Charles' Law and the Rising Water Activity[3]

(Reinforcement Activity)

Materials

One set of materials per group of 3 students:

- Tall glass
- 25 ml water
- Birthday candle
- Small ball of clay
- Match
- Flat plastic dish
- *What Causes the Water to Rise in the Glass?* (p. 141) activity sheet

Background Information

When a glass is placed over a burning candle in a plate of water, the water level rises significantly when the candle burns out. This is due to a combination of factors. First, the burning candle significantly increases the temperature of the air in the glass. When the candle burns out, the rapid decrease in temperature slows the movement of the molecules that make up the air inside the glass, creating lower pressure. The air pressure outside of the glass remains the same. This creates an air pressure differential of greater outside air pressure, which results in the water rising in the glass. In addition, going from a higher temperature to a lower temperature causes water vapor in the air to condense, which also produces lower air pressure in the glass. Although it is difficult to tease apart which one of these variables has the more significant impact, both result in rising water in the glass.

Steps

1. Pass out *What Causes the Water to Rise in the Glass?* activity sheet to each student.
2. Have students work in groups of three.
3. Go through the procedure for setting up the activity so students are clear about what to do. In the activity, students try to determine what causes the liquid to rise in a glass that contains a burning candle under it. Emphasize that they are doing the work in small groups so that they can closely observe what happens. *They should observe that the water rises significantly once the candle goes out.* Have them complete the activity using the sheet to guide them. They may not complete it in one day.
4. If they need more time, pick a good place to stop. (For instance, they could run the experiment once before the end of class and think about it for homework.)
5. Have three or four students put their models on the board and explain them to

the class. Try to get one model that focuses on the candle burning, with oxygen being used up as the cause of the water rising. Note to the class that this is a non-obvious cause.

6. Look for similarities in the models and list them on the board next to the similarities noted in the balloon/flask activity. Ask, "Are these the same?" (*Hopefully students will notice the moisture in both*.) Ask, "What about the models are not similar? Can anyone think of a way we can test some of these models?"

If a model of burning oxygen is on the board (see resource sheet on p. 143 for explanation):

7. Do the activity again, but this time, have students note **<u>when</u>** the water rises the most. They should note that it does so once the flame has gone out. Does this fit the burning oxygen model? (*No. If that were the cause, then the water would rise as the oxygen was used up, but that does not fit their observations*.)
8. What else could be going on? Elicit ideas from the class.
9. If students still are not convinced that the "oxygen being used up" model does not fit, have them predict what would happen if they added more candles to their system. If the oxygen model is correct, the water should eventually rise to the same level no matter how many candles are added, since there is a fixed amount of oxygen in the glass. They should see that the more candles they add, the higher the water rises in the glass. Have them think of why this may be so.

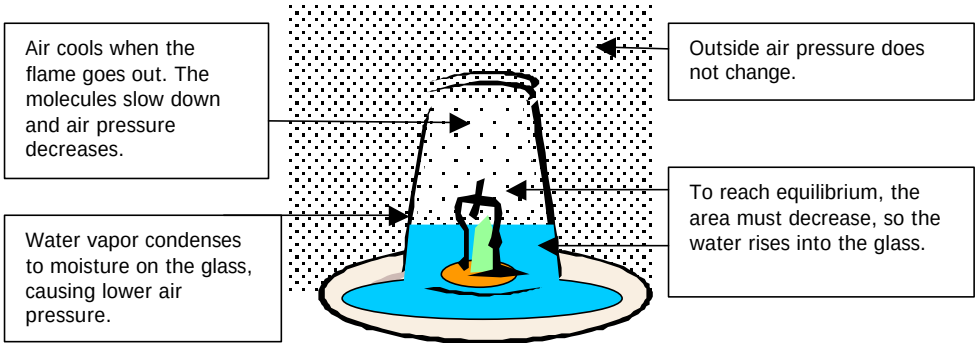
If a temperature model is not on the board (see resource sheet on p. 143 for explanation):

