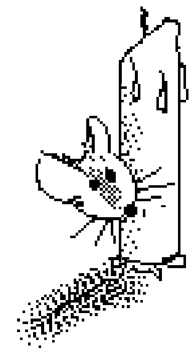
Student Laboratory Investigation
The Chemistry of Combustion and Respiration

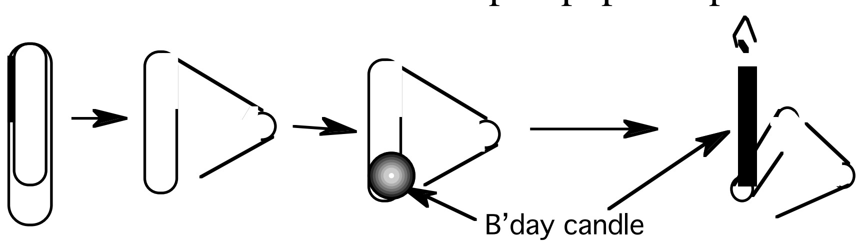
Objective

On a quiz that follows you will be asked to:
1. Demonstrate how a chemical equation is written
2. Write the equation for combustion
3. Identify the reactants and products of combustion and discuss what happens to them during the reaction
4. Write the equation for animal respiration



Investigation Procedure:

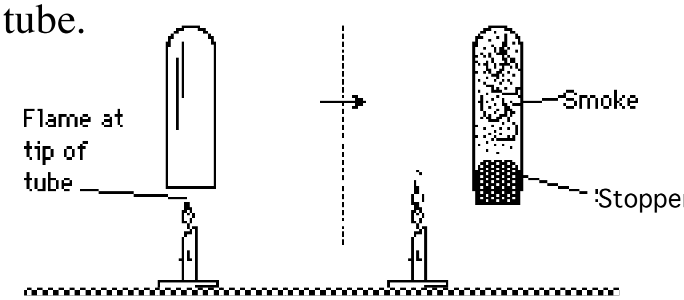
Attach a small candle to an open paper clip as follows: [___]



Light the candle. [___] As you watch the candle burn, realize that it is using up two **requirements**. In the process, four *products* will form. Scientists call this burning process, ***combustion***. In combustion, a chemical reaction is taking place where the requirements are converted into **products**. Your task will be to determine the two requirements and four products of combustion.

1. One of the products of combustion should be apparent when you observe the flame. Two forms of energy are being given off in the flame. What are they?

Locate a test tube and be sure it is clean and perfectly DRY inside. [___]
Find the cork or stopper that will fit this tube.
[___]



Collect some smoke from the burning candle in a test tube. Use a test tube holder to hold the tube upside-down over the flame. Lower the tube slowly until it covers the flame. Allow the flame to touch the inside edge of the tube. After 4-7 seconds, cork the tube as shown.
DO NOT TOUCH THE LIP OF THE TEST TUBE. IT'S **HOT**. See the above drawing. [___]

2. Examine the inside of the test tube carefully. You should be able to observe 2 products of combustion. Look CAREFULLY. One is black and the other has collected on the inside glass of the test tube. Name the two products observed in the test tube.

Blow out the candle. [___]

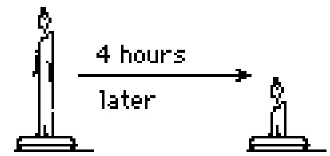
There is one more product of combustion to be identified. Open the corked tube just long enough to pour dilute bromthymol blue indicator into the tube to fill it about 1/3 full. Bromthymol blue is yellow when CO_2 (carbon dioxide) is present and blue when there is no CO_2 present. A green color indicates very small amounts of CO_2. Shake the tube several times and observe the results. [___]

3. What did you observe?

4. What is your interpretation of these results?

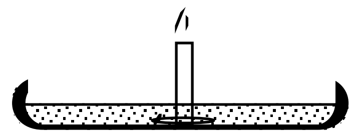
5. List all four of the **products** of combustion.

Now you will determine the two **requirements of combustion**. The first requirement is not difficult to determine. Remember that requirements (or reactants) are used up in the reaction. Consider the following observation of a candle burning in air: (See drawing at right)



6. What is the requirement used up during the four hours?

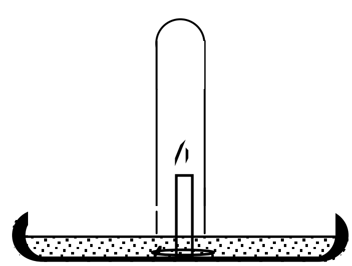
The second requirement for combustion will take more time to discover. You can identify this requirement by placing a sealed container of air over a burning candle. To do this, fill a flat container about 1/3 full of water. [___] Place the candle, held by the paper clip, in the water as shown at the right. Do not light the candle yet. [___]



Now place a test tube upside-down in the water to the side and away from the unlit candle. (Not over the candle) [___]

7. Where is the water level in the tube?

Light the candle. **Be careful not to burn yourself.** [___] Quickly lower the test tube over the candle until it rests on the paper clip and creates a seal with the water. You may have to hold the tube to keep it from falling over. See drawing below. [___] Wait about 1 minute and mark the water level in the test tube while it is still over the candle. [___]



8. Describe what you observed.

9. Offer a reason (interpretation) for your observations.

Use the following information to possibly refine your interpretation about what happened to the water in the experiment. Air is composed of about 4/5 nitrogen, 1/5 oxygen and less than of 1% carbon dioxide and trace gasses.

