EXPERIMENT

Identification of Gases

Hands-On Labs, Inc.
Version 42-0189-00-02

Review the safety materials and wear goggles when working with chemicals. Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

You will learn the properties of gases. You will investigate a series of chemical reactions that generate different gases with unique properties. You will generate a series of gases and explore the properties of gases through flame tests and chemical reactions. You will also use your results to identify an "unknown" gas.

Learning Objectives

Upon completion of this laboratory, you will be able to:

- Define solids, liquids, and gases.
- Identify the unique properties of gases.
- Explain how gases are identified.
- Describe a gas generation tube and how it is used to isolate gases.
- Perform flame and chemical tests on isolated gases from controlled experiments.
- Categorize gases produced in experimental reactions.
- Analyze experimental results to identify unknown gases.

Time Allocation: 3 hours

Materials

Student Supplied Materials

Quantity	Item Description
1	Aluminum pie pan
1	Baking soda, 1 tablespoon
1	Box of matches
1	Coffee cup
1	Dish soap
1	Hydrogen peroxide, 3% 20 mL
1	Metal spoon
1	Pair of scissors, 4 in
1	Roll of paper towels
1	Sheet of white paper
1	Source of tap water
4	Toothpicks
1	White vinegar, 20 mL

HOL Supplied Materials

Quantity	Item Description
1	Drinking straw
1	Gas assembly, copper and plastic tubing in rubber stopper
1	Gas assembly, plastic tube in rubber stopper
2	Pairs of gloves
1	Pair of safety goggles
1	Permanent marker
4	Test tubes, 13 x 100 mm
1	Test tube cleaning brush
3	Short, thin-stem pipets
1	Well plate - 24
1	Experiment Bag: Identification of Gases (or Properties of Gases) 2 - Antacid tablets in bag 2”x 3” 1 - Bromothymol blue- 4 mL in Pipet 1 - Calcium hydroxide, 6 mL in dropper bottle 1 - Hydrochloric acid, 2.0 M, 20 mL in dropper bottle 3 - Pipet bulb, wide-neck with 1/4” stem 1 - Manganese, 4-6 pieces in bag 2” x 3” 1 - Mossy zinc, 4-6 pieces in bag 2” x 3”

***Note:** To fully and accurately complete all lab exercises, you will need access to:*

1. A computer to upload digital camera images.
2. Basic photo editing software, such as Microsoft Word® or PowerPoint®, to add labels, leader lines, or text to digital photos.
3. Subject-specific textbook or appropriate reference resources from lecture content or other suggested resources.

***Note:** The packaging and/or materials in this LabPaq kit may differ slightly from that which is listed above. For an exact listing of materials, refer to the Contents List included in your LabPaq kit.*

Background

Matter

Matter is defined as any substance that has mass and volume. Matter consists of atoms, which are the building blocks of molecules and compounds. Particles exist in one of three **states of matter:** solid, liquid, or gas. The states of matter are distinguishable by having either a fixed or fluid structure or volume. The **solid** phase of matter consists of particles that are closely packed into a fixed volume and shape. The **liquid** phase of matter has a fixed volume but a fluid shape, giving it the ability to conform to the shape of its container. A **gas** phase of matter has no fixed volume or shape, conforming to both the shape and the volume of its container. See Figure 1.

