Activity: Understanding Pressure

Objective

Describe how temperature, volume, and the amount of a gas affect pressure in a closed system.

Materials and Equipment

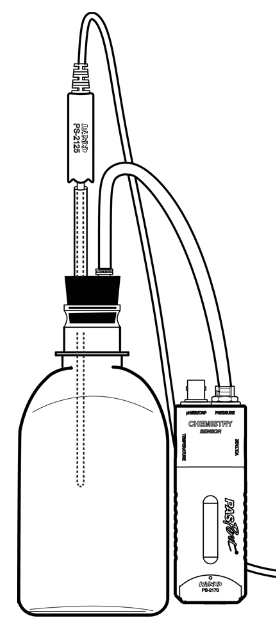
- Data collection system
- Absolute pressure sensor
- Stainless steel temperature sensor with blue tubing
- Syringe with quick-release connector attached
- Sampling bottle, plastic, 500-mL
- Beaker, 1000-mL
- Rubber stopper, two-hole, to fit the sampling bottle and fitted with a 50-cm piece of tubing with a quick-release connector at the end
- Stopcock connected to a tubing connector
- Crushed ice, 500 mL
- Paper towels

Safety

- Wear safety goggles.
- To minimize the risk of injury or damage to the equipment, do not exceed 400 kPa when compressing air in the syringe.
- Do not point the top of the sampling bottle toward yourself or anyone else.

NOTE: *Record all work, including tables, data, diagrams, calculations, and answers, into your notebook.*

Procedure – Part 1: How does temperature affect pressure?



☐ 1. Connect the absolute pressure sensor and the stainless steel temperature sensor to your data collection system. �(2.2) Create a new file �(1.2) with a graph that displays pressure (kPa) on the *y*-axis and temperature (K) on the *x*-axis. �(7.1.1)

☐ 2. Place a 3- to 4-cm piece of blue tubing onto the stainless steel temperature sensor and then insert the sensor into the open hole in the stopper. Push the sensor all the way through the stopper so that some of the blue tubing is in the stopper's hole and an airtight seal is formed.

☐ 3. Attach the quick-release connector at the end of the tubing coming from the stopper to the pressure sensor and then firmly place the stopper into the sampling bottle so the tip of the temperature probe is in the middle of the sampling bottle.

☐ 4. List the independent and dependent variables in this experiment and then explain what you think will happen to the air pressure inside the bottle when the temperature decreases and increases.

☐ 5. Place a layer of crushed ice at the bottom of the 1000-mL beaker. Place the sampling bottle on the ice in the beaker and pour crushed ice all around the bottle. Allow the air in the sampling bottle to adjust to its new environment for 2 minutes.

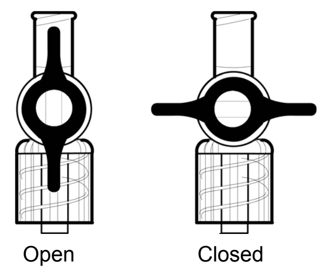
☐ 6. Start collecting data �(6.2) and continue to collect data until you have determined how decreasing temperature affects pressure. Once you detect the trend, stop collecting data.�(6.2)

☐ 7. Ensure that the stopper remains in the sampling bottle as you carefully remove the sampling bottle from the beaker of ice and pat it dry with a paper towel. Lay the bottle on its side and allow the bottle to adjust to its new environment for 2 minutes. Start collecting data.�(6.2) Continue to collect data until you detect the trend, then stop collecting data. �(6.2)

