Gas Laws

Introduction to Gas Laws

Introduction

Use this activity stations lab to introduce students to the basic principles of the gas laws before studying complex equations and definitions.

Concepts

- Gas laws
- Volume of gas
- Pressure
- Density

Materials

	Activity Title			
Materials Required	Balloon on a String	Pressure Bottle	Pressure and Temperature	Pressure and Volume
Balloon, Mylar®, inflated with helium	1			
Bicycle pump w/pressure gauge		1		
Cartesian Diver Pump Cap "Fizz-Keeper"			1	1
Heat gun	1			
Ketchup, packet				1
Medicine dropper				1
Paperclips	1 to 5			
Pressure bottle kit with syringe		1		
Petrolatum		2 g		
Soda bottle, plastic, 2 L			1	1
Straw	19 piece			
String	68 piece			
Tape	3–5 pieces			
Thermometer, aquarium			1	
Water				1.8 L

Safety Precautions

The heat gun used in this activity gets very hot. Do not ever aim the gun at a person. The 2-L plastic bottle is safe if used properly. The bottle should not be inflated beyond 100 psi. Even if the bottle should explode, the plastic construction will only result in a quick release of air (perhaps with a loud noise) and a hole in the bottle. Eye protection should be worn during all experiments. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines.

Preparation

Part A. Balloon on a String

1. Cut a 1″ piece of straw and tape it to the side of the Mylar® balloon.
2. Cut a string long enough to attach one end to the lab table and the other end to the ceiling.
3. Insert the cut string through the straw attached to the balloon.
4. Tape one end of the string to the table and the other end to the ceiling.
5. Attach the fewest number of paperclips possible so that the balloon hovers near the bottom of the string. *Note:* The

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balloon should not be completely filled to allow room for expansion.

Part B. Pressure Bottle (available in the Pressure Bottle Kit, Catalog No. AP5930, from Flinn Scientific)

How the Bottle Works

The pressure bottle is an ordinary 1-L soda bottle with a tire valve mounted in the cap. When the cap is screwed on tightly and an air-tight seal is obtained, the bottle can be pumped up just like a tire. The pressure can be varied inside the bottle by adding or releasing air using the air valve mounted in the cap. The bottle can be "inflated" using any pump that is normally used to pump up a tire. Pumps with a built-in pressure gauge are the safest, easiest, and most convenient to use.

1. Place a small bead of petroleum jelly around the rim of the bottle.
2. Cap the bottle and tighten.

Part C. Pressure and Temperature (no preparation required)

Part D. Pressure and Volume

1. Obtain a ketchup packet that will float in water.

Procedure

Part A. Balloon on a String

1. Turn on the heat gun and aim it towards an empty pocket of air in the balloon.
2. Continue to heat the balloon until it travels up the string.
3. Observe physical traits of the balloon as it rises and falls. *Hint:* In terms of volume, mass and density.

Part B. Pressure Bottle

1. Adjust the volume of air inside a 10-mL hypodermic syringe to read exactly 10.0 mL. Then seal the syringe by firmly pressing a tip cap onto its open end.
2. Remove the bottle cap and place the syringe inside the pressure bottle. Replace the cap and be certain that the cap is as tight as possible.
3. Record the initial volume of gas in the syringe.
4. Pump air into the bottle to achieve a pressure of 50–60 psi on the tire gauge. **Do NOT exceed 100 psi.**
5. Record the final volume of gas in the syringe.
6. Release a small amount of air from the bottle by loosening the connection between the tire valve and the bicycle pump. Record the pressure and the volume of gas in the syringe.
7. Repeat step 6 until several measurements have been recorded.
8. Carefully release the pressure by loosening the connection between the pressure bottle-tire valve and the bicycle pump. When the pressure on the tire gauge measures close to zero, remove the tire valve from the pump.

Part C. Pressure and Temperature

1. Tape the aquarium thermometer inside the 2-L bottle.
2. Attach the Fizz-Keeper to the top of the bottle.
3. Record the initial temperature reading of the thermometer.
4. Pump the Fizz-Keeper 50 times.
5. Record the final temperature reading of the thermometer.

Part D. Pressure and Volume

1. Fill a 2-L plastic bottle almost full with water, leaving 1–2″ of air space at the top.
2. Place a ketchup packet and empty medicine dropper in the bottle. *Note:* Both the ketchup packet and the eye dropper should float.
3. Attach the Fizz-Keeper to the top of the bottle.
4. Pump the Fizz-Keeper while observing the ketchup packet and medicine dropper.
5. Remain pumping until both the ketchup packet and the medicine dropper sink.

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 water used in this lab may be rinsed down the drain according to Flinn Suggested Disposal Method #26b. Other apparatus may be dried (if necessary) and stored for future use.

Tips

- If the pressure bottle starts to leak air from the cap, remove the cap, run a bead of petroleum jelly around the liner of the cap, and retighten the cap on the bottle. Vaseline® may also be used in place of the petroleum jelly.
- Use 10 mL as the approximate volume of the syringe. The volume of the actual syringe will be one possible "experimental" error. Some students may want to measure it by displacement.
- If the bottle is replaced, be sure to avoid damaged bottles. Those with obvious flaws, scratches, or marks should be avoided. Do *not* use water bottles since they are not designed to withstand high pressures like soda bottles.