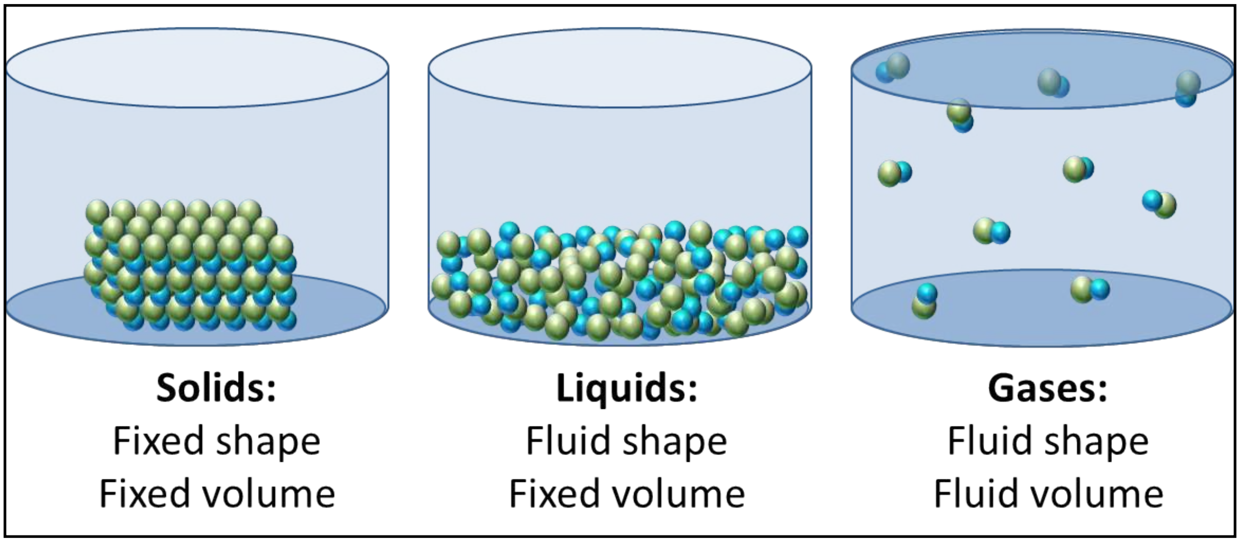

Figure 1. Properties of solids, liquids, and gases.

Unique Properties of Gases

Unlike solids and liquids, gases have great mobility, and gas molecules are in a constant state of random motion. Properties of gases are dependent upon the pressure, temperature, and volume of the container they are in, as well as the number of gas particles. Gas laws are equations that can be used to find unknown values of pressure, temperature, or volume.

Gases are composed of one or more elements. They are often difficult to detect because many are colorless and odorless. The human senses are unable to detect the nitrogen, oxygen, and argon gases that are the primary components of the air we breathe. One way of detecting a gas is to observe its behavior in a chemical reaction. Gases that are produced by a chemical reaction are commonly observed as bubbles. For example, when a metal is placed in an acidic solution, bubbles may form indicating that a gas has been produced. See Figure 2.

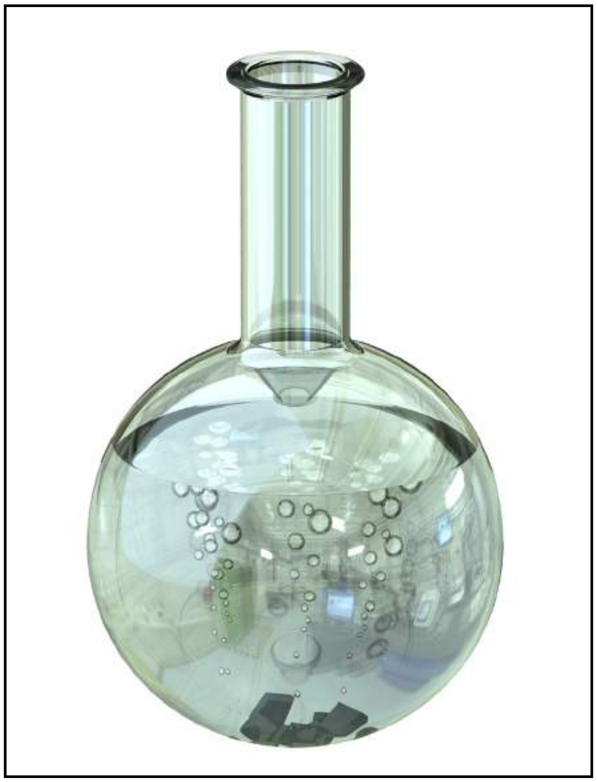

Figure 2. Gas bubbles generated by acid/metal reaction. ©Jan Kaliciak

Identifying Gases

Gases may be identified by their behavior in chemical reactions. For example, carbon dioxide (CO_2) can be identified through its reaction with limewater (calcium hydroxide, $Ca(OH)_2$), a clear and colorless liquid. The products of the CO_2 and limewater reaction are water and a white precipitate. Limewater does not react with other gases, such as hydrogen or oxygen, in a similar fashion. Therefore, if tasked with determining whether an unknown gas sample is composed of CO_2, one could test the gas in the presence of limewater.