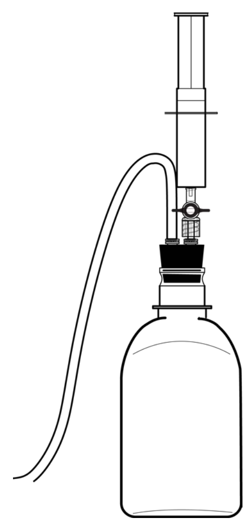
- ☐ 8. The following questions apply to your observations for both cooling and warming the sampling bottle:
  - a. What happens to the pressure in the bottle as the temperature of the air in the bottle decreases?
  - b. What happens to the pressure in the bottle as the temperature of the air in the bottle increases?
  - c. Explain why these trends occur and draw diagrams that show the gas molecules' positions, speed (long arrows for faster speeds; short arrows for slower speeds), and relative number in both a warm and a cool environment.
- ☐ 9. In your notebook,
  - a. Sketch both runs of the data collected onto a graph of pressure versus temperature.
  - b. Label each run and then state whether or not your predictions were correct and explain any differences.
- ☐ 10. Describe the relationship you observed between pressure and temperature.
  - a. Is pressure directly proportional ($P \propto T$) or inversely proportional ($P \propto 1/T$) to temperature? How do you know?
  - b. What variables must be held constant to observe this relationship?
  - c. Assuming this is the correct relationship, what will happen if the temperature is reduced by half?
- ☐ 11. Disassemble the setup and disconnect and remove the sensors from your data collection system.

Procedure – Part 2: How does the amount of gas (*n*) affect pressure?

- ☐ 12. Connect the pressure sensor to your data collection system�(2.1) and create a new file.�(1.2)



- ☐ 13. Configure the data collection system to manually collect pressure (kPa) and amount of air (syringes) in a table. Define "amount of air" as the manually entered data set with units of "syringes". �(5.2.1)
- ☐ 14. Insert the tubing connector, with the stopcock attached, into the empty hole of the stopper. Make sure the stopcock is in the "closed" position.
- ☐ 15. Attach the quick-release connector at the end of the tubing coming from the stopper to the pressure sensor and then firmly place the stopper into the bottle.



- ☐ 16. List the independent and dependent variables in this experiment and then explain what you think will happen to the air pressure inside the bottle when air is added and when air is removed.
- ☐ 17. Start a manually sampled data set �(6.3.1), record the pressure, and enter "0" as the number of syringes of air added. �(6.3.2)
- ☐ 18. Record the pressure with 1, 2, and 3 syringes of air added using the following procedure:
  - a. Pull the plunger of the syringe out as far as possible (so it fills with air) and then attach the syringe to the stopcock (still in the closed position).
  - b. Open the stopcock and then push the plunger of the syringe down to force the air molecules from the syringe into the sampling bottle.
  - c. Close the stopcock, remove the syringe from the stopcock, and record the data point (both pressure and the total number of syringes of air added at this point). �(6.3.2)
  - d. Repeat this process until you have added three syringes of air to the bottle, then stop the manually sampled data set. �(6.3.3)

☐ 19. Open the stopcock to allow the pressure inside the sampling bottle to return to atmospheric pressure, then close the stopcock. Record the pressure for 0, –1, –2, and –3 syringes of air using the following procedure:

NOTE: the negative sign indicates that air is being removed from the container.

a. Start a manually sampled data set �(6.3.1), record the pressure, and enter "0" as the number of syringes of air removed. �(6.3.2)

b. Position the plunger of the syringe so there is no air inside the syringe and then attach the syringe to the stopcock (still in the closed position).

c. Open the stopcock and then pull the plunger away from the sampling bottle until the syringe is full of air.

d. Close the stopcock, remove the syringe from the stopcock, and record the data point (both the pressure and the total number of syringes of air removed at this point). �(6.3.2)

e. Repeat this process until you have removed three syringes of air from the bottle, then stop the manually sampled data set. �(6.3.3)

☐ 20. Display a graph of pressure (kPa) versus the amount of air (syringes). �(7.1.1)

a. What happened to the pressure in the bottle when air was added?

b. What happened to the pressure in the bottle when air was removed?

c. Explain why these trends occurred and draw diagrams that show the gas molecules' positions, speed, and relative number when there is a large amount of gas and when there is a small amount of gas in the bottle.

☐ 21. In your notebook,

a. Sketch both runs of the data collected onto a graph of pressure versus amount of air.

b. Label each run and then state whether or not your predictions were correct and explain any differences.

☐ 22. Describe the relationship you observed between pressure and the amount of a gas.

a. Is pressure directly proportional ($P \propto n$) or inversely proportional ($P \propto 1/n$) to the amount of a gas (n)? How do you know?

b. What variables must be held constant to observe this relationship?

c. Assuming this is the correct relationship, what will happen to the pressure if the amount of gas is doubled?

☐ 23. Disassemble the setup and disconnect and remove the sensors from your data collection system.

