ACTIVITY 2

Pressure and Volume of a Gas

BROWARD COUNTY ELEMENTARY SCIENCE BENCHMARK PLAN

Grade 5—Quarter 1
Activity 2

SC.A.1.2.1
The student determines that the properties of materials (e.g., density and volume) can be compared and measured (e.g., using rulers, balances, and thermometers).

SC.A.2.2.1
The student knows that materials may be made of parts too small to be seen without magnification.

SC.H.1.2.1
The student knows that it is important to keep accurate records and descriptions to provide information and clues on causes of discrepancies in repeated experiments.

SC.H.1.2.2
The student knows that a successful method to explore the natural world is to observe and record, and then analyze and communicate the results.

SC.H.1.2.3
The student knows that to work collaboratively, all team members should be free to reach, explain, and justify their own individual conclusions.

SC.H.1.2.4
The student knows that to compare and contrast observations and results is an essential skill in science.

SC.H.3.2.2
The student knows that data are collected and interpreted in order to explain an event or concept.

ACTIVITY ASSESSMENT OPPORTUNITIES

The following suggestions are intended to help identify major concepts covered in the activity that may need extra reinforcement. The goal is to provide opportunities to assess student progress without creating the need for a separate, formal assessment session (or activity) for each of the 39 hands-on activities at your grade.

1. Have the students describe any new measuring tools they used in this activity. (A graduated syringe was used to measure the volume of air in units of cubic centimeters.) Ask, *How is a graph helpful?* (It is a visual model. It can show the relationship between two things, like pressure and volume.)

2. Use the Activity Sheet(s) to assess student understanding of the major concepts in the activity.

In addition to the above assessment suggestions, the questions in bold and tasks that students perform throughout the activity provide opportunities to identify areas that may require additional review before proceeding further with the activity.

ACTIVITY 2

Pressure and Volume of a Gas

OBJECTIVES

Students explore the inverse relationship between the pressure and volume of a gas at a constant temperature.

The students

- measure the volume of a gas as the pressure is increased
- graph the relationship between the pressure and volume of a gas
- discuss the concept of inverse relationships

SCHEDULE

About 40 minutes

VOCABULARY

Boyle's law
inverse relationship

MATERIALS

For each student

1	Activity Sheet 2
1 sht	paper, graph

For each team of four

1	block, foam
1	syringe
4	textbooks*

For the class

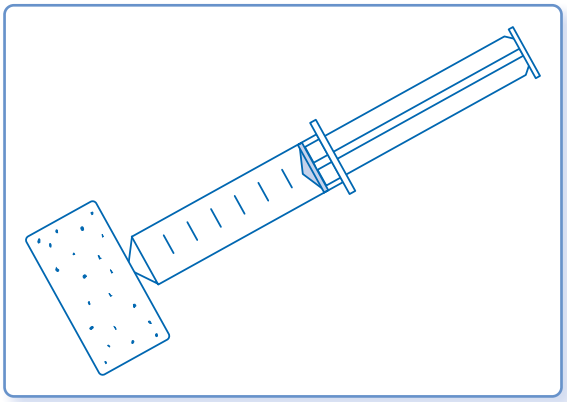
1	balance (accurate to 0.1 kg)*
1	balloon
1 btl	glue
1	toothpick

*provided by the teacher

PREPARATION

1. Make a copy of Activity Sheet 2 for each student.

2. At least 24 hours before conducting this activity, prepare the syringes. First, pull the plunger almost all the way out, so that the volume of air in the syringe is 60 cc. Then glue the syringe cap to the tip of the syringe as follows: Put a large drop of glue in the cap; if it does not drip down into the bottom of the cap, poke it down with a toothpick. Put another drop of glue on the tip of the syringe. Place the cap securely onto the tip of the syringe, taking care not to depress the plunger. Allow the glue to dry overnight. Finally, push the capped end of the syringe firmly into the block of foam (see Figure 2-1). Each team will need one prepared syringe in a foam base.



▲ ***Figure 2-1.*** *A prepared syringe in a foam base.*

3. On the day of the activity, have students bring to class a book that they all use, such as their math books.

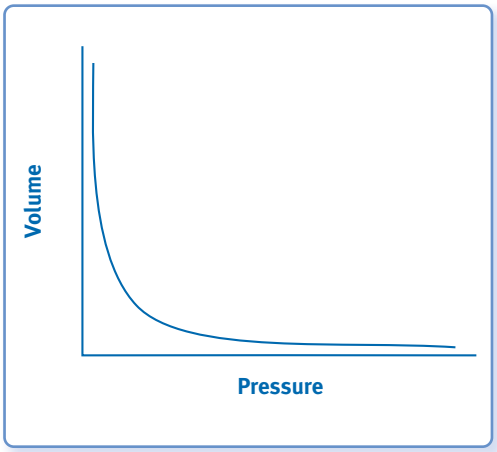
BACKGROUND INFORMATION

A solid has a definite volume and a definite shape. A liquid has a definite volume, but not a definite shape. A gas has neither a definite volume nor a definite shape, and will fill whatever size and shape container it is put into. If a quantity of gas is put into a large container, the molecules of that gas will spread out to fill the entire container. Conversely, if the same quantity of gas is compressed into a tiny container, the molecules will be packed close together.

In a container, gas molecules bounce around and hit the walls of the container. In doing so, they put pressure on the walls of the container. When gas molecules are far apart, relatively few of them hit the walls, and the pressure is low. When the gas is compressed, the molecules move closer together. The closer together they are, the more they hit the container walls, and the greater the pressure inside the container. This relationship between volume and pressure is described by ***Boyle's law,*** which states that at a constant temperature, the pressure of a fixed quantity of a confined gas varies inversely with its volume. This means that increasing the pressure decreases the volume. The mathematical formula used to express this relationship is:

$$k = P \times V$$

where k is a constant, P is the pressure that the gas exerts, and V is the volume of the gas. (Figure 2-2 graphs the relationship.) The value of k depends on the quantity of gas and the temperature.



▲ ***Figure 2-2.*** *Boyle's law states that at a constant temperature, the pressure and volume of an ideal gas are inversely proportional.*

According to Newton's third law of motion, whenever one object exerts a force on a second object, the second object exerts an opposite force of equal magnitude on the first object. In this activity, students will increase the pressure of gas in their syringes by depressing the plunger beneath the weight of one or more books. The weight of the books represents the force that the plunger is exerting on the gas. By increasing the pressure on the syringe (by adding books to the plunger), the pressure of the gas in the syringe also increases, in an equal magnitude. For this reason, the weight of the books can be used to measure the pressure of the gas inside the syringe.

According to Boyle's law, as the pressure of the gas in the syringe increases, the volume that the gas in the syringe occupies decreases. Conversely, if the pressure of the gas decreases, the volume that the gas occupies increases. These are known as ***inverse relationships.***

▼ **Activity Sheet 2**

Pressure and Volume of a Gas

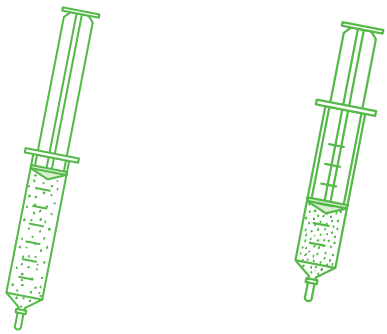
1. Record your data in the table.

Number of Books	Mass of Books (kg)	Units of Air Pressure	Volume of Air (cc)
0	0	0	60.0
1	2.3	2.3	45.0
2	4.5	4.5	35.5
3	6.7	6.7	29.5
4	9.0	9.0	25.0

2. Graph your data from the table. Be sure to label both axes.
Graph should resemble Figure 2-3.
Based on your graph, what can you conclude about the relationship between the pressure of the air in the syringe and the volume that the air occupies?
It is an inverse relationship: As the air pressure increases, the volume decreases.

3. Draw a diagram of how the air molecules might look in a syringe whose plunger is fully extended.

4. Draw a diagram of how the air molecules in that same syringe might look if the plunger were pushed down halfway.



Guiding the Activity

Additional Information

1. Introduce the concept of gas pressure by blowing up a balloon. Ask, **Why does the balloon get bigger?**

   The balloon gets bigger because air is being blown into it.

   Ask, **What form of matter is air?**

   Air is a gas.

   Remind the students that, unlike liquids and solids, gases do not have a constant volume. The molecules of a gas can spread out to fill a large container or be pushed together to fill a small container. Ask, **What are the air molecules inside the balloon doing?**

   The air molecules are moving around and bumping into the walls of the balloon.