Discussion

French physicist, Jacques Charles (1746–1823) developed a law that related temperature to volume. At constant pressure, the volume of a given mass of an ideal gas increases or decreases by the same factor as its temperature (in Kelvin) increases or advances. As the balloon is heated the air inside the balloon increases in temperature. Since the mass remains constant as the balloon is heated its density decreases.

The systematic study of gases began almost 350 years ago with Robert Boyle (1627–1691). Boyle built a simple apparatus to measure the relationship between the pressure and volume of air. Based on a series of measurements of pressure changes when air is compressed and expanded, Boyle published his findings in 1662 which is known today as Boyle's Law. According to *Boyle's Law* the pressure of a gas is inversely proportional to its volume if the temperature and number of moles are held constant. This relationship may be expressed mathematically as $P \propto 1/V$ or by Equation 1 for the initial and final conditions designated as P_1 and V_1, and P_2 and V_2, respectively.

$$P_1V_1 = P_2V_2$$

Part C of this lab investigates the relationship between pressure and temperature. Joseph Louis Gay-Lussac developed an equation that explains the relationship between pressure and temperature known as Gay-Lussac's Law. It states that the pressure of a fixed mass and fixed volume of a gas is directly proportional to the gas's temperature. Therefore, as the pressure of the bottle increased so did the temperature.

Part D demonstrates the relationship between pressure, volume, and mass. As the pressure inside the bottle increases, the volume of air inside the medicine dropper decreases as it fills with water. This change in mass results in an increased density causing the medicine dropper to sink. The ketchup packet's mass remains constant, but the pressure of the bottle increases, which decreases the volume of the ketchup packet, causing it to sink.

Answers to Worksheet Questions

Part A. Balloon on a String

1. What happens to the mass of the balloon as the temperature increases using the heat gun?
   The mass of the balloon remains constant. Only if the balloon is physically opened to let air in or out would the mass change.
2. What happens to the volume as the balloon is heated?
   As the air inside the balloon is heated, the temperature and volume increase.
3. How does volume and mass affect the density of the balloon?
   As the air inside the balloon is heated, the temperature and volume increase while the mass remains constant. Therefore, the density decreases causing the balloon to float.

Part B. Pressure Bottle

4. Initial volume of gas in the syringe.
   Answers will vary.
5. Final volume of gas in the syringe at 50 psi.
   Answers will vary; however, the final volume should be less than the initial volume.
6. What is the relationship between pressure and the volume of the syringe?
   Once the pressure of the system (in the bottle) increases, the volume of air in the syringe decreases.

Part C. Pressure and Temperature

7. Initial temperature (°C) inside the bottle.
   Answers will vary.
8. Final temperature (°C) inside the bottle.
   Answers will vary (final temperature should be higher than the initial temperature).
9. What is the relationship between pressure and temperature?
   The more the fizz-keeper is pumped the higher the pressure inside the bottle. When the pressure is increased, the temperature is also increased.

Part D. Pressure and Volume

10. What happens to the volume of air in the medicine dropper as the pressure of the system increases?
    As the pressure increases, water enters the medicine dropper increasing the mass while decreasing the volume of air causing it to sink.
11. What causes the ketchup packet to sink?
    The ketchup packet does not change in mass. As the pressure of the system increases, the volume decreases, causing it to sink.

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 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, motions and forces
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, chemical reactions, motions and forces

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Gas Laws* activity, presented by Peg Convery, is available in *Introduction to Gas Laws*, part of Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Gas Laws* are available from Flinn Scientific, Inc.

Materials required to perform Part B of this activity are available in the *Pressure Bottle Kit* from Flinn Scientific. Additional materials may also be purchased separately.

Catalog No.	Description
AP5930	Pressure Bottle Kit
FB0238	Aquarium Thermometer
AP6884	Bicycle Pump with Pressure Gauge and Release Valve
AP4676	Cartesian Diver Pump Cap, "Fizz-Keeper"
AP5102	Medicine Dropper
P0230	Petrolatum, 28 g

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

Gas Laws Worksheet

Part A: Balloon on a String

1. How does the mass of the balloon vary as the temperature increases using the heat gun?

2. What happens to the volume as the balloon is heated?

3. How does volume and mass affect the density of the balloon?

Part B: Pressure Bottle

4. Initial volume of gas in the syringe_____.
5. Final volume of gas in the syringe at 50 psi_____.
6. What is the relationship between pressure and the volume of the syringe?

Part C: Pressure and Temperature

7. Initial temperature (°C) inside the bottle _____.
8. Final temperature (°C) inside the bottle_____.
9. What is the relationship between pressure and temperature?

Part D: Pressure and Volume

10. Describe how the volume of air in the medicine dropper changes as the pressure of the system decreases?

11. What causes the ketchup packet to sink?