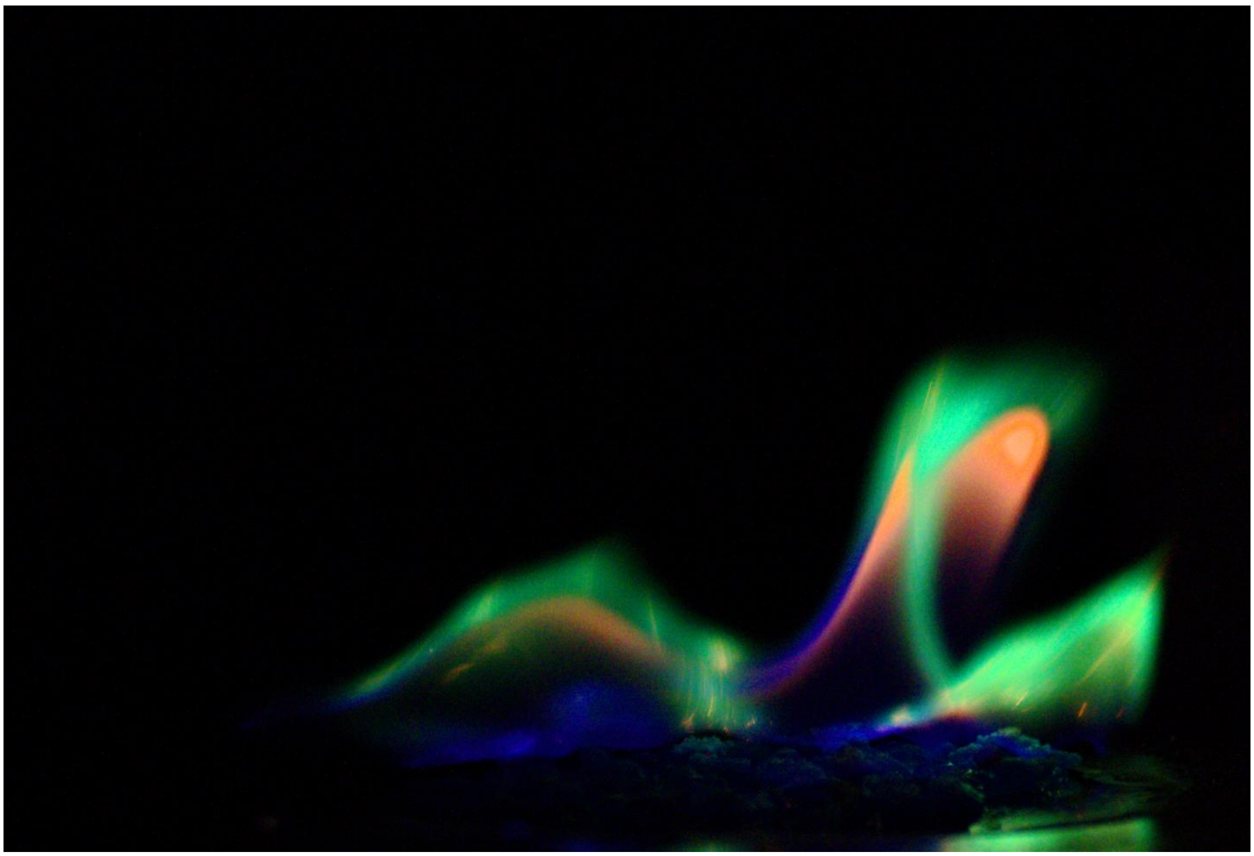
Group Project #2 – Burning Copper(II) Sulfate



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Team Delta: Doug Schwichtenberg, Andrew Fish,

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MCEN 4151

Professor Hertzberg

3/20/2012

Purpose

The purpose for this visualization was for the “Group Project #2” assignment assigned in the Flow Visualization course given at the University of Colorado – Boulder, led by Professor Hertzberg. The goal of the “Group Project #2” assignment was to display the physics of fluid flow in both an experimental and artistic way. It was my intent to display the intricate green colored flame that results from burning copper(II) sulfate pentahydrate.