10. Do the activity again, but this time, have students think about it in terms of temperature. *There are two explanations related to temperature. First, the lower temperature created when the candles go out causes lower air pressure, so the outside air pressure is greater (most students don't note this unless you specifically mention it to them). The outside air pressure pushes more on the water than the inside pressure, so the water is then pulled up into the glass until equilibrium is reached. Second, when you add more candles, the air becomes proportionally hotter, and the rapid temperature change (from high to low) when the candle goes out causes water vapor inside the glass to condense on its sides. This creates lower air pressure inside the glass, so the outside air pressure pushes more on the water than the inside pressure. This causes the water to rise in the glass until equilibrium is reached.*

If a vacuum model is on the board (see resource sheet on p. 144 for explanation):

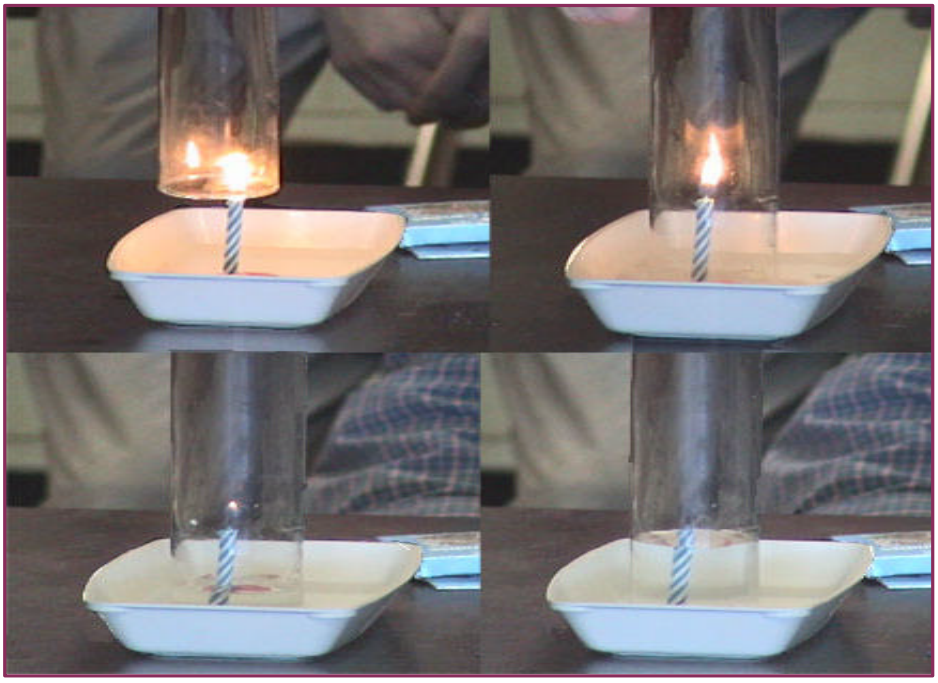
11. Tell the class, "People often say 'Nature abhors a vacuum.' Why do you think people say this?" Gather responses. "If a true vacuum were created, what would you observe?" (*The glass would implode.*)

What actually happens?



The evaporation of the water to water vapor as the candle burns, and the cooling that occurs when the candle goes out, cause lower air pressure inside the glass than outside. The water is pushed into the glass until equilibrium is reached.)

Demonstration of Rising Water Activity



What Causes the Water to Rise in the Glass?

(Reinforcement Activity)

Name_____ Date_____

How can you use what you've learned about obvious and non-obvious causes and relational causality to come up with a model to explain why the water rises in the glass? Think about all of the possible variables involved and how they relate to each other.