Gases may also be identified by their behavior in the presence of fire. **Flammable gases**, such as hydrogen, butane, and methane gas, burn in the presence of flame, and can be explosive in the correct proportions. See Figure 3. **Oxidizers**, such as chlorine and oxygen gas, facilitate combustion of other materials. For example, fanning oxygen over a wood fire causes flames to surge and the carbon that composes the wood burns more quickly. **Inert gases**, such as nitrogen gas and noble gases, are not flammable.

Figure 3. Methane burning from a well. © Leonid Ilkan

Flammable gases are used by a variety of everyday technologies. Gas grills are fueled by propane gas (C_3H_8), many homes are heated by natural gas (a mixture of gases), and lighters contain "lighter fluid", which is pressurized butane gas (C_4H_{10}). However, not all flammable gases may be safely used in daily practices. For example, hydrogen gas is a highly flammable gas that filled the Hindenburg, a blimp that burned in an infamous disaster in 1937.

Isolating Gases

To test the gas or gases produced during a chemical reaction, the gas must first be captured. Moreover, the gas sample must not be contaminated by gases that compose the air we breathe. A **gas generation tube** is an apparatus that contains the start reactants involved in a chemical reaction and captures gases as they are produced. In the following experiment, a simple gas generation tube will be assembled with a test tube, a stopper having a short plastic tube through its middle, and a pipet bulb. As shown in Figure 4, the reactants are placed in the glass test tube, which is sealed with the stopper. The pipet bulb is filled with water, inverted, and placed over the stopper. As the chemical reaction takes place, gas bubbles move up through the test tube and into the top of the pipet bulb. The gas slowly displaces the water in the pipet bulb; trickling down the outside of the test tube as gas takes its place in the pipet bulb. Once all of the water has been displaced, the pipet bulb may appear empty, but it is filled with the gas produced by the reaction. The isolated gas can then be subjected to further experimentation and flame tests.

Figure 4. Gas generation tube.

Several gases are produced frequently in the laboratory and it is important to be able to identify them by their physical and chemical properties. The gases that will be investigated in the following experiment are hydrogen (H_2), oxygen (O_2), and carbon dioxide (CO_2). These gases will be generated using small-scale techniques through the following reactions:

$$\text{Hydrogen } (H_2)\text{: } Zn(s) + 2HCl(l) \rightarrow ZnCl_2(s) + H_2(g)$$

$$\text{Oxygen } (O_2)\text{: } 2H_2O_2(l) \xrightarrow{MnO_2} 2H_2O(l) + O_2(g)$$

$$\text{Carbon dioxide } (CO_2)\text{: } NaHCO_3(s) + 2HCl(l) \rightarrow NaCl(s) + H_2O(l) + CO_2(g)$$

Exercise 1: Gas and Flame Tests

In this exercise you will produce a series of gases and monitor their behavior in the presence of a flame.

Caution: *Wear safety goggles and gloves during each exercise. You will handle strong acids and gases during the experimentation. Do not perform this experiment in a carpeted room.*

Procedure

Part 1

1. Fill a cup with tap water.
2. Put on your safety gloves and goggles.
3. Place a sheet of paper towel on your working surface.
4. Use a small amount of paper towel to "wedge" a clean, empty test tube into the well plate so that the test tube stands vertically in the well. See Figure 5.

