4. Percent Oxygen in Air

Driving Questions

We get the oxygen we need for respiration from the air around us. We hear on the news that the amount of greenhouse gases in the air is increasing. Obviously, air isn't only oxygen, but rather, a mixture of different gases. What percent of the molecules in air is oxygen?

Background

Air is a mixture made of nitrogen molecules, oxygen molecules, and a very small amount of other molecules, such as carbon dioxide and water. These gas molecules are in constant motion, zipping through space and colliding into things. These collisions create air pressure. Pressure is the average force spread over an area and is measured in the SI unit of newton per square meter (N/m^2) also known as a pascal (Pa).

Air pressure can change when temperature, volume, or the number of air molecules changes. When air is heated, the air molecules move faster, causing more collisions per second, increasing the pressure. When the volume of a container holding a gas increases, the pressure decreases. This is because the particles have more space to move in and therefore collide with the container less often. Finally, if more particles are added, there will be more collisions and a correspondingly higher pressure.

In this lab, oxygen gas molecules will be removed from a container through the following reaction:

Oxygen gas (O_2) from the air reacts with iron (Fe) in steel wool to form rust (Fe_2O_3).

$$3O_2(g) + 4Fe(s) \rightarrow 2Fe_2O_3(s)$$

Notice that when oxygen is a reactant in this equation, it is a gas that contributes to the total pressure. After the reaction, the oxygen has combined with the iron to become a new substance, rust, which is a solid. This removal of oxygen gas will affect the gas pressure. Nitrogen and the other molecules in the air do not react with iron and will bounce off unchanged.

Materials and Equipment

For each student or group:

- Data collection system
- Absolute pressure sensor
- Sensor extension cable
- Quick-release connector
- Tubing connector
- Tubing, 1- to 2-cm
- Beaker, 150-mL
- Test tube, 25-mm x 150-mm
- One-hole stopper to fit the test tube
- Stir rod
- White vinegar (~5% acetic acid), 50 to 60 mL
- Steel wool, fine mesh (#000), 1.0 g
- Paper towels
- Glycerin, 2 drops

Safety

Add this important safety precaution to your normal laboratory procedures:

- Vinegar is a weak acid. Avoid contact with the eyes and wash your hands after handling glassware, steel wool, and equipment.

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.

Measure and record the initial pressure.	Clean the steel wool with vinegar so that oxygen can react with the iron.	Create a closed container with air and steel wool.	Measure the final pressure value.	Calculate the percent oxygen in air.

Procedure

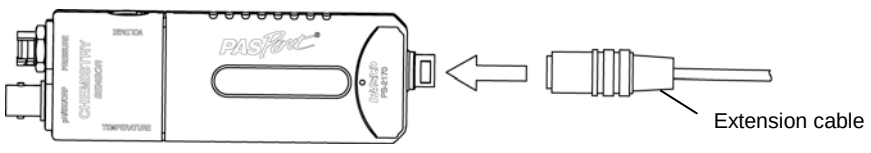
After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "**◆**" 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.

Set Up

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

2. ☐ Connect the absolute pressure sensor to the data collection system using a sensor extension cable. ◆(2.1)

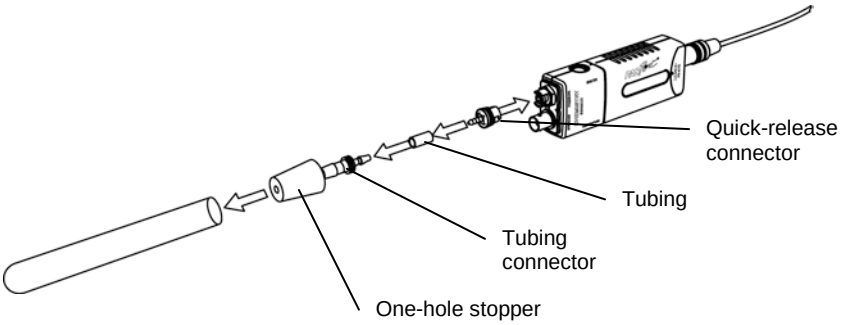


3. ☐ Connect the quick-release connector to the stopper using the tubing connector and the 1- to 2-cm piece of tubing by following the steps below. Use the picture as a guide.