Materials

- Tall glass
- Birthday candle
- Matches
- Water
- Flat dish
- Small ball of clay

Directions

1. Stick the bottom of a candle into a ball of clay. Press the ball of clay into the center of the dish. The candle should be standing straight up in the center of the dish.
2. Fill the glass half full with water and pour the water into the shallow dish.
3. Light the candle, invert the glass over the candle and set the glass mouth down into the water. (See figure above.) Carefully observe what happens.
4. You may have to repeat the procedure several times.
5. Write an explanation and draw a model to explain what caused the water to rise in the glass.

Draw your model here:

Write your explanation here:

Examples of Student Models: 'What Causes the Water to Rise in the Glass?'*

Burning Oxygen Model

This is the most common model that students use when explaining why the water rose in the glass. In this model, students reason that as the candle burned, it "used up" the oxygen that was trapped under the glass. The water rose because the candle "used up" all of the oxygen that was in the air. Students often fail to explain how the lack of oxygen in the air caused the water to rise in the glass. Rather, they focus on the most obvious aspect of the experiment, the candle going out, and attribute that as the cause of the water rising. Although the cause of the candle going out was a lack of oxygen, it was not the cause of the water rising in the glass. To have students question this model, do the activity again, but this time have students note **when** the water rises the most. They should note that it does so once the flame has gone out. Does this fit the burning oxygen model? No. If that were the cause, then the water would rise as the oxygen was being used up, and would stop rising when the candle went out, but that does not fit the evidence. If students still are not convinced that the "oxygen being used up" model does not fit, have them predict what would happen if they added candles to their system. If the oxygen model is correct, the water should rise to the same level no matter how many candles are added, since there is a fixed amount of oxygen in the glass. However, they should see that the more candles they add, the higher the water rises in the glass, evidence that is not supported by the oxygen model.

Temperature Model

Most students focus on the burning of the candle. Few make the connection between the burning candle and a subsequent rise in the temperature of the air trapped under the glass. There are two possible explanations for how temperature results in the water rising in the glass that students may mention. First, the lower temperature created when the candle goes out causes lower air pressure (the molecules that make up the air slow down). The outside air pressure is greater (most kids don't note this unless you specifically mention it to them) so the outside air pressure pushes on the water to a greater extent than the inside air pressure, and the water is pulled up into the glass until equilibrium is reached. Second, when you add more candles, the air becomes proportionally hotter, and the rapid temperature change (from high to low) when the candle goes out causes water vapor inside the glass to condense on its sides. This creates lower air pressure inside the glass, so the outside air pressure pushes more on the water than the inside air pressure. This causes the water to rise in the glass until equilibrium is reached.

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* These ideas and models were generated by a group of teachers during a summer workshop.

Vacuum Model

Some students might mention that a vacuum is created inside the glass by the burning candle, which sucks the water up. To address this model, tell the class that people often say, “Nature abhors a vacuum.” Ask: “Why do you think people say this?” Gather students' ideas. Then, have them think deeply about what we would observe if a true vacuum were created inside the glass. That would mean that there was no air whatsoever in the glass. If that were the case, the higher outside air pressure would immediately implode the glass. Since this does not occur, students should conclude that a vacuum was not the cause of the water rising in the glass. However, you might find that some of your students still hold on to the idea of a “partial vacuum.” Ask them to explain what they mean by a “partial vacuum.” It might be the case that their ideas are those of a lower air pressure, but they are using the token agent of a partial vacuum, since this terminology might be more familiar to them.

Air Pressure Differential Model

The cause of the water rising in the glass can actually be attributed to several variables that result in the creation of an air pressure differential between the inside and the outside of the glass. As the candle burns, the temperature of the air inside the glass increases rapidly. This temperature increase also results in additional water vapor in the air. When the flame uses up all of the oxygen in the glass, the candle goes out. This causes the air to cool rapidly, and causes condensation to form on the inside of the glass. Both of these variables create an area of lower air pressure inside the glass as compared to the higher air pressure outside the glass. This results in the outside air pushing on the water, which causes it to rise in the glass until the two air pressures reach equilibrium.