

The Ideal Gas Law

Tom Kuntzleman, Spring Arbor University

Introduction

The ideal gas law is an excellent approximation which expresses the relationship between the pressure (P), temperature (T), volume (V) and moles (n) of a gas at high temperatures and low pressures:

$$PV = nRT \quad \text{Equation 1}$$

Where R is the universal gas constant ($R = 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1} = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$). Dividing both sides of Equation 1 by V gives:

$$P = \frac{nRT}{V} \quad \text{(Equation 2)}$$

If we let $y = P$, $x = 1/V$ and $m = nRT$, then Equation 2 takes on the form of a line:

$$y = mx + b \quad \text{(Equation 3)}$$

Where b is equal to zero in this case. Equation 3 implies that if experimentally determined values of pressure and volume are plotted in (x, y) pairs as $x = 1/V$ and $y = P$, a straight line with a slope equal to nRT results:

$$\text{In a plot of } P \text{ vs. } 1/V: \quad \text{slope} = nRT \quad \text{(Equation 4)}$$

While it is unlikely that the intercept of the best-fit line resulting from a P vs. $1/V$ plot will be **exactly** zero, an intercept close to zero increases confidence in the results. Dividing Equation 4 on both sides by RT yields:

$$\frac{\text{slope}}{RT} = n \quad \text{(Equation 5)}$$

Therefore, the number of moles of a gas may be found by measuring the pressure and volume of the gas at constant temperature, then finding the slope of a P vs. $1/V$ plot. Dividing this slope by the quantity RT yields an experimental determination of the moles of the gas.

Let's say the number of moles of a sample of gas has been found. If the mass of the gas is known, then the molar mass of the gas, M, may be determined:

$$M = \frac{\text{mass}}{n} \quad \text{(Equation 6)}$$

Materials MicroLab FS522, pressure syringe with Luer lock, SF₆ (sulfur hexafluoride) gas.

Procedure

1. Set up the MicroLab FS522 to display pressure and volume, and temperature (using a thermistor). You need to hand enter volume. To do so, choose “keyboard” as the sensor to add and follow the directions on screen.
2. Obtain a pressure syringe with a three-way valve. Note that air flow is blocked along the opening that is aligned with the long blue lever (Figure 1).

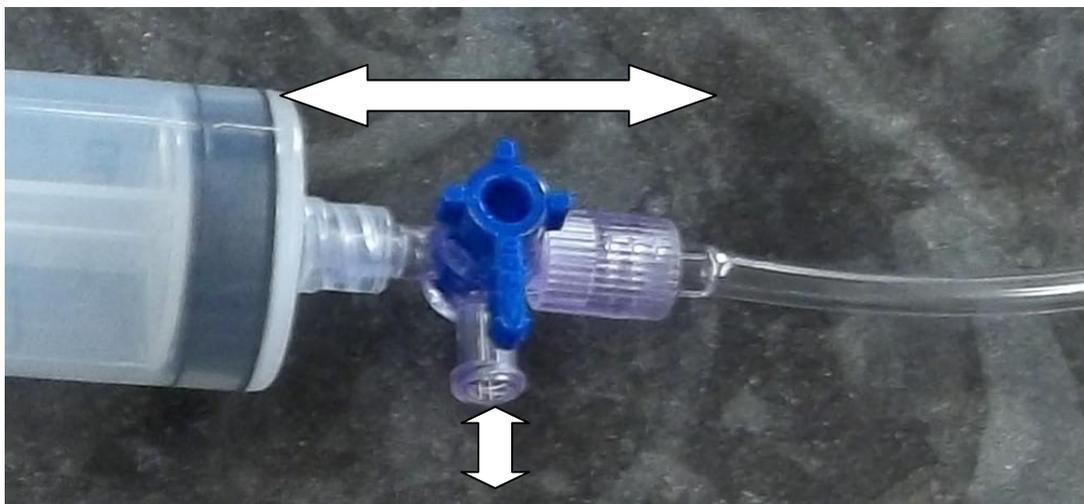


Figure 1: Pressure syringe with three way valve. Air flow is blocked into the opening indicated with a short arrow. Air flow is unobstructed through the openings indicated with the long arrow.

3. Depress the plunger of the pressure syringe all the way down as shown in Figure 1.
4. Turn the switch to block air flow as shown in Figure 1. Attach the open tubing to the tank of SF₆ gas (Figure 2).



Figure 2: Attach pressure syringe to SF₆ tank.

5. Turn the blue lever on the three-way valve in the direction of the plunger (Figure 3).



Figure 3: Lever of the three way valve turned in the direction of the plunger.

