The Burning Candle

Can you extinguish a candle without blowing it out, or light it without touching a flame to it? Try the following activity.

Materials

- 2 candles
- aluminum pie pan
- matches
- hot pad, tongs, or pliers
- metal strainer or wire mesh
- clear, narrow-necked (though greater diameter than one candle) glass container (a salad dressing bottle works well)
- water
- (optional) 2–5 drops food coloring

Safety

Use care when working with flames.

Exploration

Step 1 Mount one of the candles in the pie pan by dripping hot wax into the middle of the pie pan and setting the candle into the hot wax before it solidifies. Light the candle and allow it to burn for at least 20 seconds. Light a second candle and hold it in your hand. Gently blow out the standing candle only and quickly move the flame from the lit candle into the "smoke" rising above the extinguished candle. What happens? What is the identity of the "smoke?" (Consider the physical state of the fuel.) Explain your observation(s).

Step 2 Leave the standing candle lit and extinguish the second candle. Using a hot pad, tongs, or pliers to hold the handle of the strainer or wire mesh, lower the metal into the top of the flame. What do you see when you do this? What happens? Repeat, but this time lower the metal about halfway into the flame, leaving it there just a short time before you lift it. What property of the metal causes this to happen? (This phenomena was the basis for the invention of the miner's lamp by Sir Humphrey Davy early in the 17th century.)

Step 3 Pour about 1 inch of water into the pie pan with the standing candle. (If you have food coloring, you can add it to make the water more visible.) Light the candle in the pie pan. Assuming the formula of the wax is $C_{20}H_{42}$, write the equation representing its complete combustion. Place the clear glass container over the candle, submerging the mouth of the container under water as quickly as possible. What happens to the water and to the flame? Why?

Challenge

Based on your observations, what three factors must be present for a candle flame to exist?

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Concepts

combustion reaction, air pressure, properties of metals, Charles' law

Expected Student Responses to Exploration

Step 1 (a) The flame appears to jump from the second candle to the first candle.

(b) The white smoke is the liquid or solid wax produced by the condensation or deposition of the vapors.

(c) Since wax vapors are flammable, they ignite when another flame is held to them; the resulting flame goes back to the source.

Step 2 (a) The flame does not go above the wire strainer or mesh.

(b) The flame may appear to go out; then it appears to relight if the metal is removed quickly enough.

(c) The property is heat absorption. The metal absorbs enough heat that the wax vapors around it are cooled below their kindling temperatures. (The wire that was put around a candle in a safety lamp prevented the flame from igniting other flammable gases in the mine.)

Step 3 (a) $2\ C_{20}H_{42}(g) + 61\ O_2(g) \rightarrow 40\ CO_2(g) + 42\ H_2O(g)$

(b) Bubbles appear at the mouth of the bottle as it goes underwater. Water rises in the bottle. The candle goes out.

(c) The initial rising of the water level occurs because there is a decrease in gas volume inside the container. There are fewer moles of carbon dioxide produced than oxygen consumed. Although the water initially forms a gas, it condenses to the liquid state as soon as it cools. If a dry container is used, the condensation of water on the inside surface can be readily observed.

However, the temperature of the gases is also rising as the candle burns. This would tend to drive some of the gas out of the container due to an increase in pressure. After the candle is extinguished, there is a rapid rising of the water level inside the inverted container. This is due to the cooling of the gases which results in a lowering of the pressure inside the container. Because the pressure of the atmosphere exceeds the pressure of the gases inside the container, the water is pushed up into the container.

Expected Student Answer to Challenge

Wax vapors (the fuel), heat, and oxygen (from the air) must be present for a candle flame to exist.

Reference

"Investigating a Burning Candle"; *Fun with Chemistry: A Guidebook of K–12 Activities*; Sarquis, M., Sarquis, J., Eds.; Institute for Chemical Education: Madison, WI, 1993; Vol.2, pp. 339–346.

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