PHYS101 Lab: The Ideal Gas Law
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Introduction: In this lab you will be measuring the specific heat of a couple different metal samples using calorimetry.

Equipment Needed:

Computer	850 Universal Interface
Ideal Gas Law Adapter	Absolute Pressure/Temperature Sensor

Theory

The Ideal Gas Law is an equation of state for an "Ideal Gas". An ideal gas is approximated as being made of solid sphere that undergo perfectly elastic collisions. This simplifies their interactions significantly, since we ignore the fact that atoms are made of charged particles, namely protons and electrons. The Ideal Gas Law is

$$PV = nRT$$

Where P is the the absolute pressure in Pascals (Pa), V is the volume of a gas in m^3, T is the temperature of the gas in Kelvin (K), and n is the number of moles (mol) of the gas in your sample. IN the equation we also have the Universal Gas Constant, R = 8.314 J/mol K, which applies to all ideal gases, regardless of their composition.

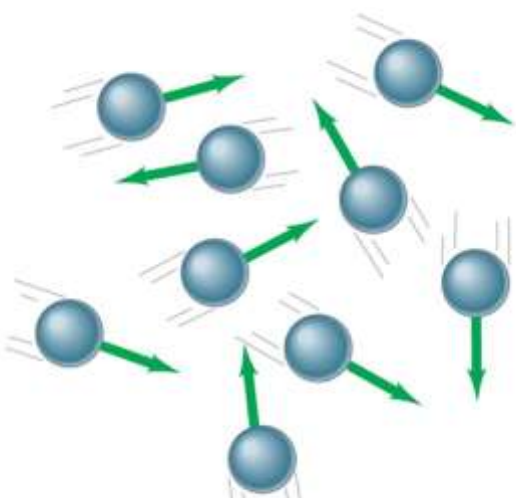


Figure 1: An "Ideal" Gas made of hard spheres moving around and colliding elastically.

Figure 2: A sealed container of an ideal gas. The system is sealed, so the amount of gas is going to stay constant. The pressure, temperature, and volume can change, however.

When using the ideal gas law you must use absolute quantities. This means that you need to use absolute pressure and absolute temperature. Absolute pressure is defined as $P_{abs} = P_{gauge} + P_{atm}$. Absolute temperature is the temperature of a material on the Kelvin temperature scale. In the lab we typically measure every in Celsius, so we will need to convert: $T_K = T_C + 273.15$.

In this lab your system will be comprised of a syringe full of air, as shown in the diagram above. You will fill it with an ideal gas (air) and then quickly compress the gas. Based on the ideal gas law, the pressure and temperature of the gas should increase quite dramatically, since we are rapidly decreasing the volume of the gas. After that, you will release the piston, which will be full of a high pressure gas, so it will expand rapidly. In that case, the pressure and temperature of the case will decrease dramatically. Either way, the system is sealed, so the amount of gas in the syringe, n, will never change. This means that we can rearrange the ideal gas law to say the following:

$$\frac{PV}{T} = nR = constant.$$

If this is true, then we can relate the initial state of the gas to the final state of the gas for either the compression or the expansion process:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}.$$

In this lab you will be measuring the absolute pressure, absolute temperature, and the volume of your ideal gas. You can predict the final pressure in the gas by rearranging the equation above to the following:

$$P_2 = P_1 \frac{V_1}{V_2} \frac{T_2}{T_1}.$$

Schematic of Device

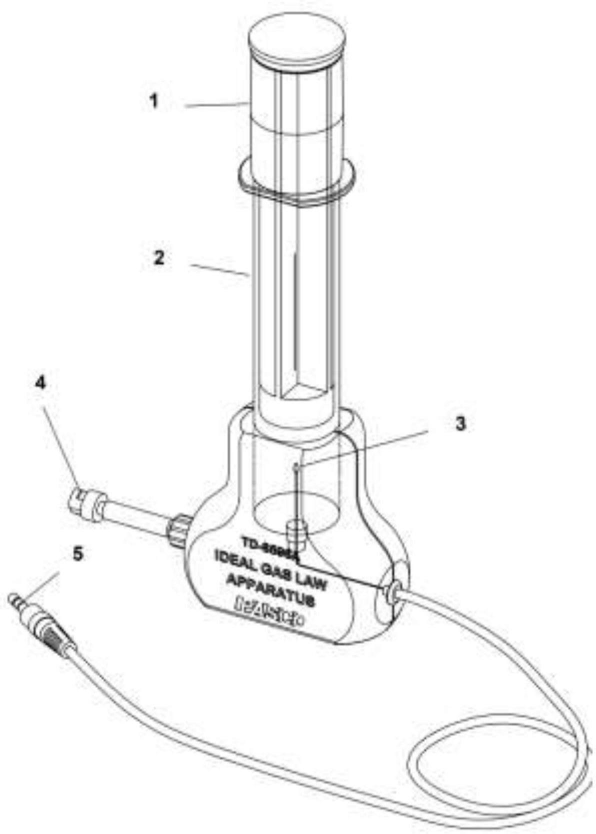


Figure 3: A schematic of the Ideal Gas Law Apparatus. The labeled components are given below.

1. Mechanical Stop
2. Syringe and Plunger
3. Thermistor
4. Pressure Connector (quick-release connection)
5. Temperature Connector (mini stereo jack)

Procedure:

1. Connect the Absolute Pressure/Temperature Sensor to the P850. You need to connect to "PasPort 1". Make sure the P850 is on.