6. Gently turn on the gas flow from the SF₆. This will purge the gas line of any air.
7. With the flow still running, turn the blue lever to the position shown in Figure 1. Once the syringe has filled with ~40 mL of SF₆, return the blue lever to the position shown in Figure 3.
8. Record the air temperature. You can do this with your lab thermometer or the MicroLab FS522.
9. Connect the Luer lock on the pressure syringe to the pressure sensor input on the MicroLab FS522 (Figure 4).

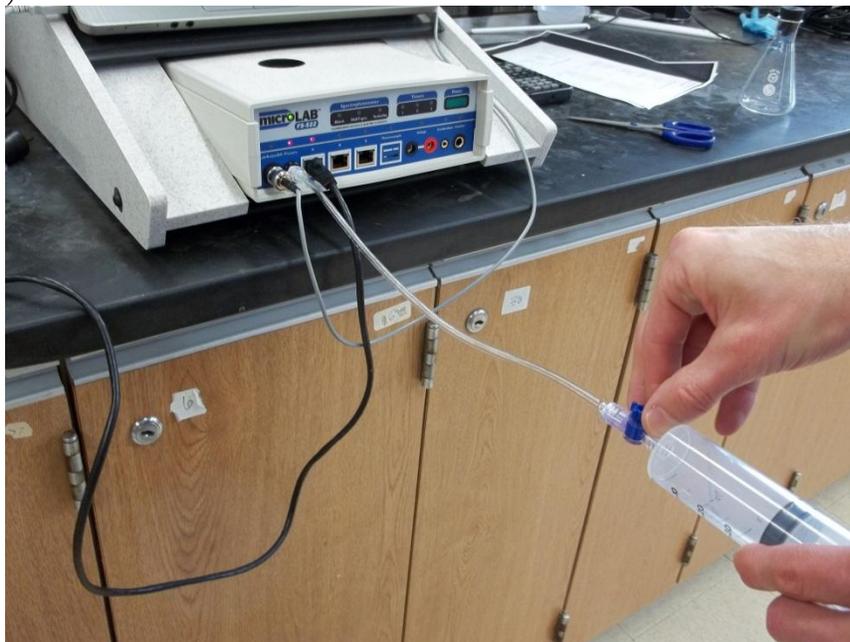


Figure 4: Pressure syringe connected to the pressure sensor input on MicroLab

10. Turn the blue lever to the position shown in Figure 1.

11. Start the experiment. A dialog box should appear. Input the volume of SF₆ in the syringe into the dialog box, and hit return. MicroLab should automatically record the pressure in the syringe.
12. Gently pull back on the plunger to increase the volume of the gas by no more than 5 mL. Record both the new volume and the new pressure of the gas.
13. Repeat step 11 until you have collected several data points.
14. Repeat step 11, but push in on the plunger to decrease the volume of the gas. **DO NOT PUSH IN THE PLUNGER TO PRESSURES GREATER THAN 1.5 ATM!!!** Record both the new volume and the new pressure of the gas.
15. Repeat step 13 until you have collected several more data points.
16. Export the MicroLab data into a file readable by Excel.
17. Turn the blue lever to the position shown in Figure 3.
18. Remove the plunger from the pressure sensor input on the MicroLab FS522.
19. Place the plunger in an empty beaker, and place the plunger and beaker on a balance. While the plunger/beaker is on the balance, zero the balance.
20. Remove the plunger from the beaker. Turn the blue lever to the position shown in Figure 1.
21. Push on the plunger so as to remove SF₆ from the syringe.
22. Replace the plunger in the beaker. Record the absolute value of the mass indicated on the balance. This is the mass of SF₆ that was in the syringe during the experiment.
23. Repeat this experiment at least one time. If your results from this second experiment are within 5% of the first trial, you are done! If not, repeat the experiment a third time.

Data

Temperature: _____

Mass of SF₆ in the syringe:

Experiment 1: _____

Experiment 2: _____

Experiment 3 (if necessary): _____

Data Analysis

1. Convert all pressure data to units of atmospheres, all volume readings to units of liters and all temperature readings to units of Kelvins.
2. Prepare a plot of P (y-axis) vs. 1/V (x-axis). Be sure to take the reciprocal of your volume readings!
3. Determine the slope and intercept of your P vs. 1/V plot. You should recognize that the units of your slope are the units of your y-axis divided by the units of your x-axis. If you have done things correctly, the units of your slope should be "L atm".
4. Use Equation 5 to determine the number of moles of gas contained in the syringe.

5. Use Equation 6 to determine the molar mass of SF_6 .

Questions

1. What did you find for the molar mass of SF_6 in all of your experimental trials?

Trial 1:

Trial 2:

Trial 3:

2. What is the molar mass of SF_6 ?

3. What was the percent error in all of your trials?

Trial 1:

Trial 2:

Trial 3: