The Candle Snuffer

Properties of Carbon Dioxide

Introduction

Carbon dioxide is an odorless, colorless gas. Place lit candles on a trough, create some invisible CO_2 gas in a beaker, and then "pour" the CO_2 down the trough. The gas becomes dramatically visible to the students as successive candles are extinguished.

Concepts

- Properties of gases
- Combustion
- Gas density

Materials

Sodium bicarbonate, $NaHCO_3$, 40 g (baking soda)
Hydrochloric acid, 3 M, HCl, 40 mL
Balance, 0.1-g precision
Beaker, 400-mL
Buret clamp
Clay, modeling
Erlenmeyer flask, 1000-mL
Graduated cylinder, 100-mL
Lighter
Ring stand
Tea candles, 5
Trough, clear plastic, 30 inches
Weighing dish

Safety Precautions

Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please consult current Material Safety Data Sheets for additional safety, handling, and disposal information. The resulting solution may be flushed down the drain with excess water.

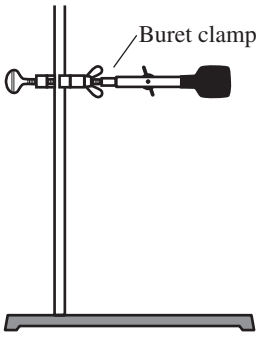

Figure 1.

Procedure

1. Attach a buret clamp to the ring stand. Place the clamp about seven inches above the base. Rotate the clamp so that it faces away from the ring stand base (see Figure 1).
2. Equally space and attach four tea candles to the trough with modeling clay, so that the candles are angled up from the surface of the trough.
3. Place the fifth candle in the 400-mL beaker and position the beaker at the bottom of the trough.
4. Place the top of the trough on the buret clamp and the bottom of the trough on the beaker. Secure the bottom in place with a piece of modeling clay (see Figure 2).
5. Adjust the position of the tea candles so that they are parallel to the bench top.
6. Mass 40 g of sodium bicarbonate and transfer the sodium bicarbonate to the 1000-mL Erlenmeyer flask.
7. Measure out 40 mL of hydrochloric acid in a graduated cylinder.
8. Light the five tea candles.
9. Gently pour the hydrochloric acid into the flask with the sodium bicarbonate. Bring the flask up to the edge of the trough and tilt to pour the gas down the trough.
10. Watch the candle flames go out one by one as the carbon dioxide "pours" down the trough!

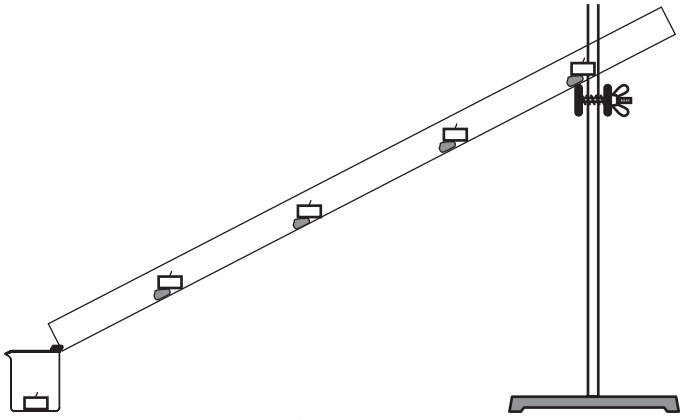

Figure 2.

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Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The resulting solutions may be rinsed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tips

- Acetic acid (1 M) or vinegar may be used in place of the hydrochloric acid.
- Practice the demonstration until you are comfortable producing the correct amount of carbon dioxide when adding the acid to the beaker.
- Pick a demonstration area that is free from drafts and air currents. This is key.
- A 2-L soda pop bottle may be used in place of the Erlenmeyer flask. This can be compressed to expel all the gas to ensure that all five candles go out.
- A variation of the demonstration uses an aquarium tank. Use blocks to place the candles at different heights. Place the beaker with baking soda in the bottom of the aquarium. Slowly add the acid to the beaker. The CO_2 will displace the air, extinguishing the candles from the bottom to the top. Experiment with the amounts of baking soda and acid to produce enough CO_2 to extinguish all the candles.

Discussion

When a dense solution of sugar is gently poured through water, little mixing occurs even though the sugar solution and the water are quite soluble. The water layer sits on top of the sugar solution. Soluble gases act in the same way. Carbon dioxide has a density of 1.80 kg/m^3 at STP, while that of air is 1.29 kg/m^3. This difference in density is demonstrated by the act of "pouring" the carbon dioxide over the candles. The carbon dioxide gas is generated when an acid is added to the sodium bicarbonate.

$$\underset{\textit{Sodium bicarbonate}}{NaHCO_3(s)} + \underset{\textit{Proton from the acid}}{H^+(aq)} \rightarrow \underset{\textit{Sodium ion}}{Na^+(aq)} + \underset{\textit{Water}}{H_2O(l)} + \underset{\textit{Carbon dioxide}}{CO_2(g)} \qquad \textit{Equation 1}$$

This carbon dioxide gas is poured down the trough and the candles are extinguished one by one as the column of CO_2 flows over them.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Answers to The Candle Snuffer Worksheet *(Student answers will vary.)*

The reaction taking place in the beaker is:

$$\underset{\textit{Vinegar}}{CH_3CO_2H(aq)} + \underset{\textit{Baking Soda}}{NaHCO_3(s)} \rightarrow \underset{\textit{Carbon dioxide}}{CO_2(g)} + \underset{\textit{Acetate}}{CH_3CO_2^-(aq)} + \underset{\textit{Water}}{H_2O(l)}$$

1. What do the candles need to remain lit?

   The candles need a source of oxygen.

2. In what order were the candles extinguished?

   The candles were extinguished from top to bottom.

3. Why were the candles extinguished?

   As the carbon dioxide flowed down the trough, the carbon dioxide displaced the air above each candle.

4. Carbon dioxide is soluble in air. Did the carbon dioxide from the reaction mix with the air? Why or why not?

   Because the candles were extinguished, the column of gases did not have any significant amount of oxygen, which it would if the carbon dioxide had mixed with the air.

5. Based on your observations, how does the density of the carbon dioxide compare to that of air?

   Because the carbon dioxide flowed down the trough, it must be more dense than the air it displaced.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *The Candle Snuffer* activity, presented by Jesse Bernstein, is available in *Properties of Carbon Dioxide* and in *Combustion Reactions*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *The Candle Snuffer* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Seeing the Invisible—Chemical Demonstration Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP7046	Seeing the Invisible—Chemical Demonstration Kit
S0042	Sodium Bicarbonate, $NaHCO_3$, 500 g
H0034	Hydrochloric Acid, HCl, 3 M, 500 mL

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

The Candle Snuffer Worksheet

The reaction taking place in the flask:

$$\underset{\textit{Vinegar}}{CH_3CO_2H(aq)} + \underset{\textit{Baking Soda}}{NaHCO_3(s)} \rightarrow \underset{\textit{Carbon dioxide}}{CO_2(g)} + \underset{\textit{Sodium acetate}}{NaCH_3CO_2(aq)} + \underset{\textit{Water}}{H_2O(l)}$$

1. What do the candles need to remain lit?

2. In what order were the candles extinguished?

3. Why were the candles extinguished?

4. Carbon dioxide is soluble in air. Did the carbon dioxide from the reaction mix with the air? Why or why not?

5. Based on your observations, how does the density of the carbon dioxide compare to that of air?