2. Tell the students that the force of the molecules of gas (air) against the balloon walls is the pressure of the gas. When the molecules exert a lot of force, the pressure is high. When the molecules exert a small amount of force, the pressure is low. Tell the students that in this activity they will investigate the relationship between gas pressure and volume.

3. Distribute a copy of **Activity Sheet 2** to each student and a syringe in its foam base to each team of four. Ask, **What is inside the syringe?**

   Some students may say that the syringe is empty. Help them to see that it is filled with gas (air).

   Ask, **What do the numbers on the syringe tell you?**

   The numbers on the syringe tell the volume of material (air) that is inside the syringe.

   Ask a volunteer to demonstrate how to read the numbers on the syringe. Then ask, **What is the volume of air in your syringe right now?**

   The volume of air in the syringe is 60 mL, or 60 cc.

   In the metric system of measure, 1 mL of water occupies 1 cubic centimeter (cc) of volume and has a mass of 1 gram (g). Therefore, 1 mL and 1 cc are equivalent. Explain that the syringe is calibrated in milliliters (mL). Have the students record the volume at the top of the last column in the table on Activity Sheet 2.

Note: *Cubic centimeters and milliliters can be treated as equivalent measures.*

Guiding the Activity

	Additional Information
4 Set a balance on a desk and have a volunteer measure the mass of a textbook on the balance. Assuming all students are using the same book, have them record the mass in the table on the activity sheet. Then ask, **What is the unit of measurement used to weigh the book?**	*The mass of the book is measured in kilograms (kg).*
5 Instruct the teams to gently place one textbook on top of the syringe plunger and hold it steady. Make sure that the students do not press down or lean on the book, as this will affect the accuracy of their data. Ask, **What do you observe? What does this tell you about what happened to the volume of air in the syringe?** Tell the students to record this volume of air in the table on their activity sheets.	*They should notice that the plunger goes down. This tells them that the volume of air decreased.*
6 Ask, **How does the book affect the pressure that the syringe exerts on the air?** Explain that the pressure of the air against the syringe is the same as the pressure of the syringe against the air. Therefore, the mass of the book is an indicator of the pressure of the air and can be used to measure it. Tell the students that the units of mass can be translated into units of air pressure. Have students fill in on the activity sheet the units of air pressure resulting from the placement of one book.	*It increases the pressure.* *If students have trouble understanding this, have them place a book on top of their hand and feel the pressure of the book. Tell them that their hand is exerting, in return, a force equal to the mass of the book.*
7 Instruct the students to continue adding books to the syringe, one at a time, and recording the total mass of the books, the units of air pressure, and the volume of air in the syringe after each book has been added.	*Remind students to add the mass of each additional book to the total mass of all the other books already on the plunger. This is the number they should enter on the table.*

Guiding the Activity

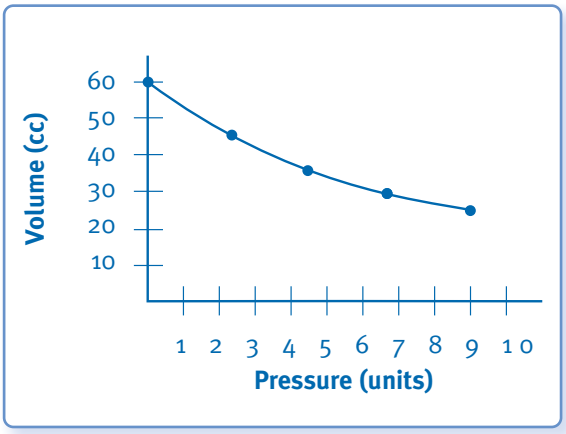
Additional Information

8 When teams have finished, distribute a sheet of graph paper to each student and tell them they will now graph their data. Ask, **What will you label the two axes?**

One axis should be labeled Volume (cc) *and the other,* Pressure (units). *It doesn't matter which is which. However, to make it easier to compare graphs, have all the students put the units of volume on the vertical, or* y*-axis, and the units of pressure on the horizontal, or* x*-axis.*

Have the students draw their graphs, plot the points on the graph, and connect the points by a curved line (Figure 2-3). After students have had time to look at their completed graphs, tell them to answer the question in step 2 of the activity sheet. Discuss the relationship between air pressure and volume. Ask, **What can you conclude about what happens to the volume of a gas when the pressure of a gas increases?**

Students should be able to conclude that as air pressure increases, volume decreases.



▲ ***Figure 2-3.*** *Sample data showing the inverse relationship between air pressure and volume.*

9 Write the term *inverse relationship* on the board. Tell the students that an **inverse relationship** exists between two factors if, as one quantity increases, the other decreases in such a way that their product remains constant.

Guiding the Activity

	Additional Information
10 Write the phrase *Boyle's law* and its formula *($k = P \times V$)* on the board. Explain that the results of their tests demonstrate **Boyle's law,** which describes the relationship between the pressure and volume of gases. Ask, **What do you think each letter represents?**	*Students can probably figure out that* P *stands for pressure and* V *for volume, but you may need to tell them that* k *represents a constant. Boyle's law: For a given mass at constant temperature, the pressure times the volume is a constant.*
Ask, **How does this formula express the relationship between the pressure and the volume of a gas?**	*Students should be able to see that this is an inverse relationship; in order for the value of* $P \times V$ *to remain constant, when one factor increases, the other must decrease.*
Some students may notice that $P \times V$ is not constant for all points on the graph. Assure them that this is due to the limitations of their equipment only.	
11 Ask the students to think about the molecules of gas in the syringe. Ask, **What do you think happens to the molecules of gas as the plunger is pushed down? How does this affect the gas pressure?**	*Students should be able to say that as the plunger is depressed, the molecules of gas get pushed together. They bump against the sides of the syringe harder and more often, thus increasing the gas pressure.*
Have the students complete the activity sheet.	

Reinforcement

To demonstrate mathematically the relationship between *P* and *V,* give *k* an arbitrary value of 12. Write on the board all the possible values for *P* and *V,* and ask students to note what happens to one factor when the other changes.

Science Notebooks

Have students place their completed activity sheets in their science notebooks.

Cleanup

Have the students return the syringes and foam blocks to the kit.

Connections

Science Challenge

Challenge students to suggest an explanation for why popcorn pops. Let students share their ideas, then ask interested volunteers to do research to determine which ideas were correct. (When popcorn kernels are heated, water inside each kernel becomes superheated but cannot vaporize because it is trapped inside the stiff outer hull and does not have room to expand. The water pressure inside the kernel finally increases to such a high level that it suddenly ruptures the hull, allowing the water to vaporize and expand according to Boyle's law. The heated starchy material inside the kernel also expands suddenly, forming the fluffy, white piece of popcorn.)

Science Extension

- Give each team three identical round balloons, and tell them to blow up the balloons to the same size and knot the ends securely. Tell students to measure the volume of each balloon, using the displacement method described in the Science Challenge for Activity 1. Have students leave one balloon (the control) in a shaded area of the classroom, another in sunlight, and the third in a refrigerator for about 30 minutes, then remeasure the volume of each. Barring any leaks in the balloons, the volume of the heated balloon will increase, that of the refrigerated balloon will decrease, and that of the control balloon will remain the same. Ask students to explain these results. (The amount of gas in all three balloons remained the same, but the volume of the gas—the amount of space it occupies—increased or decreased as the gas was heated or cooled.) Explain that this relationship between the temperature and the volume of a gas is known as *Charles's law,* represented by the formula $V/T = k$ or $V = kT$. (Also see Science and Social Studies below.)
- Do the following activity as a teacher demonstration or as a small-group activity. Insert a small balloon into a narrow-necked glass bottle, and stretch its open end over the lip of the bottle. Have students try to inflate the balloon by blowing into it. They will discover that no matter how hard they blow, they cannot inflate the balloon more than slightly. Ask them to suggest an explanation for this phenomenon. (The air already in the bottle presses against the outer surface of the balloon. A person blowing into the balloon cannot compress that air more than slightly.)

Science and the Arts

Give each team a large helium-filled balloon to decorate and outfit like an actual hot-air balloon used for travel. Encourage each team to find the right amount of weight to attach to the balloon to keep it floating in the air at a constant level without escaping.

Science and Social Studies

Suggest that students research and report on Robert Boyle, the scientist who discovered the law of gas pressure-volume relationships that bears his name, or Jacques Charles, the scientist who discovered the law of gas volume-temperature relationships that bears his name.

Science, Technology, and Society

Encourage students to investigate how a tire gauge works and to explain why tire pressure should be tested and, if necessary, adjusted only when the automobile has not been driven very far. (When the automobile is driven for a longer time, the air in the tires becomes heated and produces a higher pressure reading.)