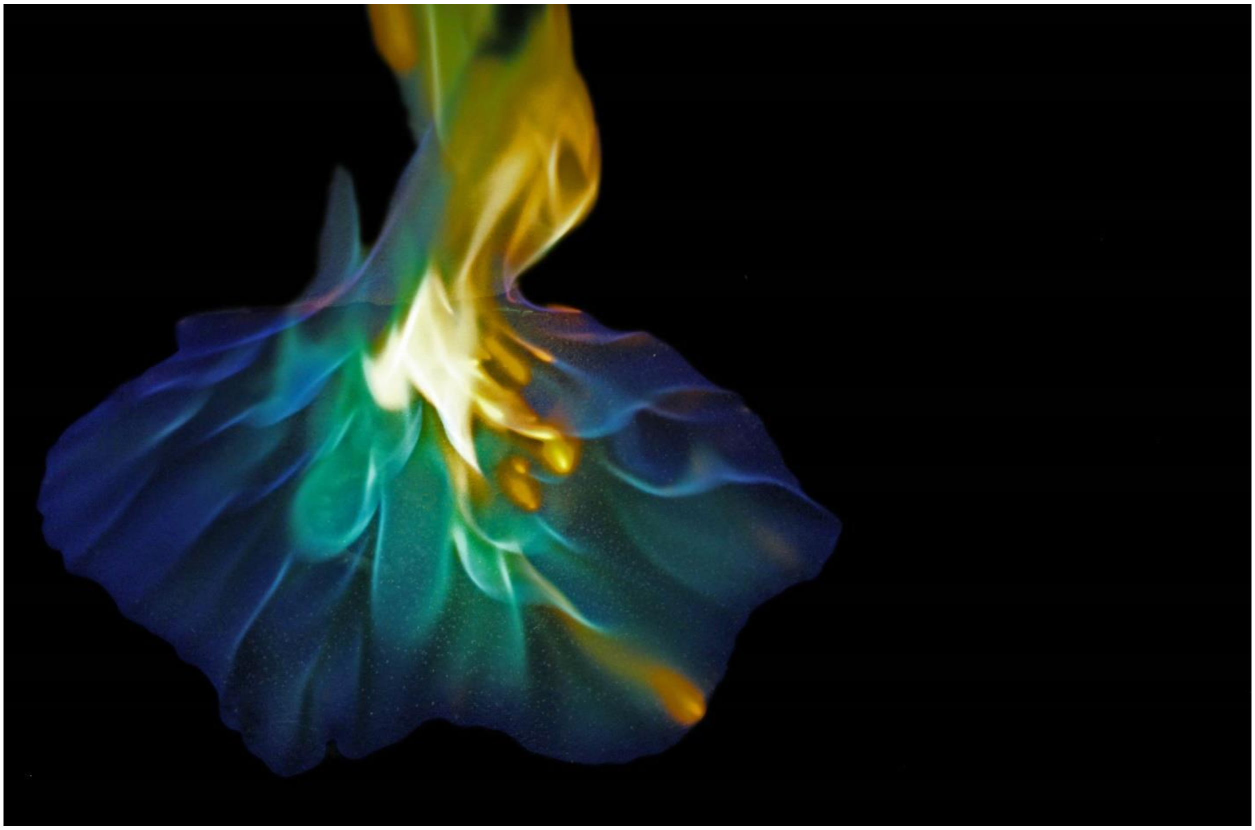

Figure 1: Second Team Image

Image Context

For the image shown in Figure 1, the team consisting of myself, Ryan Daniels, Joey Hall, and Schuyler Vandersluis were aiming to capture green fire. We used Boric Acid, found in rat poison, to give the green color when added to methyl alcohol which produced the blue fire. Some grains of salt were added during experimentation to give the orange flames. This image shows how different molecules emit different colored light, and a first look at the image shows a cool phenomenon where the flame is spread low on the ground but pinches into a natural chimney.

Flow Apparatus

Fire color is dependent on the elements present in the flame. The base of the fire in this experiment is blue and reaches up into orange colors as is typical of common flames in which we see that are created by alcohols and other hydrocarbon compounds. The color from the base of alcohol is representative of the temperature of the flame, and as the soot which is being given off by the reaction travels up, the color will change according to the level at which the majority of particles are being excited to (Douma, 2008). The way flame colors can be created and we did so in this experiment is based on a typical science experiment called a flame test. Flame tests are meant to determine the presence of an alkali or metal in an unknown substance based on the known emission spectrum for an element. The heat from burning the alcohol provides energy to excite electrons into a higher energy level, but when they fall back to their ground state they emit the energy absorbed as light at a specific wavelength corresponding to the change in energy from their excited to ground state. This is visualized in Figure 2 from *Causes of Color*:

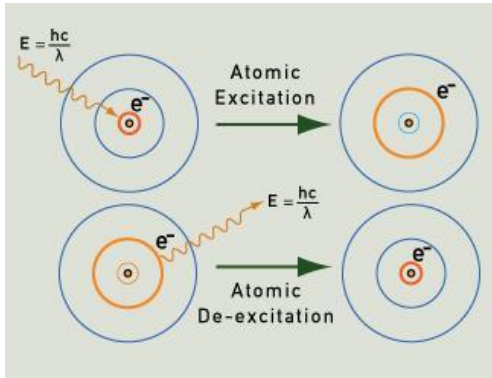

Figure 2: Excitation of Atoms and Emitted Light (Douma, 2008).