Team

For this assignment, I was assigned to Group Delta, consisting of the following members:

1. Ryan Kelly
2. Andrew Fish
3. Doug Schwichtenberg
4. Nicholas Travers
5. George Seese

Materials

For this representation, the team chose to use several materials that can be easily found at a local hardware store. This was done to allow the reader an easier way of replicating the team’s results for future endeavors. The materials were as follows:

1. Roebic K-77 Root Killer (99% Copper(II) Sulfate Pentahydrate)
2. Good Sense 70% Isopropyl Rubbing Alcohol
3. 6” diameter steel dish/bowl
4. Flame source (Scripto lighter)
5. Fume hood
6. 4’length x 3’height black background
7. Canon EOS REBEL T2i DSLR Camera

Procedure

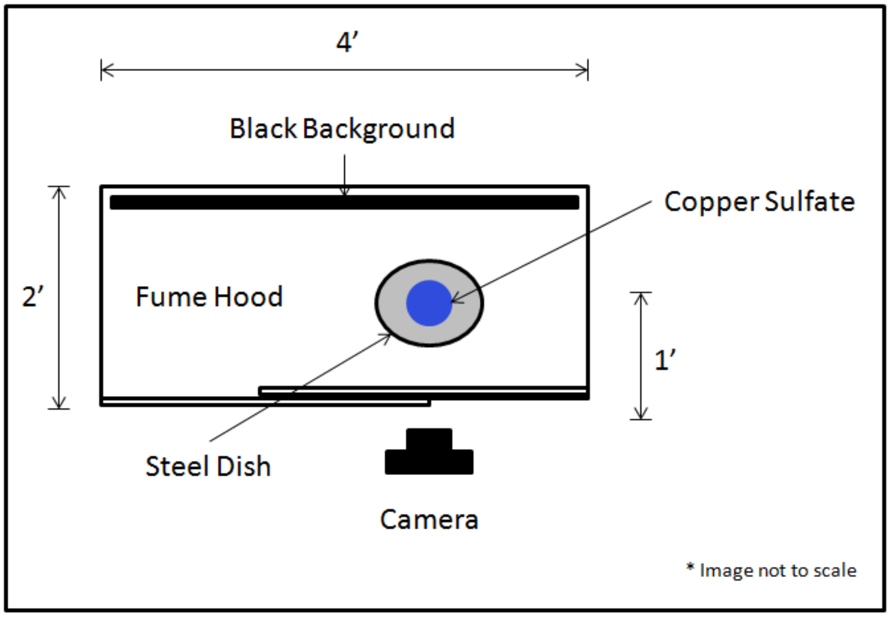

Figure 1: Experiment Setup

The full experimental setup can be seen in Figure 1 above. To setup this experiment, the team placed the steel dish in the fume hood located in the basement of the ITLL, placing the dish upside down so that the flat bottom of the dish was facing upwards. The team then proceeded to extract approximately ½ cup of copper(II) sulfate pentahydrate from the container and crushed the solid particles to form particles roughly 1-2 mm in diameter. The copper(II) sulfate pentahydrate was then placed on the dish. A black background was placed behind the steel dish, allowing for a solid background capable of displaying all of the physics of the chemical reaction. A member of the team poured approximately 2 tablespoons of rubbing alcohol on the crushed copper(II) sulfate pentahydrate. The team then positioned the doors of the fume hood so that the experiment experienced as little wind draft as possible, leaving a slight opening so that the camera could capture the image without any interference. The last step of the setup was turning off all surrounding lights.

To start the experiment, one member of the team positioned themselves with the camera level to the copper(II) sulfate pentahydrate, approximately 1 foot away. Another member of the team would light the alcohol on fire with our fire source (Scripto lighter). Immediately after the chemical reaction occurred, green, blue, and orange flames were visible and lasted for up to 2 minutes. Different amounts of rubbing alcohol could be added to the experiment to increase or decrease the longevity of the chemical reaction.

Fluid Dynamics

The physics/chemistry theme displayed in this image is the burning of copper(II) sulfate pentahydrate. It is a very simple process that involves the following chemical reactions:

$$CuSO_4 * 5H_2O ----\rightarrow CuSO_4 + 5H_2O$$ Copper(II) Sulfate Pentahydrate reaction (1)[1]

$$2C_3H_7OH + 9O_2 ----\rightarrow 6CO_2 + 8H_2O$$ Isopropyl Alcohol reaction (2)[2]

Equation 1 expresses how the water within the copper(II) sulfate pentrahydrate separates itself when being burned. When the water is removed, the copper(II) sulfate is allowed to burn. Since copper(II) sulfate can't be burned by simply lighting it on fire (because it won't catch fire), a fuel is used to start this process, and the process will continue until the entire fuel source is burned off (shown in Equation 2). The blue color of the copper(II) sulfate crystal is due to water of hydration[3]. When heated in an open flame, the blue crystals become dehydrated and turn into a grayish-white color because of losing its water. This color can be easily restored by simply adding water to the burned copper(II) sulfate.

