Experiment 17
It's A Gas and More!

OUTCOMES

After completing this lab activity, the student should be able to:

- explain a simple method for distinguishing carbon dioxide gas from oxygen gas.
- determine whether a process is endothermic or exothermic.
- write balanced chemical equations for the reactions that occurred in this lab.
- explain the purpose of sweating.

DISCUSSION

Every chemical reaction and phase change involves some sort of change in energy, though it may not always be apparent. This is typically due to the quantities involved or the amount of energy change. This lab activity looks at three processes – two chemical reactions and one phase change – that involve obvious changes in energy.

When studying energetics, scientists define both the system and the surroundings. The **system** includes all of the substances that participate in the actual reaction or phase change. The **surroundings** are anything that is in the vicinity of the system with which energy is exchanged. The surroundings may include the flask in which a reaction is being conducted, the water in which the reacting substances is dissolved, or the air near the container.

Most commonly, changes in the temperature of the surroundings are observed, though different types of energy besides heat energy may be involved (such as electrical or light). By observing what happens to the energy of the surroundings, one can determine what happened to the energy of the system. For example, if the surroundings get warmer, that means the system has released energy to the surroundings and the process is classified as **exothermic**. If the surroundings get cooler, that means that the system has absorbed energy from the surroundings and the process is classified as **endothermic**.

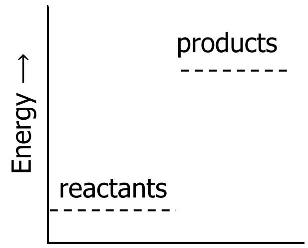


Figure 1. The figure above shows an endothermic process – energy is absorbed.

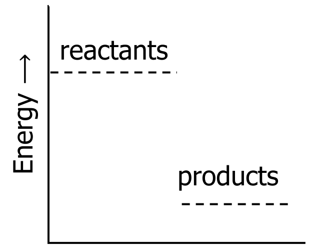


Figure 2. The figure above shows an exothermic process – energy is released.

Here are some examples:

Exothermic Processes	**Endothermic Processes**
Mixing household ammonia and white vinegar causes the temperature to increase.	Dissolving solid ammonium nitrate in water causes the temperature to decrease.
Glow sticks release light when the glow stick is bent and the inner solutions mix together.	Plants absorb sunlight to convert carbon dioxide and water into sugar and oxygen.
Steam from boiling water condenses on the skin, releasing heat and causing skin burns.	Liquid water begins to boil and turn into steam when it absorbs heat from the stovetop.
The metabolism of food provides energy for muscles and keeps our bodies warm.	An egg is cooked when it absorbs heat from the surroundings.

On a somewhat different note, the two chemical reactions that will be performed in this laboratory activity are gas-producing reactions. Gases commonly produced in chemical reactions include hydrogen, oxygen, and carbon dioxide. If one knows that these three gases are the only possible gaseous products of a chemical reaction, they may easily be distinguished by using a flaming wood splint or glowing wood splint. A flaming splint inserted into the mouth of a test tube or beaker containing hydrogen gas will produce a pop and/or whistling sound, while a flaming splint placed into a test tube or beaker containing carbon dioxide gas will simply be extinguished. Oxygen gas may be identified by inserting a glowing splint into the mouth of a test tube or beaker and observing the flame rekindle.

Finally, balanced chemical equations will be written for the two chemical reactions observed in this lab activity. When writing the equations, remember to use proper phase labels and to ask if any elements may be present in their diatomic form. Look over the equation to ensure that the number of atoms of each element on both sides of the balanced chemical equation is the same.

