Boyle's Law

How Does a Trapped Gas Behave?

Driving Question

How does a change in volume of a confined gas affect its pressure?

Materials and Equipment

For each student or group:

- ☐ Data collection system
- ☐ Absolute pressure sensor
- ☐ Quick-release connector[1]
- ☐ Sensor extension cable
- ☐ Syringe, 20-ml or 20-cc
- ☐ Plastic tubing[1]
- ☐ Clean toilet plunger

Safety

Add this important safety precaution to your normal laboratory procedures:

- ■ Wear protective goggles for this activity.

Thinking about the Question

Observe a clean toilet plunger pressed against a smooth surface like the floor. It may be necessary to lightly wet the rim with a wet towel so that no more air can get under the rim once you press down on the plunger. Propose an explanation about why the plunger sticks to the floor when you gently pull it away.

Discuss with the members of your group whether the volume of the pocket of trapped air changes when you pull on the plunger. Record your thoughts below. Be prepared to share your thoughts with the class.

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Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

○	○	○	○	○
Calculate the inverse pressure and graph inverse pressure versus volume. What is the relationship?	Make certain each lab group member is aware of safety rules and procedures for this lab.	Obtain absolute pressure data points as you decrease the volume, then begin again and increase volume.	Make a table of the pressure and volume data when decreasing the volume and when increasing the volume.	Set the initial volume of the syringe and then connect it to the pressure sensor (connected to the data collection system).

Investigating the Question

Note: When you see the symbol "**[2]**" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Part 1 – Making predictions

1. ☐ Predict the effect of decreasing the volume on the pressure in the syringe (as volumes go from 20 mL to 18 mL, 16 mL, 14 mL, 12 mL, 10 mL, 8 mL, and 6 mL) of the syringe. Describe and explain your prediction.

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2. ☐ Predict the effect on pressure in the syringe of increasing the volume (from 6 mL to 8 mL, 10 mL, 12 mL, 14 mL, 16 mL, 18 mL, 20 mL) of the syringe. Describe and explain your prediction.

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Part 2 – Decreasing the volume of trapped gas

3. ☐ Start a new experiment on the data collection system. (1.2)

4. ☐ Put the data collection system into manual sampling mode with manually entered data. (5.2.1)

   Note: Enter "Absolute pressure" with the units of "kPa" and "Distance" with the units of "cm", with two digits past the decimal point displayed.

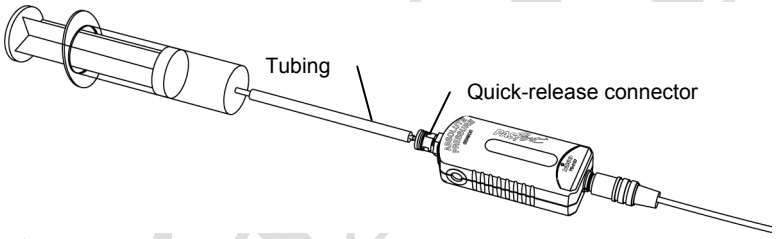
5. ☐ Use the sensor extension cable to connect an absolute pressure sensor to the data collection system. (2.1)

   Note: The syringe should not yet be connected to the sensor.

6. ☐ Display Pressure on the y-axis of a graph with Volume on the x-axis. (7.1.1)

7. ☐ Move the plunger of the syringe to the 20 mL mark.

8. ☐ Connect one end of the plastic tube to the syringe. Attach the other end of the tube (with the quick-release connector) to the pressure sensor by twisting until it clicks into place. Check with your teacher if you have any questions about how to connect this system properly.



9. ☐ Start a new manually sampled data set. (6.3.1)

10. ☐ Move the plunger to the 18 mL mark. Record this data point. (6.3.2)

11. ☐ Move the plunger to the 16 mL mark. Record this data point (both pressure and volume). (6.3.2).

12. ☐ Move the plunger to the 14 mL mark. Record this data point (6.3.2)

13. ☐ Move the plunger to the 12 mL mark. Record this data point (6.3.2)

14. ☐ Continue recording data points as you decrease the volume in the syringe by 2 mL increments, until you reach a volume of 6 mL.

15. ☐ When you have recorded all of your data, stop the data set. (6.3.3)

Part 3 – Increasing the volume of trapped gas

16. ☐ Disconnect the tube from the pressure sensor.

