Finding the Density of Air

Density of Gases

Introduction

Archimedes' principle and the density of air are difficult concepts for many students to understand. This simple demonstration uses a balloon filled with dry ice to illustrate the buoyancy of air and determine the density of air.

Concepts

- Conservation of mass
- Density
- Buoyancy

Materials

Dry ice

Balance, electronic, 0.01 precision

Balloon

Funnel, powder

Gloves, insulated type (for handling dry ice)

Rubber stopper

Tape measure

Safety Precautions

Dry ice is an extremely cold solid (-78.5°C) and will cause frostbite. Do not touch dry ice to bare skin; always handle with proper gloves. Wear safety glasses or chemical splash goggles. Wash hands thoroughly with soap and water before leaving the lab. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Inflate a balloon a few times and insert the stem of a powder funnel into the mouth of the balloon.
2. Place several pieces of dry ice and a rubber stopper inside the balloon, remove the funnel, and tie off the balloon. *(The rubber stopper prevents the balloon from rolling off the balance).*
3. Place the balloon on an electronic balance and tare the balance to zero. Observe what happens to the mass as the dry ice sublimes and the balloon expands. *(The mass appears to decrease).*
4. When the balloon diameter is approximately 5–10 cm, record the apparent mass loss of the balloon on the balance. Remove the balloon from the balance and measure and record its circumference using a tape measure. Also record the room temperature and barometric pressure.
5. See the discussion section for analysis of the results.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. All materials may be disposed of according to Flinn Suggested Disposal Method #26a. Extra dry ice may be placed in a well-ventilated area and allowed to sublime.

Tips

- Slabs of dry ice may be broken or cracked using a hammer. Wrap the dry ice slab in a towel or place in a zipper-lock bag before striking it with a hammer. Dry ice may be obtained from a local ice cream store, ice company, or grocery store. Look in your local yellow pages under ice or dry ice. Dry ice costs may vary from $8.00 to $13.00 per 10 lbs, but some sources may supply it free for educational purposes.
- It is helpful to use a larger quantity of dry ice so that the mass and volume difference will be as great as possible. This lowers the error often expected in this demonstration and produces better results

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Discussion

Air is a fluid, which means that objects can be buoyed in air, just as in water. According to Archimedes' principle, all objects that are suspended in a fluid, either gas or liquid, are buoyed up by a force equal to the weight of the displaced fluid. Additionally, the degree to which these objects are buoyant depends on the density of both the object and the fluid. The smaller the density of the fluid, the smaller the buoyant force.

In this demonstration, students will measure the density of the gas generated in a balloon by dry ice, or solid carbon dioxide (CO_2). Carbon dioxide is normally found in its gaseous state, although it forms a frosty, white solid at -78.5°C. This solid carbon dioxide undergoes sublimation at room temperature, meaning that it transforms directly from the solid phase to the gaseous phase without first melting to a liquid.

If dry ice is placed in a closed system at room temperature, the escaping gases are trapped and therefore can be measured. Approximating the volume of the gas is fairly easy and is accomplished by measuring the diameter or circumference of the balloon. Measuring the mass of the air is more problematic. However, using the knowledge of buoyancy in air, we know that the mass of the air displaced by the system, in this case the balloon, will be equal to the mass of the gas inside the system. Because balances work by measuring the downward force exerted by an object, the mass of the balloon appears to decrease as the balloon inflates and becomes more buoyant. This apparent mass loss is the mass of the air that is displaced by the balloon as it is suspended in the surrounding air. Using the measured mass and volume, the density of air can be determined. The experimental value can be compared to the accepted values given in the CRC Tables, which are partially reproduced below.

Density of Dry Air

	Barometric Pressure in cmHg		
Temperature	74.0	75.0	76.0
20	0.001173	0.001189	0.001206
21	169	185	201
22	168	181	197
23	161	177	193
24	157	173	189

Sample Data and Results

1	Barometric pressure (mmHg)	740
2	Room temperature (°C)	24
3	Apparent mass loss of the balloon (g)	1.96
4	Circumference of the balloon (cm)	46.8
5	Radius of the balloon (cm) (line 4/2π)	7.45
6	Volume of the balloon (cm^3) ($4\pi/3$ x [line 5]^3)	1733
7	Density of air (g/cm^3) (line 3/line 6)	0.001131
8	Accepted density of air (g/cm^3) (from CRC Table)	0.001157
9	Percent error ([line 7 – line 8]/line 7)	2.3%

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
Constancy, change, and measurement
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, conservation of energy and increase in disorder

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Finding the Density of Air* activity, presented by Annis Hapkiewicz is available in *Density of Gases*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Finding the Density of Air* are available from Flinn Scientific, Inc.

Catalog No.	Description
OB2141	Balance, Electronic, Flinn
AP1900	Balloons, Latex, 119, Pkg of 20
FB0524	Tape Measure, Metric, Pkg of 10
AP2268	Powder Funnel, Polypropylene

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