10. Is the above information helpful in interpreting the results of the last experiment? If so, how? If not, why not?

11. Based upon this experiment and the known composition of air, hypothesize what the other requirement for combustion might be.

Perform the following experiments to obtain additional information about your hypothesis:

Experiment A: Relight the candle setting in the water. [___] This time, when you cover the candle, determine the number of seconds it takes to go out from the moment the seal is made with the water. Record this time. [___]
Repeat this experiment with one or two progressively larger containers and record the times. [___]

12. What is the relationship between the time the candle stays lit and the volume of the container used?

Experiment B: Repeat the experiment using the largest container you could find. Mark the water level two minutes after the flame goes out. [___] Repeat this same experiment using 2 candles. Mark the water level. [___] And finally, repeat the experiment using 3 candles.

13. What is the relationship between the number of candles used and the distance the water rose?

14. Do the results from experiments A and B change your answers to questions 9 and 10? Explain.

It is suggested that you discuss the results obtained from all of the candle experiments and your interpretations with your other classmates and your teacher.

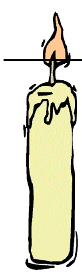
A variety of other experiments have been conducted that show conclusively that oxygen is one of the requirements for combustion.

15. If the candle used up nitrogen (N_2) instead of the O_2 in the air, how far would the water have risen into the jar?

16. Since the process of burning, or combustion, is a chemical reaction, its requirements (reactants) and products can be written in a chemical equation form using pluses and arrows. Copy this form onto your paper and fill-in the blanks:

___ + ______ ——→ ____ + ___ + ___ + ___

(Requirements) or reactants



(Products of reaction)

In reading the above chemical equation, the arrow is read as "yields" or "produces". Reread your equation substituting the word "yields" for the arrow. [___]

17. The reactants of a chemical equation are usually placed to the left of the arrow, with the arrow pointing to the products on the right.

REACTANTS --------> PRODUCTS
(requirements)

18. The reactants can be placed in any order as long as they remain on the **left side** of the arrow. The products can be arranged in any order, as long as they remain on the **right side** of the arrow. Rewrite your equation from question 16 in different order according to the above rule. The revised equation for combustion is:

The equation is not yet complete. A complete equation describes how the reactants are changed into the products. Set your candle in front of you. [___] It is surrounded by oxygen in the air, and yet it does not begin to burn. The missing requirement is a match. The match is called the "starter" or can be referred to as a catalyst. It starts the reaction. In writing an equation, the starter or **catalyst** is written over the arrow. Notice how this is done with the following equation:

$$\text{Fuel (or wax)} + O_2 \xrightarrow{\text{starter (match)}} \text{ENERGY} + CO_2 + H_2O + C$$

(any order) (any order)

In the combustion process, oxygen gas (O_2) from the air and the carbon atoms (C), hydrogen atoms (H) and oxygen atoms (O) that make up a molecule of wax, pull apart in the heated area of the candlewick. These atoms rearrange into CO_2, H_2O and carbon, (all found in smoke) with the release of heat and light energy. The chemical energy that held the atoms of wax together is changed into heat and light.

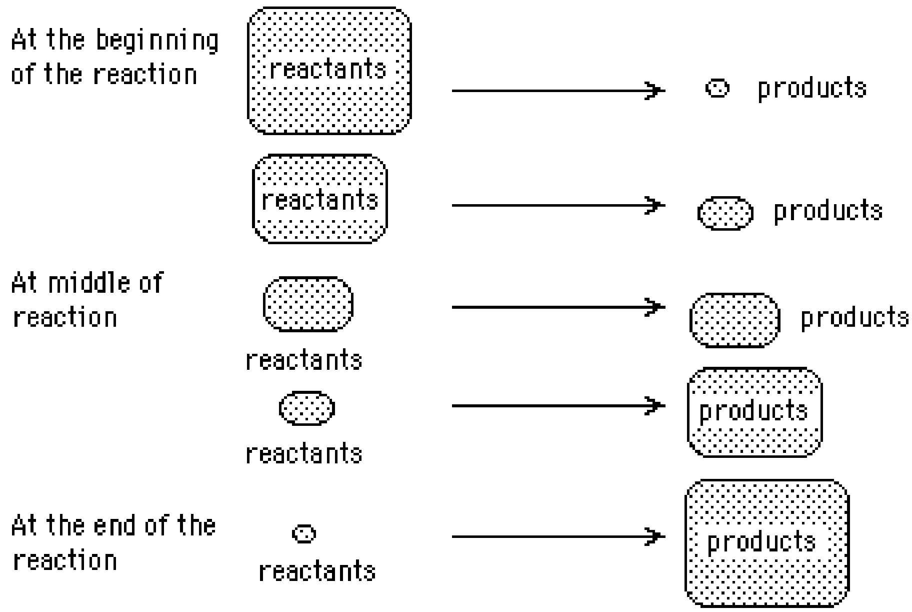
19. In any chemical equation, the reactants are on which side of the arrow?