17. ☐ Move the plunger of the syringe to the 2 mL mark.

18. ☐ Display a new graph with Pressure on the y-axis and Time on the x-axis. (7.1.1)

19. ☐ Reconnect the tube to the pressure sensor.

20. ☐ Start a new manually sampled data set. (6.3.1)

21. ☐ With the plunger at 2 mL, record this data point (6.3.2)

22. ☐ Move the plunger to the 4 mL mark. Record this data point (6.3.2)

23. ☐ Move the plunger to the 6 mL mark. Record this data point (6.3.2)

24. ☐ Move the plunger to the 8 mL mark. Record this data point (6.3.2)

25. ☐ Continue recording data points as you increase the volume in the syringe by 2 mL increments, until you reach a volume of 20 mL.

26. ☐ Stop data recording. (6.3.3)

27. ☐ Save your experiment (11.1) and clean up according to your teacher's instructions.

Answering the Question

1. What type of relationship did you see when you decreased the volume of trapped air?

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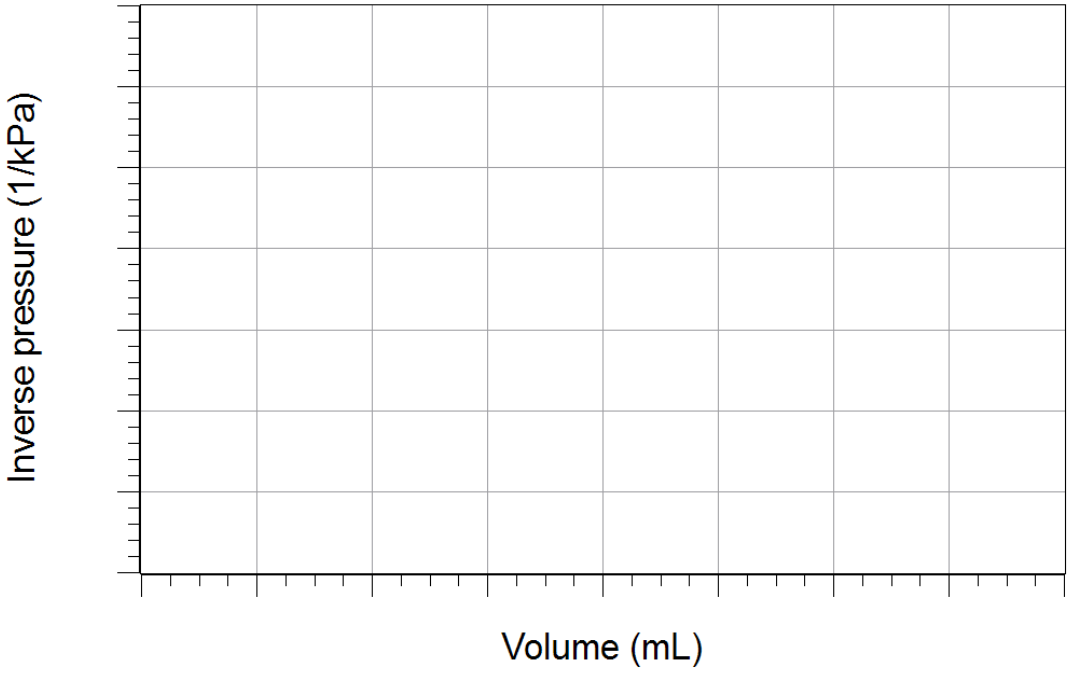
2. Using data from the first data run when decreasing the volume of trapped gas, complete Table 1. Calculate the value of 1/Pressure for each volume.

Table 1: Pressure with decreasing volume

Decreasing Volume (mL)	Pressure (kPa)	1/Pressure (kPa^{-1})
20		
18		
16		
14		
12		
10		
8		

3. Graph 1/Pressure versus Volume using the data in Table 1.



4. Does the graph show a direct or an inverse relationship? Explain your reasoning.

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5. What type of relationship did you see when you increased the volume of trapped air?