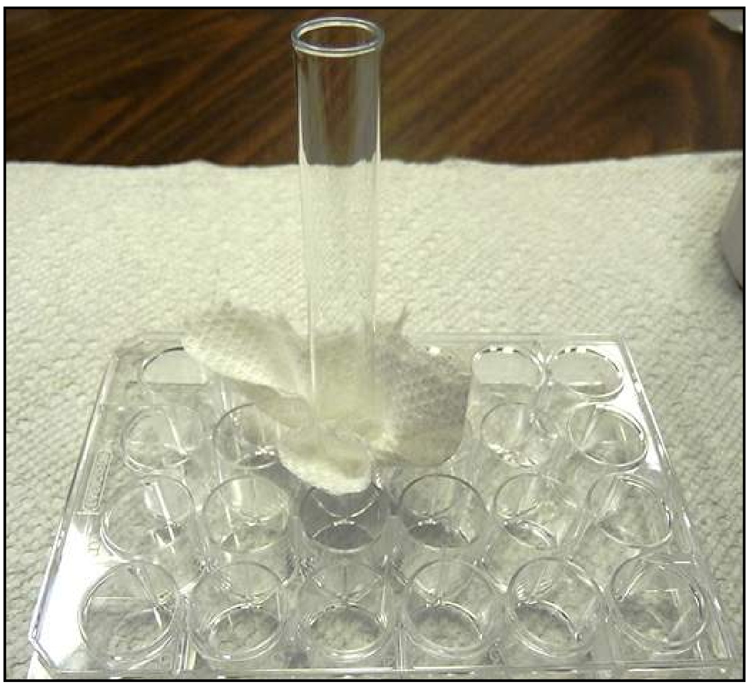

Figure 5. Test tube standing vertically in a well.

5. Place the well plate with the vertically standing test tube onto the aluminum pie plate.

Note: *The chemicals will drip down the sides of the test tube; the aluminum pie plate will protect your working surface from the chemicals.*

6. Fill the test tube ¾ full with the 2M hydrochloric acid (HCl).
7. Add 3 pieces of Zn (mossy zinc) to the test tube containing the HCl.

8. Working quickly, gather the rubber test tube stopper with the short, straight plastic tube through its middle. Firmly place the stopper in the test tube.

9. Fill an empty, clean, plastic pipet bulb with tap water from the cup that was set aside in Step 1. See Figure 6.

Note: *Fill the pipet bulb with water the same way you would fill a pipet with water, squeeze the empty pipet bulb, place it in the water and release the bulb, filling it with the water. The water will remain in the pipet bulb, even when it is inverted.*

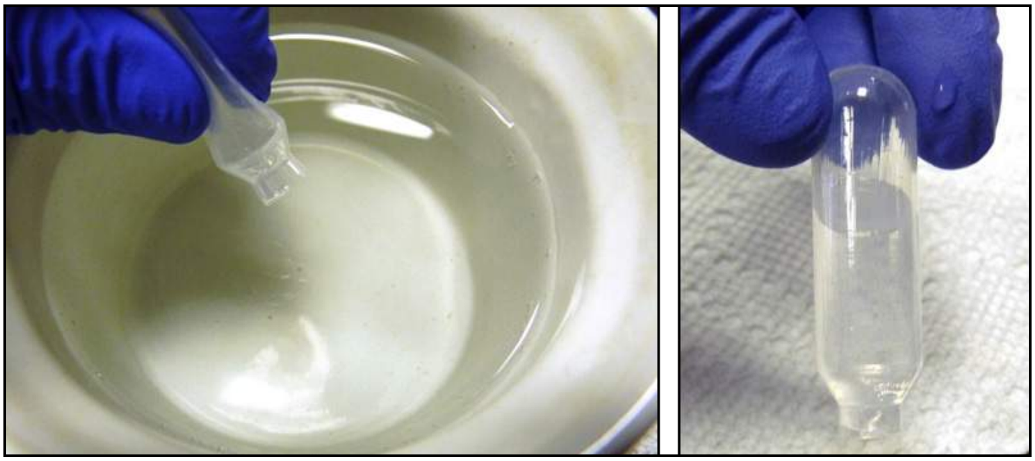

Figure 6. Filling the pipet bulb with tap water.

10. Quickly invert the tap water filled pipet bulb and place it over the stopper and tube. The gas generation tube should appear as shown in Figure 7.

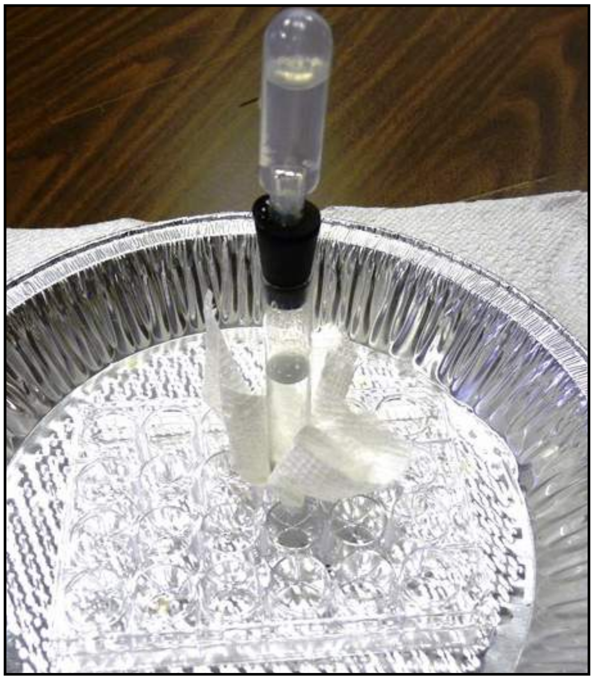

Figure 7. Gas generation tube, completely set up.