In order to capture the green fire, we used boric acid for the presence of Boron atoms. Figure 3 from Web Mineral shows the emission spectrum from boron along with its apparent color.

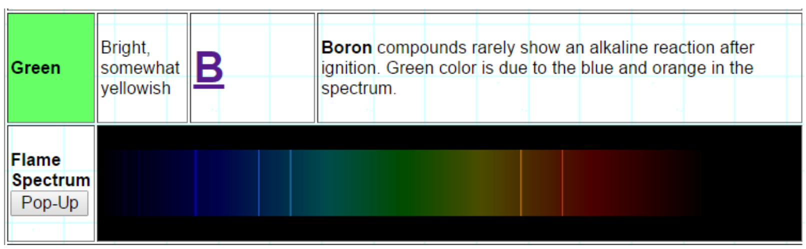

Figure 3: Boron Emission Spectrum (Web Mineral, n.d.)

The result of the highlighted colors created a flame with a yellowish green appearance, though the yellow combined with the blue flame from the alcohol made the resulting flame much more green. While it was not the original intention to have anything but green flame, some table salt consisting of Sodium Chloride was added. Sodium has a yellow emission, but in this experiment the flames appeared to flare up orange as where the sodium atoms were present (Web Mineral, n.d.).

As mentioned prior, the image shows a widespread flame at the base which converges into a central flame reaching upwards. This occurrence can be explained using the stack effect, an effect commonly used for building ventilation and design (AutoDesk, n.d.). The phenomenon uses the buoyancy of air based on temperature differences. It is commonly known that hot air rises, and for ventilation this effect within a building draws cool air through the lower levels as hot air escapes through upper levels. While the flame in this experiment is on a scale much smaller than that of a building for which the stack effect affects design parameters, we can still look at it on a micro scale. If we treat the base of the flame as a circle, the it is likely that the hotter flames will be towards the center since they are surrounded by other flames whereas the closer the flame is to the edge of the radius it has more ambient air. The increasing temperature gradient toward the center would make the center hot air rise quicker than the adjacent air not quite as hot. When the air rises, it pulls surrounding air in to fill lower pressure according to the Bernoulli Principle left by the hotter air which moved out quicker than the surrounding air (AutoDesk, n.d.). This is repeated across the radius of the flame such that lower levels of flame are pulled in as the flame increases in height. This could account for the U-shaped sections of flame present in the image which are similar to the concave base of a flame on a match as the surrounding air is pulled upwards with drag on surrounding molecules. The above described buoyancy is shown in a cross-sectional sketch in Figure 4.

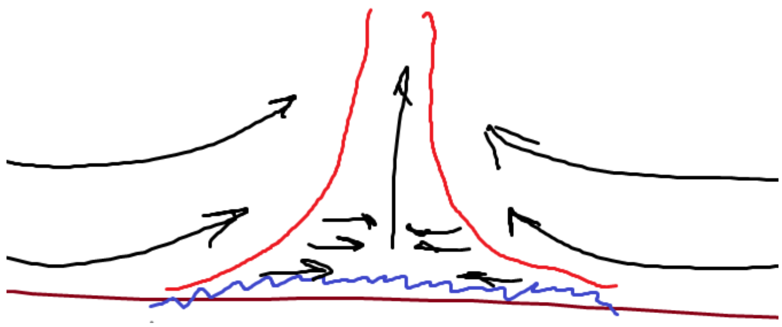

Figure 4: Cross Section of Flame Buoyancy

Visualization Technique

To visualize the effects of additions to the methyl alcohol induced fire, boric acid and table salt were used which contain the Boron and Sodium elements, respectively. These produced the colors on display. First, some methyl alcohol was poured onto a concrete pad, and then some of the boric acid was sprinkled in the wetted area. Next, the alcohol was lit on fire, and as photos were being taken, another team member sprinkled some salt to give the orange flare-ups as seen in on the bottom right edge of the flame. Due to the nature of trying to capture a flame, the images were taken in a well ventilated outdoor setting with a dark background. The photos were shot at night with a cardboard box to block lights and cast a dark shadow over the experiment area so the flames would be the only source of light.

Photographic Technique

The original photo shown in Figure 5 was 5184x3456 pixels shot on a Canon EOS Rebel T3i. The field of view is about 12 inches with an aperture of f/3.5, shutter speed of 1/40 sec, ISO of 800, and focal length of 18mm. The image was processed in Adobe Photoshop and cropped to a final size of 4240x2792 such that the flame is positioned using the rule of thirds. The image was first adjusted according to the curves diagram in Figure 6 which increased the vibrancy of the colors and made the blue boundary flames more visible. Next, the selection tool was used to select only the background and the curves were dropped according to Figure 7 such that the background became black.