   a. Insert the thicker end of the tubing connector into the hole in the stopper. If this is difficult, add a drop of glycerin.

   b. Connect the 1- to 2-cm piece of tubing to the other, thinner end of the tubing connector.

   c. Insert the barbed end of the quick-release connector into the open end of the 1- to 2-cm piece of tubing. If this is difficult, add a drop of glycerin.



4. ☐ Insert the quick-release connector into the port of the absolute pressure sensor and then turn the connector clockwise until fitting "clicks" onto the sensor (about one-eighth turn).

5. ☐ Create a graph display of Pressure (kPa) versus Time. (7.1.1)

6. ☐ What are the dependent and independent variables in this experiment? In what units are these variables measured?

_____

_____

7. ☐ Predict what will happen to the pressure as the reaction occurs?

_____

8. ☐ Obtain enough fine mesh steel wool to fill a large test tube about ⅔ full (approximately 1.0 g).

9. ☐ Stretch the steel wool apart so that a large amount of surface area is exposed.

10. ☐ Clean the steel wool by soaking it in a 150-mL beaker containing approximately 60 mL of vinegar for about one minute. Use a stir rod to fully rinse the steel wool in the vinegar.

11. ☐ Why do we need to rinse the steel wool in vinegar?

_____

_____

_____

12. ☐ Remove the steel wool from the beaker of vinegar and wring it out, draining the vinegar into the beaker.

13. ☐ Stretch apart the steel wool and thoroughly dry it with paper towels.

14. ☐ Change the paper towels and dry it again.

15. ☐ Stretch the steel wool apart and shake it in the air to make sure it is dry.

16. ☐ Put the steel wool in a large test tube making sure that a large surface area is still exposed. Do not pack the steel wool into the bottom of the test tube.

Note: You may have to gently tap the test tube to get the steel wool to slide down into the test tube.

Collect Data

17. ☐ Place the stopper into the top of the test tube and immediately start collecting data. ◆(6.2)

Note: You may have to adjust the scale of the graph to observe any changes taking place. ◆(7.1.2).

18. ☐ What molecules are contributing to the pressure you are recording on your data collection system? Be specific.

_____

_____

19. ☐ Write a sentence explaining the reaction occurring in the test tube. Explain where each substance comes from and its physical state (solid, liquid, or gas).

_____

_____

20. ☐ What is happening to the pressure as the reaction occurs? Why?

21. ☐ Write down at least three changes you observe taking place in the test tube.

22. ☐ When the pressure has stabilized (after about 20 to 30 minutes), stop data collection. (6.2)

23. ☐ Save the data file and clean up your lab station according to the teacher's instructions. (11.1)

Data Analysis

1. ☐ Determine the initial and final pressures and write them in the Table 1 below. (9.1)