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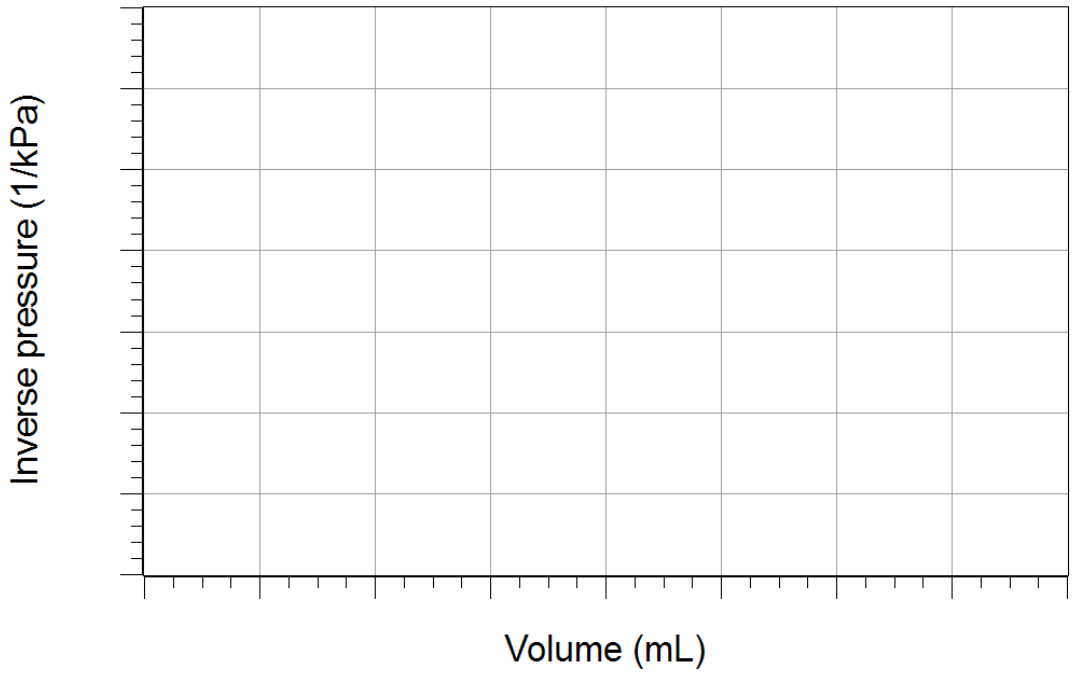
6. Using data from your second graph, when increasing the syringe volume, complete Table 2. Calculate the value of 1/Pressure for each volume.

Table 2: Pressure with increasing volume

Increasing Volume (mL)	Pressure (kPa)	1/Pressure (kPa^{-1})
4		
6		
8		
10		
12		
14		
16		
18		
20		

7. Graph 1/Pressure versus Volume using the data in Table 2.



8. Did the graph show a direct or an inverse relationship? Explain your reasoning.

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9. Describe the similarities and differences for both 1/Pressure versus Volume graphs.

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10. Explain how the graphs display Boyle's Law. Be prepared to share your thoughts with the class.

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True or False

Enter a "T" if the statement is true or an "F" if it is false.

_____1. Collisions between air molecules and the walls of their container create pressure.

_____2. There is a direct relationship between the volume of a gas and its pressure, when the gas is held at a constant temperature.

_____3. In the SI system, pressure is measured in units called newtons.

_____4. The graph of increasing volume versus increasing pressure is a straight line.

_____5. The inverse of a number is equal to one divided by the number.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. Which is the best way to characterize an inverse relationship?

   A. As one quantity decreases, the other quantity decreases at the same rate.
   B. As one quantity increases, the other quantity decreases proportionally.
   C. As one quantity increases, the other quantity undergoes a random change.

2. Air molecules confined in a closed volume undergo more collisions when that volume:

   A. Decreases
   B. Increases
   C. Is chilled by at least 10 degrees Celsius

3. The inverse of 4.0 is equal to:

   A. 40.0
   B. 1.0
   C. 0.25

4. Suppose you are given a closed air-tight container that holds a particular gas at room temperature. You then squeeze the container and put a big dent in it. Which of the following is *not* true about the gas inside the dented container?

   A. There is less room for the gas molecules that are sealed inside the container.
   B. There are exactly as many gas molecules now as there were before you dented the container.
   C. The pressure of the gas has remained the same as it was before you dented the container.

5. The relationship between the volume of a gas and its pressure can be seen in which example?

   A. The adhesive used to glue labels onto containers
   B. A suction cup used to attach something to a wall
   C. An empty balloon waiting to be inflated with helium gas