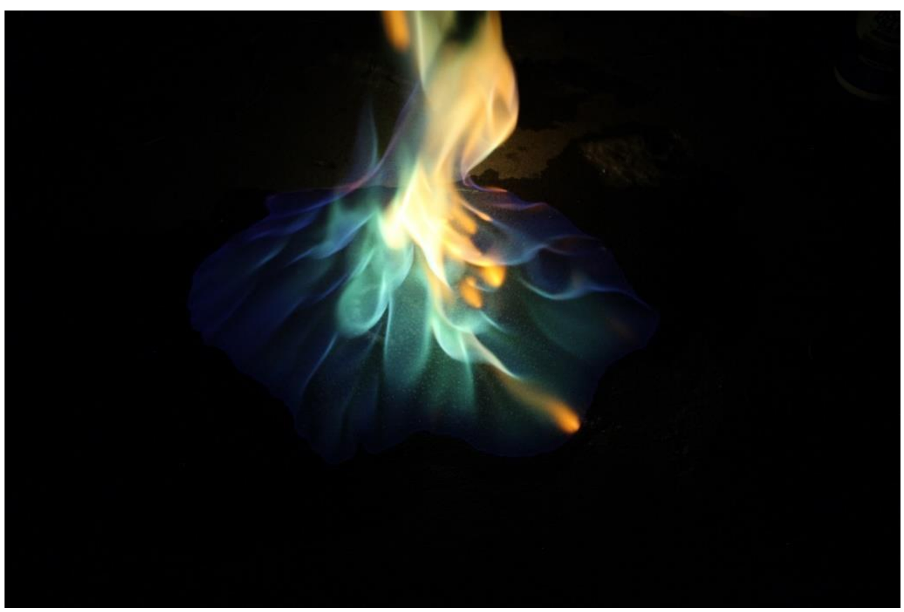

Figure 5: Original Image

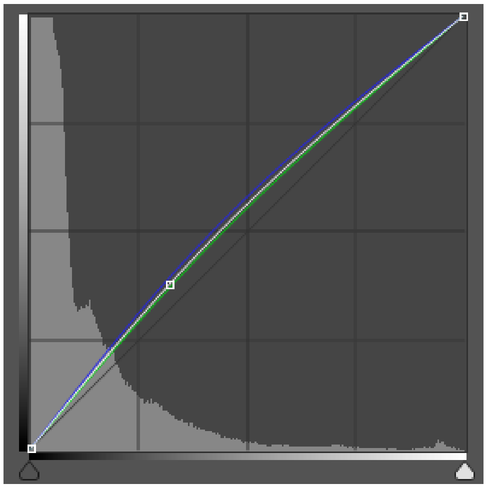

Figure 6: Color Adjustment Curves

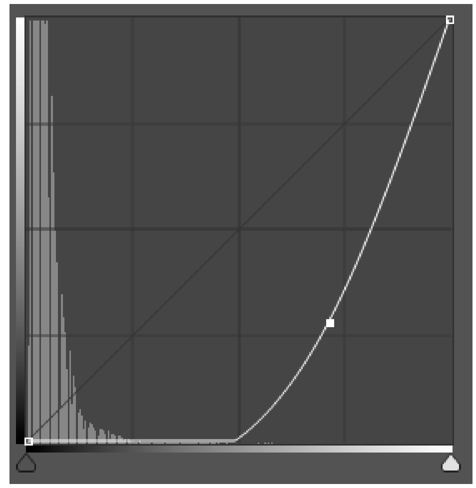

Figure 7: Background Curve

Conclusion

In conclusion, this experiment exemplifies the effect of atomic energy levels on light emission which can be used to create artistic flames not typically observed unless conducting a science experiment. In addition, an interesting phenomenon due to natural buoyancy was observed in the process. If the experiment were to be repeated, I would like to change the background since there is a light section outside of the flames permitted that is observed behind the flames reaching upwards that I was unable to edit to black. I do like the texture of the concrete within the foreground of the flames, but the background is slightly distracting. I think trying other elements would also be cool to make other colored flames and even combining more together for a rainbow flame. Having a larger fire to create brighter flames might also be worthwhile experimenting with so that the shutter speed could be increased for better resolved flames. In the end, this image went beyond the original intent, so I am pleased with the outcome.

References

AutoDesk. (n.d.). *Stack Ventilation and Bernoulli's Principle*. Retrieved from AutoDesk Sustainability Workshop: http://sustainabilityworkshop.autodesk.com/buildings/stack-ventilation-and-bernoullis-principle

Douma, M. c. (2008). *Flame Tests*. Retrieved from Causes of Color: http://www.webexhibits.org/causesofcolor/3BA.html

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