Figure 2: Alcohol[4] (left) and Copper(II)[5] (right) burned individually

Figure 2 above shows what flame colors are produced when burning alcohol and copper(II) by themselves. It is easy to see in the final photo that these two flames mix with one another and create a beautiful image.

When analyzing the behavior of the flame photographed, it is important to find the Reynolds Number of the flow to distinguish if it's laminar or turbulent flow. The equation for Reynolds Number can be seen below[6]:

$$R_e = \frac{\rho v L}{\mu}$$

where ρ = density of fuel, v = velocity of flame, L = characteristic length (diameter of dish), and μ = dynamic viscosity of fuel. The values that will apply to this equation are those for the isopropyl alcohol as it's the fuel to the system. The following numbers were found for isopropyl alcohol[7]: ρ = 0.786 g/cm^3 @ 20 degrees Celsius and μ = 1.96 cP @ 25 degrees Celsius. Velocity of the flame was calculated by determining the height of the flame at its highest point and dividing it by the time it took to get to that height. In this system, the flame reached its highest point at 12 cm and it took 1 second to achieve it. Therefore, v = 12 cm/s. The characteristic length of the system is the diameter of the dish which was 6 in. Therefore, L = 15.24 cm. When applying these values to the Reynolds Number equation, we receive the following result:

$$R_e = \frac{\left(0.786\ \frac{g}{cm^3}\right)\left(12\ \frac{cm}{s}\right)(15.24\ cm)}{1.96\ cP} = 73.387$$

A Reynolds Number of 73.387 indicates that the flame in experiencing a very laminar flow. Despite this being the case, the intricate flame behavior in the final photo is due to a mild amount of wind entering through the fume hood's doors, indicating that the flame is most likely experiencing turbulent flow. It can be seen that the flame attempts to curl at its highest point. If no wind had been present, the flame would look much more stable like those of Figure 2. The wind speed was not recorded for this system.

Photo Technique

For this experiment, the team chose to use Doug Schwichtenberg's Canon EOS REBEL T2i with 18-55 mm kit lens DSLR camera as it proved to be the best camera for capturing the intricate physics. The field of view for the original photograph is 15 inches in height by 8 inches in width, and for the finished photograph is 4 inches in height by 5 inches in width. The distance from the flame to the camera was 1 foot. The dimensions for the original photo are 3465 pixels in width by 5202 pixels in height, and for the finished photo are 2544 pixels in width by 1720 pixels in height. The aperture was 3.5, with an exposure time of 1/125 of a second, ISO of 800, and a focal length of 18 mm. I used the GIMP 2 software to perform editing on the image. There's a tutorial on YouTube explaining how to make your images appear as if they were shot as a HDR image[8]. This tutorial had me download a patch for GIMP 2 known as Dodge and Burn[9]. The editing process was as follows:

1. Duplicate original layer
2. On the background copy layer, go to Colors → Desaturate, and select Average, and OK
3. Go to Colors → Invert
4. Go to Filters → Artistic → Softglow, and accept the default settings
5. Set the layer mode as Soft Light, and lower the opacity to 50%
6. Duplicate the background copy, and set the opacity to 75%
7. Duplicate the original background
8. Go to Colors → Levels, and enter a value of 100 for black point for the new duplicate layer
9. Set the layer mode to Darken Only, and lower the opacity to 35-50%
10. Go to Image → Merge Visible Layers, and merge
11. Since the Dodge and Burn patch has been installed, go to Script-Fu → Enhance → Dodge and burn
12. Set the thin amount to 10 and click OK
13. Select the background layer and go to Colors → Hue-Saturation
14. Set the Saturation to 50

I found that this process made the image more vivid and pleasing to the eye. Once this editing was complete, I cropped the image. I initially cropped the image to just the flame, but found it to be too grainy. I decided to crop the image by leaving the fire in the lower right hand corner, and introducing a large amount of negative space to the image. The intent of this was to create a cool desktop background.

Conclusion

It was Team Delta's objective of the "Group Project #2" assignment to display the green flames created from burning copper(II) sulfate. The team believes they were successful in displaying the basic physics and chemistry themes of the image in an artistic yet scientific way. The team created images that are appealing to the eye, creating interest and intent to know more on the reader's part. In the future, I would like to perform this experiment with intent of displaying an explosion containing the copper(II) sulfate, producing a green fireball explosion. I would also like to take a digital video of the phenomena to display its unique color mixing and forms with wind added to the experiment.