11. Observe the reaction between the zinc and hydrochloric acid and record your observations in **Data Table 1** of your **Lab Report Assistant**.

12. Allow the HCl + Zn reaction to continue until ***almost*** all of the water in the pipet bulb has been displaced. This may take anywhere from 2 to 10 minutes. Check the pipet often to ensure that a slight amount of water remains in the pipet bulb.

13. Remove the pipet bulb from the gas generation tube, **quickly placing your thumb under the opening to prevent any gas from escaping.**

14. Light a match.

15. With your thumb still covering the pipet bulb opening, hold the bulb sideways with its mouth about 1 cm from the flame.

16. Remove your thumb from the opening and gently squeeze a small portion of the contents of the pipet into the flame.

17. Record your observations of the reaction of the gas and flame in **Data Table 1**.

Note: *If you would like to repeat Step 16, you may refill the pipet bulb with tap water and once again place it on the rubber stopper. Repeat steps 12 – 16 as necessary. Gas is produced more rapidly the longer HCl and Zn are in contact.*

18. Once you have recorded your observations, prepare another sample of hydrogen gas for use in Part 3. Fill an unused pipet bulb with tap water and place it over the stopper of the test tube containing the HCl and Zn.

19. Use the permanent marker to label a clean, short stem pipet "tap water."

20. Use the labeled pipet to fill 1 of the wells of the 24-well plate half full of tap water.

21. When the pipet bulb is filled approximately 2/3 with gas, remove the pipet from the gas generation tube, **quickly placing your thumb under the opening to prevent any gas or water from escaping.**

22. Place the pipet bulb, **with the opening facing down,** into the well containing tap water. See Figure 8. Reserve the captured gas sample for use in Part 3.

Figure 8. Pipet bulb, facing down, in tap water.

23. Remove the stopper with the small plastic tube from the reaction and use a paper towel to remove any excess solution from the assembly. It will be used in the remainder of the experiment.

Part 2

24. Use the permanent marker to label an empty, clean, short-stem pipet "hydrogen peroxide."
25. Use a small amount of paper towel to "wedge" a clean, empty test tube into the well plate so that the test tube stands vertically in the well as in Part 1.
26. Use the "hydrogen peroxide" pipet to fill the test tube approximately 1 cm from the top with hydrogen peroxide (3% H_2O_2).
27. Add 3 pieces of Mn to the test tube containing the H_2O_2.
28. Working quickly, gather the rubber test tube stopper with the short, straight plastic tube through its middle. Firmly place the stopper in the test tube.
29. Fill an empty, clean, plastic pipet bulb with tap water.
30. Quickly invert the tap water filled pipet bulb and place it over the stopper and tube.
31. Observe the reaction that occurs between the manganese and the hydrogen peroxide and record your observations in **Data Table 1.**
32. Allow the H_2O_2 + Mn reaction to continue until *almost* all of the water in the pipet bulb has been displaced. This may take anywhere from 2 to 10 minutes. Check the pipet often to ensure that a slight amount of water remains in the pipet bulb.

33. Light a match and transfer the flame to a wooden toothpick. ***Extinguish both flames*** and working quickly, while the toothpick is still glowing, remove the pipet bulb from the gas generation tube and insert the toothpick into the pipet bulb.