Table 1: Initial and final pressure

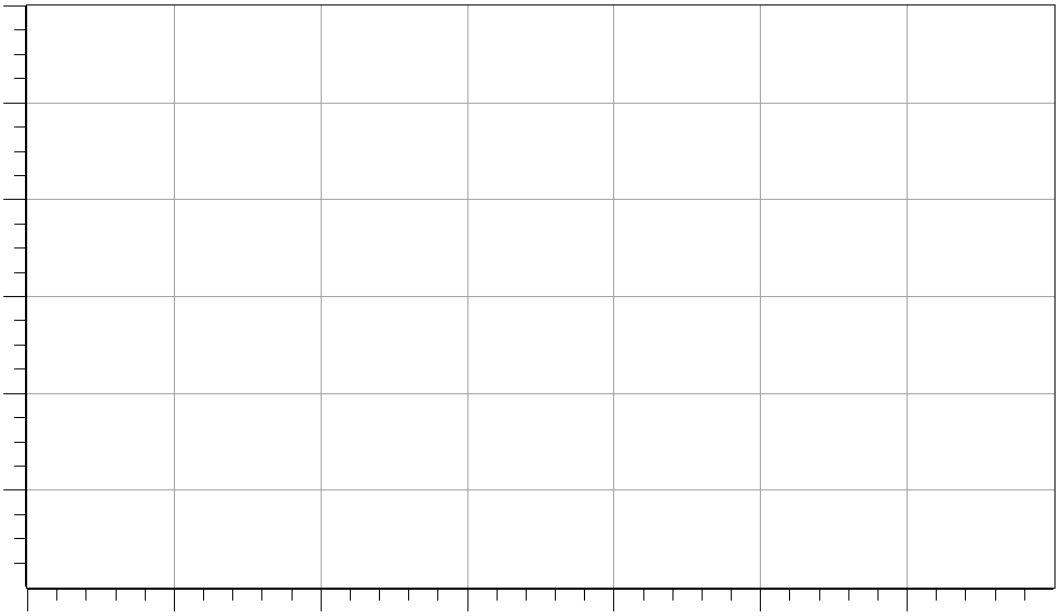
Initial Pressure (kPa)	
Final Pressure (kPa)	

2. ☐ Calculate the change in pressure.

3. ☐ Calculate the percent oxygen in air.

$$\frac{\text{change in pressure (kPa)}}{\text{initial pressure (kPa)}} \times 100 = \%\ \text{oxygen}$$

4. ☐ Sketch or print a copy of the graph of Pressure (kPa) versus Time (s). Label the overall graph, the x-axis, the y-axis and include units on the axes. ◆(11.2)



Analysis Questions

1. **Why did the pressure graph flatten out after a while? (Hint: think about what is happening to the amount of oxygen in the test tube.)**

_____

_____

2. **Why was the pressure not reduced to zero?**

_____

_____

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Gases are often described as having no definite shape and filling the container they occupy. Explain what is happening at the molecular level to give gases these properties.**

_____

_____

2. **Explain why solids have a definite shape.**

_____

_____

3. **Chemical reactions stop when one of the reactants is used up. This reactant is called the *limiting reactant* because it limits the amount of product that is made. In this lab, rust was the product. What was the limiting reactant?**

_____

_____

Multiple Choice Questions

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

1. **Which of the following variables affects the pressure of a gas?**

   A. The number of gas molecules
   B. The temperature of the gas molecules
   C. The volume of the container the gas molecules are in
   D. All of the above

2. **If you increase the temperature of a gas, what will happen to the pressure?**

   A. It will stay the same
   B. It will increase
   C. It will decrease
   D. Not enough information

3. **If you increase the number of gas molecules in a container, what will happen to the pressure?**

A. It will stay the same
B. It will increase
C. It will decrease
D. Not enough information

4. **Approximately what percentage of air is made up of oxygen gas?**

A. Less than 5%
B. 20%
C. 70%
D. More than 80%

5. **Pressure is best described as**

A. A force spread out over an area
B. The motion of molecules
C. The space between molecules in a gas
D. A strong force

Key Term Challenge

Fill in the blanks from the list of words in the Key Term Challenge Word Bank.

1. Pressure is a force spread out over an _____. Gas pressure is caused by gas molecules flying through space and _____ off surfaces. If the collision rate increases, the _____ goes up. An increase in _____ causes greater pressure because the gas molecules are moving with more kinetic energy, and therefore are moving faster. A decrease in volume causes an _____ in pressure because the gas molecules are closer together and have less distance to travel to hit the walls of the container, so collisions are more frequent. At a given temperature, all gas molecules contribute to the total pressure. If 70% of the gas molecules in a container are nitrogen, then _____ of the pressure will be due to the nitrogen molecules.

Key Term Challenge Word Bank

Paragraph 1

20%

30%

70%

area

bouncing

decrease

force

increase

pressure

sticking

temperature

volume