Original Image

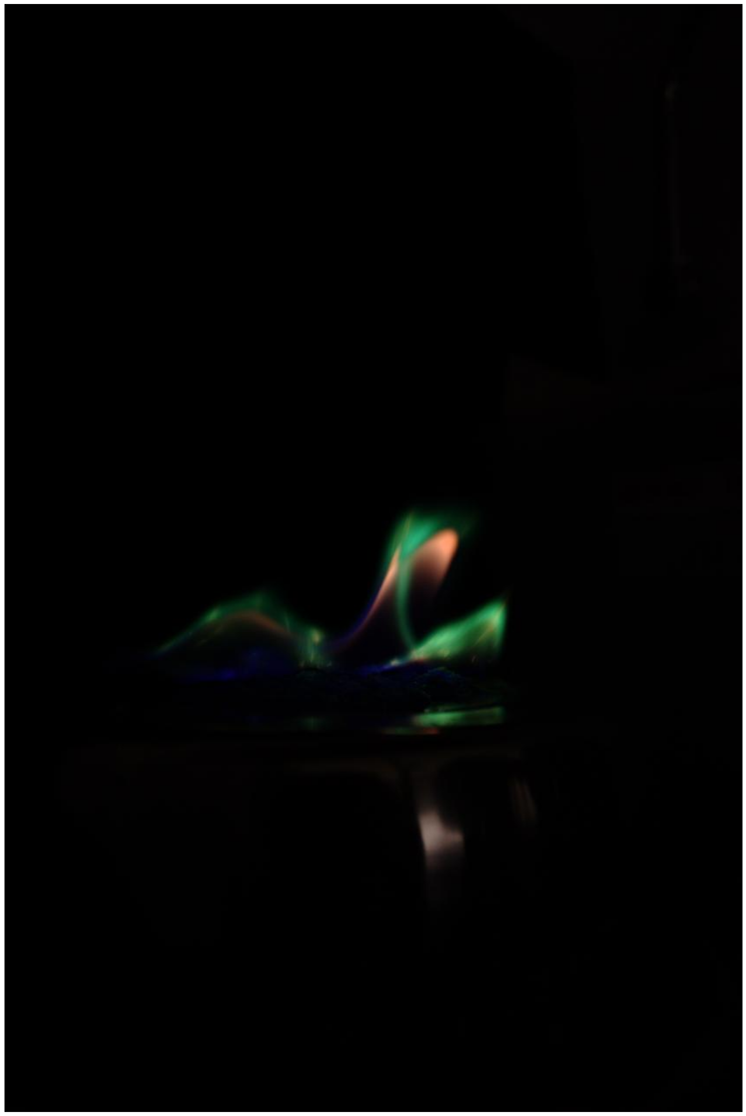

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Image Assessment Form

Flow Visualization

Spring 2010

Name(s): Ryan Kelly

Assignment: Group 2 Date: 4/9/2012

Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

Art	Your assessment	Comments
Intent was realized	!	
Effective	!	
Impact	!	
Interesting	!	
Beautiful	!	
Dramatic	!	
Feel/texture	!	
No distracting elements	!	
Framing/cropping enhances image	!	

Flow	Your assessment	Comments
Clearly illustrates phenomena	!	
Flow is understandable	!	
Physics revealed	!	
Details visible	!	
Flow is reproducible	!	
Flow is controlled	√	
Creative flow or technique	!	
Publishable quality	!	

Photographic technique	Your assessment	Comments
Exposure: highlights detailed	!	
Exposure: shadows detailed	!	
Full contrast range	!	
Focus	!	
Depth of field	!	
Time resolved	!	
Spatially resolved	!	
Clean, no spots	!	

Report		Your assessment	Comments
Describes intent	Artistic	!	

	Scientific	!	
Describes fluid phenomena		!	
Estimates appropriate scales	Reynolds number etc.	!	
Calculation of time resolution etc.	How far did flow move during exposure?	!	
References:	Web level	!	
	Refereed journal level	√	
Clearly written		!	
Information is organized		!	
Good spelling and grammar		!	
Professional language (publishable)		√	
Provides information needed for reproducing flow	Fluid data, flow rates	!	
	geometry	!	
	timing	!	
Provides information needed for reproducing vis technique	Method	!	
	dilution	!	
	injection speed	!	
	settings	!	
lighting type	(strobe/tungsten, watts, number)	!	
	light position, distance	!	
Provides information for reproducing image	Camera type and model	!	
	Camera-subject distance	!	
	Field of view	!	
	Focal length	!	
	aperture	!	
	shutter speed	!	
	film type and speed or ISO setting	!	
	# pixels (width X ht)	!	
	Photoshop techniques	!	
	Print details		
	"before" Photoshop image	!	