Note: *If no observable action happened, or if you would like to repeat Step 33, you may refill the pipet bulb with tap water and once again place the pipet bulb on the rubber stopper. Repeat steps 32 – 33 as necessary. Gas is produced more rapidly as* H_2O_2 *and Mn are in contact.*

34. Record your observations of the oxygen gas + smoldering toothpick in **Data Table 1**.

35. Dispose of the used pipet bulb in the trash.

36. Do ***NOT*** disturb the Mn + H_2O_2 gas generation tube. It will be used in Part 3.

Part 3

37. Locate the pipet bulb 2/3 full of hydrogen gas that was reserved at the end of Part 1.

38. Remove the pipet bulb from the well plate, ***and quickly place*** the pipet bulb on top of the H_2O_2 + Mn gas generation tube reserved from Part 2.

39. Allow gas to collect in the pipet bulb until almost all of the water has been displaced.

Note: *The bulb should be 2/3 filled with hydrogen gas from Part 1 and 1/3 filled with oxygen gas from Part 2.*

40. Light a match.

41. Working quickly, remove the pipet bulb from the gas generation tube and gently squeeze a small portion of the contents of the pipet into the flame. Observe what happens as a result of the gas mixture contacting the flame and record in **Data Table 1**.

Questions:

A. Write a balanced chemical equation describing the reaction of zinc and hydrochloric acid.

B. What gas was produced by the reaction of zinc and hydrochloric acid? How did this gas behave in the presence of fire?

C. What gas was produced by the decomposition of hydrogen peroxide? What happened when the smoldering toothpick came in contact with the gas?

D. Compare the behavior of the mixture of gases with each solitary gas in the presence of flame.

E. Outline the procedures you would use to determine whether a gas sample was composed of hydrogen or oxygen.

Exercise 2: Gas and Reactions

In this exercise you will expose a series of gases to a variety of chemicals. You will use your results to identify an "unknown" gas.

Part 1

1. Put on your safety gloves and goggles.
2. Add 20 drops of limewater ($Ca(OH)_2$) to a clean well of the 24-well plate.
3. Gather the gas assembly stopper with the hooked copper tube. Set the stopper aside, near the well plate.
4. Place approximately a pea-sized amount of baking soda (sodium bicarbonate, $NaHCO_3$) in a clean, dry test tube.
5. Use the permanent marker to label a short stem pipet "vinegar." Fill this pipet with household vinegar (acetic acid, CH_3COOH).
6. Holding the test tube of baking soda over the sink, add the pipet full of vinegar to the test tube.

Note: *The test tube will overflow during the baking soda + vinegar reaction. The gas produced is* CO_2.

7. After the overflow has stopped, ***immediately*** place the hooked gas assembly stopper into the test tube and insert the end of the stopper tube in the well containing the limewater, as shown in Figure 9.

Figure 9. Hooked gas assembly in the limewater well.

8. Observe the reaction between the limewater ($Ca(OH)_2$) and the CO_2. Record your observations in **Data Table 2** of your **Lab Report Assistant**.

Part 2

9. Use scissors to snip off the tip of the pipet from the bromothymol blue (BTB) indicator.

Note: *Bromothymol blue, or "BTB", remains blue in the presence of a base and turns yellow in the presence of an acid.*

10. Add 20 drops of BTB in a clean well of the well plate.
11. Place the gas assembly stopper with the hooked copper tube to the side of the well plate.
12. Place approximately a pea-sized amount of baking soda (sodium bicarbonate, $NaHCO_3$) in a clean, dry test tube.
13. Fill the "vinegar" pipet with household vinegar (acetic acid, CH_3COOH).
14. Holding the test tube of baking soda over the sink, add the pipet full of vinegar to the test tube.

Note: *The test tube will overflow during the baking soda + vinegar reaction. The gas produced is* CO_2.

15. After the overflow has stopped, ***immediately*** place the hooked gas assembly stopper into the test tube and insert the end of the stopper tube in the well containing the BTB. Observe the reaction that occurs.
16. Gently set the test tube/gas assembly against the well plate for a moment, so that nothing leaks from the assembly and you are able to perform the next step. See Figure 10.