20. In the following equation, name the products: $H_2O \text{ ---------> } O_2 + H_2$

21. In an equation like combustion, which materials get used up?

22. As a chemical reaction proceeds, what happens to the quantity of the products?

The changing amounts of reactants and products in a chemical equation can be diagrammed as follows: (The size of each block represents the amount of substance.)



What Does a Burning Candle Have to Do With How You Obtain Energy from Respiration?

Now that you understand how a burning candle uses the requirements oxygen and fuel (wax) to produce heat and light energy along with carbon, carbon dioxide and water vapor, you should be able to understand how animals (including humans) obtain energy in a very similar manner. This energy producing process in animals is called **respiration.** In animal respiration, animals require oxygen and fuel. The fuel in respiration is the sugar **glucose**. Many foods can be changed into glucose and used for respiration. The chemical formula for glucose is $C_6H_{12}O_6$. The products of respiration are carbon dioxide, water and energy in the form of heat and chemical energy needed for body processes. Oxygen is taken into the body with every breath of air. The blood stream transports the oxygen from the lungs and glucose from the digestive system to all body cells where respiration takes place in the cell's cytoplasm. The blood stream transports carbon dioxide produced by cellular respiration to the lungs, which exhale it to the outside.

23. Write the equation for respiration and then write the equation for combustion just below it to compare the similarities and differences. What are the similarities? What are the differences?

24. Review the objectives at the beginning of this lab investigation as you begin reviewing for the quiz.

Teacher Information for:

The Chemistry of Combustion and Respiration

Materials Needed:

Each group of students to perform the experiment will need the following:

- 1 container of at least 20 mL of dilute bromthymol blue indicator (BTB). Prepare dilute BTB indicator by adding enough drops or mL of BTB to tap water to create a light blue to medium blue color that is easily visible when poured into test tubes. Label each bottle "Dilute bromthymol blue." If the dilute BTB indicator solution is green or yellow in color after dilution, the tap water used has a low pH. Either use neutral pH distilled water or use the tap water and carefully adjust the pH using 0.01 N. NaOH solution.

(To make the 0.01 N NaOH solution

Mix 0.4 g. of NaOH crystals in 1000 mL of tap water. Distribute to small labeled dropper bottles. **CAUTION: TEACHERS ONLY SHOULD PREPARE NaOH** (Sodium hydroxide) Use gloves, apron and goggles. Caution students to avoid contact with the body and face. .01 N is an extremely weak concentration and not nearly as harmful as stronger solutions)

-) Add the NaOH slowly, drop-by-drop, until the color remains blue after stirring.

- 1 test tube (20 mm X 150 mm or larger) and stopper
- 3 birthday candles and paper clips
- 2 -3 miscellaneous glass containers of different volumes
- matches
- 1 flat plastic or glass tray to hold water

- 1 roll of masking tape or glass marking pencil
- 1 wire test tube holder

Discussion of Candle Experiments

When a candle burns, it uses up oxygen and produces carbon dioxide. The fact that a candle goes out in a sealed container indicates that it used up "something" in the air. This experiment does not allow us to say which of gasses in the air was actually used in combustion. Generally, the water will rise from between 15% and 20% of the height of the container used to cover one candle. Water rises when any of the air is used up. The water will rise to replace the gas used. Water will also rise when the warm air in the container cools. Cooler air occupies less space that warm air. Since air is 20% oxygen, some have concluded that this shows that oxygen is the gas that the candle used. One problem with this interpretation is that the candle produces carbon dioxide, which reclaims some of the space created by the oxygen used up in the reaction. One way to reduce this problem is to place ascarite or another strong base inside the jar. The ascarite will absorb most of the carbon dioxide produced by the candle. Note: This step was eliminated from this lab due to the danger of working with this corrosive base. (See the *Biology: As Scientific Inquiry* (Unit II, 5-6) version for a description of how this can be done.)

The other problem is that when the flame heats the air in the container, the volume of air increases. This usually occurs just before the seal is created. After the seal is made, the air cools, resulting in a volume decrease. This will draw the water up into the container. To verify this, experiment "B" was performed. The more candles, the higher the water will rise. Students usually find that with 3 candles the water rises about 33% in the container. If the rise in the water level were due entirely to using up all of the oxygen, it could not go higher than 20%. This experiment shows that heat is a large contributing factor in the rise of the water when one candle is used.

The teacher can discuss each of these variables with the students as their grade level and ability will allow.