Procedure – Part 3: How does volume affect pressure?

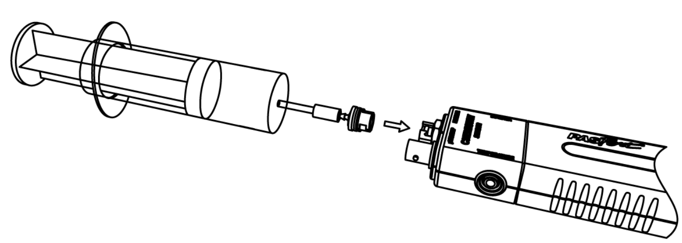
☐ 24. Connect the pressure sensor to your data collection system �(2.1) and create a new file. �(1.2)

☐ 25. Configure the data collection system to manually collect pressure (kPa) and volume (mL) in a table. Define "volume" as a manually entered data set with units of milliliters (mL). �(5.2.1)

☐ 26. List the independent and dependent variables in this experiment and then explain what you think will happen to the air pressure inside the syringe as the volume of the syringe decreases and increases.

☐ 27. Collect one run of data as you decrease the volume in the syringe using the procedure below. You will determine the pressure of the starting volume and of four additional volumes that become sequentially smaller, such as 30 mL, 25 mL, 20 mL, 15 mL, and 10 mL. Use these data points to determine how pressure changes as volume decreases.

a. Start a manually sampled data set. �(6.3.1)



b. Adjust the plunger so air occupies half the syringe and then attach the syringe to the sensor using the quick-release connector.

c. Record the pressure and volume of the first data point. �(6.3.2)

d. Adjust the plunger to the next volume and then record this data point. �(6.3.2) Repeat this step until all the data points have been recorded.

e. Stop the manually sampled data set �(6.3.3) and disconnect the syringe from the sensor.

☐ 28. Collect one run of data as you increase the volume in the syringe using the procedure below. You will determine the pressure of the starting volume and of four additional volumes that become sequentially larger, such as 30 mL, 35 mL, 40 mL, 45 mL, and 50 mL. Use these data points to determine how pressure changes as volume increases.

a. Start a manually sampled data set. �(6.3.1)

b. Adjust the plunger so air occupies half the syringe and then attach the syringe to the sensor.

c. Record the pressure and volume of the first data point. �(6.3.2)

d. Adjust the plunger to the next volume and then record this data point. �(6.3.2) Repeat this step until all the data points have been recorded.

e. Stop the manually sampled data set �(6.3.3) and disconnect the syringe from the sensor.

☐ 29. Display a graph of pressure (kPa) versus volume (mL). �(7.1.1)

a. What happened to the pressure as the volume decreased?

b. What happened to the pressure as the volume increased?

c. Explain why these trends occur and draw diagrams that show the gas molecules' positions, speed, and relative number in both a large and a small volume.

☐ 30. In your notebook,

a. Sketch both runs of the data collected onto a graph of pressure versus volume.

b. Label each run and then state whether or not your predictions were correct. Explain any differences.

☐ 31. Describe the relationship you observed between pressure and volume.

a. Is pressure directly proportional ($P \propto V$) or inversely proportional ($P \propto 1/V$) to the volume of a gas (V) in a container? How do you know?

b. What variables must be held constant to observe this relationship?

c. Assuming this is the correct relationship, what happens to pressure if the volume of a container is reduced by half?

Questions

1. Define "pressure" and describe how gases exert pressure at the molecular level (use the word "molecules" in your answer).

2. List the mathematical relationships you determined, in the above procedures, between pressure and each independent variable (V, n, T), using "P" for pressure and the corresponding symbols for the other variables.

3. Combine these three mathematical relationships into one that includes all the variables.

4. A mathematical relationship can be changed into a mathematical equation by adding a proportionality constant, that is, a constant that will result in the two sides of the equation being equal. For example, $a \propto b$ can be changed into an equation by writing $a = kb$, where k is the proportionality constant.

   Use "R" as your proportionality constant and change the mathematical relationship in your answer to the previous question to an equation.

5. The Ideal Gas Law is often written as $PV = nRT$. Does the equation in your answer to the previous question agree with the Ideal Gas Law? Explain your reasoning.