Example: Sodium metal reacts with water to produce an aqueous solution of sodium hydroxide and hydrogen gas. The balanced equation for this reaction, including phase labels is:

$$\mathbf{2}\ \mathrm{Na}\ (s) + \mathbf{2}\ \mathrm{H_2O}\ (l) \longrightarrow \mathbf{2}\ \mathrm{NaOH}\ (aq) + \mathrm{H_2}\ (g)$$

Example: When electrolyzed, liquid water decomposes in the presence of a sulfuric acid catalyst to yield hydrogen gas and oxygen gas. The balanced equation for this reaction is:

$$\mathbf{2}\ \mathrm{H_2O}\ (l) \xrightarrow{\mathrm{H_2SO_4}} \mathbf{2}\ \mathrm{H_2}\ (g) + \mathrm{O_2}\ (g)$$

Notice the phase labels. Water is a liquid – not aqueous, since aqueous refers to a compound dissolved in water. Also, notice that the formula for hydrogen gas is H_2, not simply H, and the formula for oxygen gas is O_2, not O. This is because hydrogen and oxygen are diatomic elements. Note that the formula for sodium metal is Na and not Na^+, since metals are only found in their ionic form when they are chemically bonded with elements that yield negatively charged ions. Lastly, notice that H_2SO_4 is written above the arrow, since it is a **catalyst**. Catalysts are substances that speed up a chemical reaction without being consumed.

PROCEDURE

⚠ ***Wear safety glasses or goggles at all times for this experiment.***

⚠ ***Keep rubbing alcohol away from all flames in this experiment.***

Part 1. Baking Soda and Vinegar

1. Plug the Go! Temp temperature probe into a convenient USB port on your computer and launch the *Logger Pro* application. The temperature probe should automatically be identified by the software and interface.

2. Click the Stopwatch icon on the top toolbar. On the **Collection** tab, the **Mode** should be set to "Time Based", **Duration** to "180 seconds", and **Sampling Rate** to "1 sample/second" ("1 second/sample"). Check the box to take a "Sample at Time Zero". If done correctly, it should read near the bottom of the window, "Samples to be Collected: 181."

3. Place a small portion cup onto a balance and add 2.0 g of baking soda to the cup.

4. Using a graduated cylinder, add 25 mL of vinegar to a large plastic cup.

5. Place the Go! Temp temperature probe into the cup containing the vinegar and allow the temperature readings to stabilize. To avoid tipping the cup and speed the process, the temperature probe may be used as a stirrer.

6. Once the temperature has stabilized, click the green **Collect** button on the *Logger Pro* tool bar. After one or two readings have been recorded, slowly add the baking soda into the vinegar – slow enough to prevent the mixture from bubbling over. Stir the mixture while the reaction proceeds. Notice what happens to the temperature.

7. Once the data collection has stopped, remove the probe from the reaction mixture. If desired, the data collection may be stopped early by clicking on the red **Stop** button. (*NOTE: When data collection begins, the green **Collect** button becomes a red **Stop** button.*)

8. **As soon as possible** and away from the top of the cup, use a lighter or match to light the end of a wood splint. Lower the lit end of the splint **into** the top of the cup containing the reaction mixture. The splint should **not** be lowered into the liquid, but rather into the gas just barely above the surface of the liquid.

   *Note what happens to the flame. If nothing happens, repeat **Part 1** (steps 3-4, 6, and 8) without collecting any temperature data, while placing a watch glass over the top of the cup. This allows a small amount of the gas produced to escape, while preventing a large amount of air from entering the cup.*

9. Examine the data in the table and on the graph. If satisfied with the trial, select **Experiment > Store Latest Run**, so a new set of data may be graphed. If not satisfied, select **Experiment > Clear Latest Run**, and repeat the reaction to obtain data or to retest the gas.

10. **Save the file** before proceeding to prevent accidental loss of data. If, for whatever reason, the computer were to lock up, the most recently saved set(s) of data may be retrieved. *Failure to do so may result in all data being lost in an experiment. It is always a good practice to **save early and often** when working on a computer*.

11. Empty the contents of the cup into the designated waste container. Rinse the large plastic cup, small portion cup, and probe with water and dry them off.

Part 2. Hydrogen Peroxide and Yeast

12. Place the small portion cup onto a balance and add 0.5 g of yeast to the cup. Use a graduated cylinder to add 25 mL of fresh 3% hydrogen peroxide to the large plastic cup.

13. Place the temperature probe into the cup containing the hydrogen peroxide and allow the temperature readings to stabilize. To avoid tipping the cup and speed the process, the temperature probe may be used as a stirrer.

14. Once the temperature has stabilized, click the **Collect** button. After one or two readings have been recorded, slowly add the yeast to the hydrogen peroxide solution – slow enough to prevent the mixture from bubbling over. Stir the mixture while the reaction proceeds. Notice what happens to the temperature as the reaction proceeds.

15. Once the data collection has stopped, remove the probe from the reaction mixture. If needed, the data collection may be stopped early by clicking on the **Stop** button.

16. **As soon as possible** and away from the top of the cup, use a lighter or match to light the end of a wood splint. Allow the splint to burn for a few seconds and blow out the flame, leaving a glowing ember at the end of the splint.

17. Lower the glowing end of the splint **into** the top of the cup containing the reaction mixture. The splint should NOT be lowered into the liquid, but rather into the gas just barely above the surface of the liquid.

    *Note what happens to the splint. If nothing happens, repeat **Part 2** (steps 12, 14, and 16-17) without collecting any temperature data, while placing a watch glass over the top of the cup. This allows a small amount of the gas produced to escape, while preventing a large amount of air from entering the cup.*

18. Examine the data in the table and on the graph. If satisfied with the trial, select **Experiment > Store Latest Run**, so a new set of data may be graphed. If not satisfied, select **Experiment > Clear Latest Run**, and repeat the reaction to obtain data or to retest the gas.

19. Save the file before proceeding to prevent accidental loss of data. Empty the contents of the plastic cup into the designated waste container. Rinse the plastic cup, portion cup, and probe with water and dry them off.

Part 3. Comparative Evaporation of Liquids

20. Wrap the tip of the temperature probe using a small piece of a paper towel or 2-3 layers of Kimwipe® tissue, and securing it with a piece of tape.

21. Add water to a plastic cup to a depth of 1-2 cm. The water should be at or near (within ±1°C) room temperature. If you are unsure of your actual room temperature, allow the dry temperature probe to sit out in your room until the readings stabilize. If necessary, adjust the temperature of the water to be within ±1°C of room temperature before moving on. Lower the temperature probe into the cup and allow the temperature readings to stabilize.

22. Once the temperature has stabilized, click the **Collect** button. After one or two readings have been recorded, lift the probe out of the water and begin waving the tip back and forth, causing the water to evaporate from the tissue or paper towel. Notice what happens to the temperature as the water evaporates. Instead of waving the tip back and forth, you may choose to direct a fan or stream of air at the tip and holding the probe at a fixed distance.

23. If needed, the data collection may be stopped early by clicking on the red **Stop** button. Otherwise, allow the data collection to proceed and stop on its own.

24. Examine the data in the table and on the graph. If satisfied with the trial, select **Experiment > Store Latest Run**, so a new set of data may be graphed. If not satisfied, select **Experiment > Clear Latest Run**, and collect a new set of data. ***NOTE**: If the temperature does not change, **repeat the trial**.*

25. Save the file before proceeding to prevent accidental loss of data. Empty the water down the drain. Dry the cup and the tip of the probe.

⚠ ***Keep rubbing alcohol away from all flames. All flames in the lab should be out.***

26. Repeat steps 20-25, using rubbing alcohol in the place of water and wrapping the tip with a fresh piece of paper towel or 2-3 layers of Kimwipe® tissue. Upon completion, pour the rubbing alcohol into the designated waste container.

EXTENSION

Place a couple drops of water on the back of your hand. Gently blow over the surface of the drops. How does it feel? Dry off the water and repeat using rubbing alcohol. Do you notice any difference? Can you think of ways this observation may have any uses?

Name____ Lab Section______________

PRELAB QUESTIONS

1. Write balanced chemical equations using proper phase labels for these reactions:

   a) Iron metal reacts with oxygen gas to produce solid iron (III) oxide, also known as rust.

   b) Solid calcium carbonate is added to a solution of hydrochloric acid, yielding an aqueous solution of calcium chloride, water, and carbon dioxide gas.

2. Identify each of the processes below as endothermic, exothermic, or neither.

Process	**Endothermic, exothermic, or neither?**
A hydrogen balloon is ignited by a flame at the end of a candle, causing the balloon to explode with a big ball of fire.	
The vial inside a chemical cold pack is broken, bringing the chemicals into contact with each other, causing the pack to become cold.	
The process of melting ice into water.	
The process of freezing water into ice.	

3. A chemical reaction produced a gas. You know it must be hydrogen, oxygen, or carbon dioxide. How may a wood splint be used to determine the gas produced?

4. Which safety precautions, if any, must be observed during this lab activity?

Name______________________________________ Lab Section_____________

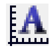
Partner's Name________________________________

DATA

Parts 1 and 2	**Baking Soda and Vinegar**	**Hydrogen Peroxide and Yeast**
Initial Temperature (Before adding baking soda)		
Temperature Reached (Where it leveled off or came close to leveling off)		
Did the temperature increase, decrease, or stay the same?		
What was the change in temperature?		
Was the reaction endothermic, exothermic, or neither?		
What happened to the flaming splint when it was placed into the gas?		**X X X X**
What happened to the glowing splint when it was placed into the gas?	**X X X X**	
Which gas was produced by this reaction?		
Part 3	**Water**	**Rubbing Alcohol**
Initial Temperature (Before removing probe from liquid)		
Temperature Reached (Where it leveled off or came close to leveling off)		
Did the temperature increase, decrease, or stay the same?		
What was the change in temperature?		
Was the evaporation process endothermic, exothermic, or neither?		

POSTLAB QUESTIONS

1. When finished with all of the trials:

    - Autoscale the graph by clicking the **Autoscale** icon  on the toolbar.
    - Title the graph by selecting **Options > Graph Options** and entering a title.
    - Add a text annotation for each of the four trials by selecting **Insert > Text Annotation**.
    - Drag the arrows so that each one points to a different trial on the graph. Avoid positioning the arrows near the beginning of a trial, since there is usually a significant amount of overlap in data. Also, avoid overlapping the arrows with each other. Label each of the trials by adding text to each of the text boxes. Drag the text boxes, if necessary, to make the graph look neat and organized.
    - Save the file for a final time after these additions. Make sure that each person in the pair or group has an electronic copy of this file. If desired, you may also print out a copy of the graph.

2. Write a **balanced chemical equation** using the proper **phase labels** for the reactions observed in Parts 1 & 2 of this lab.

    a) Baking Soda and Vinegar: Solid sodium hydrogen carbonate (sodium bicarbonate) reacts with an aqueous solution of acetic acid to produce an aqueous solution of sodium acetate, water, and the gas that was produced by this reaction.

    b) Hydrogen Peroxide and Yeast: An aqueous solution of hydrogen peroxide (H_2O_2) decomposes in the presence of a yeast catalyst to yield water and the gas produced by this reaction. (Note: Yeast is an organism, not a chemical, so the word “yeast” may be used in the place of a chemical formula.)

3. How did you determine which gas was produced in Parts 1 & 2 of this lab?

4. Explain how you determined whether the reactions in Parts 1 & 2 of this lab were endothermic or exothermic.

5. **Circle one word** in each set of parentheses that best complete this sentence:

   - The evaporation of rubbing alcohol is (**more** or **less**) (**endothermic** or **exothermic**) than the evaporation of water. Then explain your choices.

6. What did you observe **in this experiment** to prove that the purpose of sweating is to cool a person down?