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TEAM PROJECT II

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FLOW VISUALIZATION – SPRING 2011

Introduction

For this second Team Project I wanted to work with fire, since I think fire is fascinating. Fire is an element you cannot really control and you cannot really know what shape you would have on the picture. So there is a large part of randomness in using fire. Moreover, I wanted here to emphasize the contrast between fire and ice, two incompatible elements.

I. Set up

It soon appeared that setting an ice cube on fire was not an easy thing. I first tried to pour alcohol used to light barbecues, but it did not work. Indeed, the alcohol was mixing with water as the ice was melting. So I tried to pour more alcohol, but it still did not work. Moreover, the odor was really awful.

Finally, I decided to use another flammable product. I remembered having drinking some cocktails which were set on fire. After some research, I found that those cocktails were made with Bacardi, 151 rum more specifically. It actually worked. 151 rum burns really clean, so the first time I lighted it, I did not see anything, but as soon as I switched off the light, the blue color of the burning liquid appeared. The main issue was now to try to maintain this alcohol on the ice cube. After many tries and fails, I changed my plans.

At first I tried to make ice cube composed of water and alcohol, so the cube could burn by itself without adding liquid on it. However, it did not work because the freezing temperature of the alcohol is too low to do it in a fridge. Even if I put very little alcohol, the cube did not freeze.

So, instead of actually “burning” ice, I tried to give the illusion that the ice was burning, by pouring alcohol all around. I decided to put an ice cube in a candle, pour alcohol on this candle and light it. Unexpected effects appeared, like the reflection of the fire on the ice, which was beautiful however. I did not expect the light to be powerful enough to reflect into the ice, but the deep blue light from the burning rum and the “mirror” effect created by the ice cube gave great colors.

In one of the many tries, I noticed that when the wick of the candle was burning, after all the liquid had been burned, the light became yellow. So the picture I submitted shows indeed the limit, between the alcohol and the wick, since the flame is half blue, half yellow. That means that the alcohol on the wick started to be almost all burned.

In order to take the picture, as there was not enough light, I used an ISO of 800 and a speed of 250ms.

II. Physics

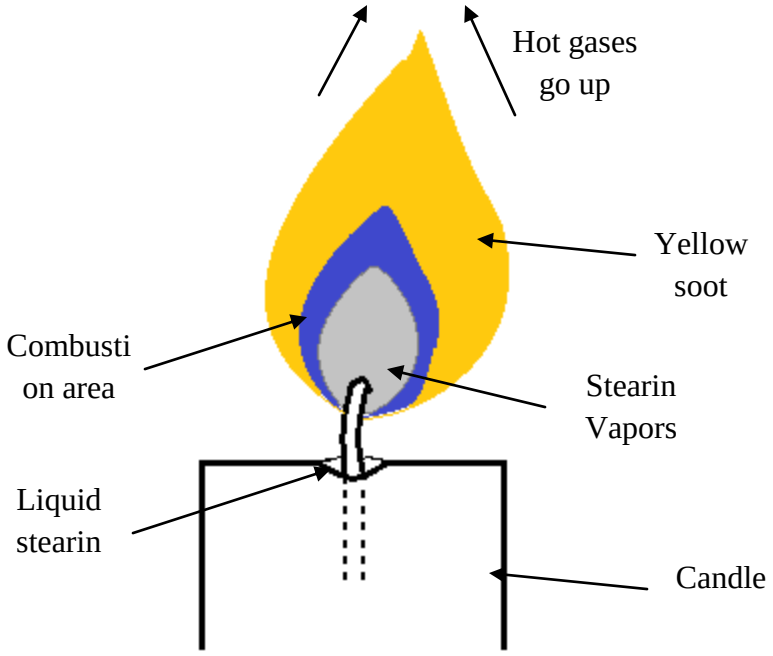
Remember of cocktails is not the only thing that make Bacardi 151 a strong candidate to light ice. Let's go back to the 18th century. In this time, rum was part of the British sailors pay. So, the United Kingdom had to find a way to prove that the rum used was of good quality, and not too watered down. To verify the quality, the proof had been made that gunpowder would ignite if poured in a spirit of at least 57.15% of alcohol by volume (abv). If the gunpowder did not, the rum was considered "under proof". The "good" rum was so defined as "100 degrees proof"

57.15% is closed to a ratio of 4:7. Thus, to calculate the alcohol contained in liquors this unit was used. Pure alcohol was defined by (7:7)x(7:4)=175 degrees proof. A 100 degrees proof was so (4:7)x(7:4)=100 degrees proof.

This "proof" unit had been used for a long time. Nowadays, liquors are sold with their percentage of abv. Many countries have different policies on the way they show the percentage of alcohol. In the United States, alcohol is measured in abv. Regulations permit to print the "proof" measure close to the abv label. The US use a 2:1 ratio for proof alcohol. That means a 50% abv alcohol is a 100-proof alcohol. The name of Bacardi 151 comes from here: the abv is 75.5%, and the proof is so 151.

Owing to its abv, Bacardi 151 is indeed highly flammable. Ethanol burns with a smokeless blue flame which cannot always be visible in the day light. It is made of short carbon chain, freeing then less carbon in the combustion than the combustion of the candle (discussed later) making the flame blue. Ethanol is miscible with water. Mixtures that contain about 50% of ethanol are easily flammable. Heated solutions that contain less than 50% of ethanol may also be flammable.

The yellow color of the candle comes indeed from incomplete combustion. The process a candle uses to burn is based on auto-regeneration. The core of the candle is made of stearin, a sort of animal fat. When a flame is put close to the wick, the stearin melts and goes up into the wick with help of capillarity action. The high temperature of the wick makes the liquid stearin evaporate: this is the first small dark area you can see just around the wick. The stearin vapors then meet the air oxygen and burn at high temperature (about 1400K). This creates a blue zone. This combustion is not total, and carbon remnants create a white third area. This area is the lightening part of the candle. As these remnants go up, their temperature goes down and so the color becomes red/orange/yellow: that is the soot the candle produce. The diagram below sums up the processes that take place in a candle reaction.



Candle Combustion Diagram

The picture I submitted shows both the candle's yellow color (on the right) and the ethanol's blue color (on the left, near the ice cube). Indeed, the wick started to burn (actually, it was the stearin) while few ethanol remained. The two combustion colors then melted, giving this bi-color aspect. At the base of the wick, you can also see a brighter blue ring that represents the ethanol poured onto the top of the candle, just under the wick.

Conclusion

This second team project was a little bit different for our team, since unlike the first team project we barely all decided to make something different. We discussed with each other in order to get some ideas, and we all did what we found the best.

This team project allows me to figure out how difficult it is to work with fire. Fire is a moving subject, so taking a good picture is not an easy thing. Moreover, a picture including fire an ice must be taken quite quickly. Since the temperature of the burning alcohol is pretty high, the ice melts rapidly so everything has to be well set up before lighting the liquid. However, I like the results, since I managed to take many great pictures and videos.