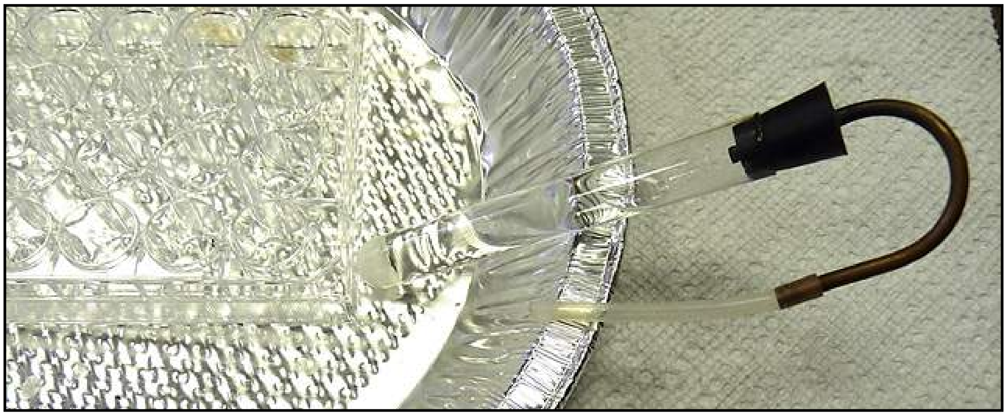

Figure 10. The test tube + gas assembly resting against the well plate.

17. Light a match and transfer the flame to a wooden toothpick. Working quickly, while the toothpick is still on fire, remove the gas assembly from the test tube and insert the toothpick into the top of the test tube.

18. Record your observations of the carbon dioxide gas + flaming toothpick in **Data Table 2**.

19. Record your observations from the reaction between the CO_2 and BTB in **Data Table 2**.

Part 3

20. Place 20 drops of $Ca(OH)_2$ in an unused, clean well of the well plate.

21. Place the gas assembly stopper with the hooked copper tube to the side of the well plate.

22. On a sheet of clean, white paper, use a clean spoon to crush a piece of the antacid tablet into a powder, see Figure 11.

Figure 11. Crushing the antacid tablet.

23. Carefully transfer the crushed antacid tablet into a clean, dry test tube.

24. Fill the "tap water" pipet with tap water.

25. Holding the test tube with the crushed antacid tablet over the sink, add the water from the pipet into the test tube.

Note: *The test tube may overflow during the antacid + water reaction.*

26. After the overflow has stopped, ***immediately*** place the hooked gas assembly stopper into the test tube and insert the end of the stopper tube in the well containing the $Ca(OH)_2$.

27. Observe the reaction that occurs between the $Ca(OH)_2$ and antacid + water gas.

28. Gently set the test tube/gas assembly against the well plate for a moment, so that nothing leaks from the assembly and you are able to perform the next step.

29. Light a match and transfer the flame to a wooden toothpick. ***Extinguish both flames*** and working quickly, while the toothpick is still glowing, remove the gas assembly from the test tube and insert the toothpick into the top of the test tube.

30. Record your observations of the gas + smoldering toothpick in **Data Table 2**.

31. Record your observations from the reaction that occurred between the $Ca(OH)_2$ and the antacid tablet in **Data Table 2**.

Part 4

32. Add 20 drops of $Ca(OH)_2$ to a clean, dry test tube.

33. Lower the drinking straw in the test tube, just above the $Ca(OH)_2$ solution. Gently blow on the $Ca(OH)_2$ solution for up to 15 seconds.

34. Observe the reaction and record your observations in **Data Table 2**.

Cleanup:

35. Wash the equipment with soap and water and allow to thoroughly dry.

36. Return the cleaned equipment to the lab kit for future use.

Questions

A. The chemical equation for the reaction of baking soda (sodium bicarbonate, $NaHCO_3$) and vinegar (acetic acid, CH_3COOH) may be written as two steps. Fill in the missing information for the chemical equation.

Step 1: ____________ + ____________ --> $CH_3COONa(aq) + H_2CO_3(l)$

Step 2: $H_2CO_3(l)$ --> $H_2O(l)$ + ____________

B. Write a chemical equation for the reaction of CO_2 and limewater ($Ca(OH)_2$). Write a physical description of the products formed.

C. When the bromothymol blue (BTB) was exposed to the CO_2 gas, what color was the solution? Did the BTB indicate presence of an acid or base? Explain your answer.

D. Did the reaction between the antacid tablet and the tap water produce hydrogen, oxygen, or carbon dioxide gas? Support your answer with results from your work in both Exercise 1 and Exercise 2.

E. Based on your observation of the reaction that occurred when limewater was exposed to your breath, what gas did you exhale? Support your answer with your observations in **Data Table 2**.