2. Download and open the program called "PHYS101_Ideal Gas Law.cap". This will bring up a program with a plot that measures Absolute Pressure (kPa) Vs. Temperature (°C).

3. Connect the audio jack to the Absolute Pressure/Temperature Sensor. The audio jack is connected to a thermistor (a type of thermometer that goes inside the Ideal Gas Law Apparatus.

4. With the pressure coupling **disconnected,** push the plunger all the way in so that the stop is bottomed out. If the sensor is not disconnected at this stage you could damage the equipment. Record the volume reading on the syringe. Is should be close to 20 mL. It is okay if the bottom of the syringe is 2 mL greater or smaller than 20 mL.

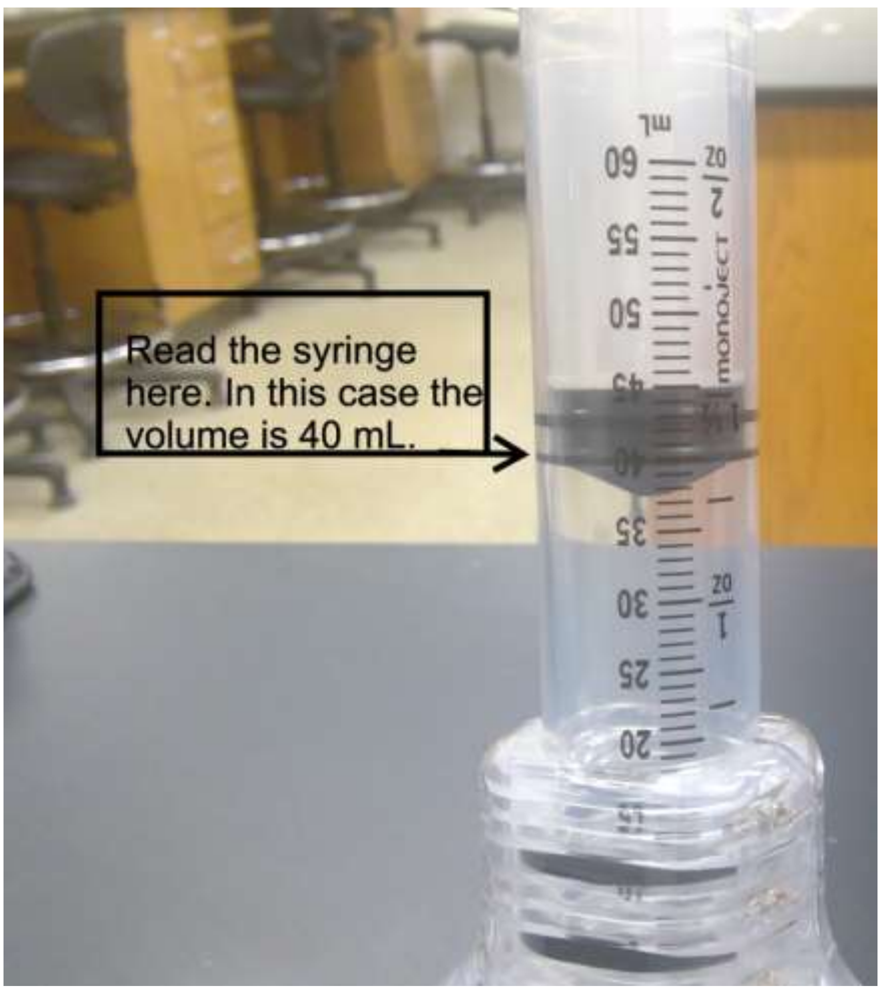


Figure 4: How to read a syringe. Make sure you don't read the very bottom. Otherwise, all of your measurements will be much too small.

5. With the pressure coupling still **disconnected**, pull the plunger out to 35 cc. **Connect** the pressure coupling. This will seal the system.

6. Look at the sample data below before you start collecting data: that will help you understand what to expect from the data. The arrows indicate the direction that the process occurred in. It would be a good idea to do a sample run and just observe the data as it is gathered so you understand how to read the plot.

7. Click on the “Record” button. The program will start recording. You should see a dot on the plot that is close to the coordinates (25°C, 100 kPa). That is location P1.

8. Firmly press the plunger down to the minimum volume of the plunger. You should see the pressure increase very rapidly. Eventually, the temperature will increase too, and will settle to some maximum value, as shown in the sample data given below (P2).

9. Wait for the temperature to settle back down to room temperature (P3). That will take roughly 30 seconds. You do not need to record any data at P3. You just need to wait for the data to reach that location.

10. Release the plunger and allow it rapidly expand. You will see the temperature and pressure of the gas decrease dramatically (P4).

11. Use the coordinate tool to see the numerical values for each of the indicated data points. The coordinate tool is located at the top of the graph of your data. It looks like a small crosshair.
12. Record your data in the provided excel spreadsheet, and make sure to perform all indicated calculations and conversions. For each trial there is a section called “Plunger Down” and “Plunger Up”. Plunger down uses the pressures and temperatures at P1 and P2. “Plunger Up” uses the pressures and temperatures at P2 and P4.

13. You should repeat the experiment a total of 4 times. Each time you reset the experiment you need to **disconnect** the pressure coupling, set the starting volume, and then **reconnect** the pressure coupling. Notice that the starting volume changes for each experiment.

14. When comparing the final pressures that you measured and calculated for the compression and expansion of the gas you should use the % difference equation, since there is not an accepted value in this experiment. Instead, we just want to see how different the two are. The equation for % difference is given below. “m” stands for measurement.

$$\% \, Difference = \frac{m_2 - m_1}{\frac{1}{2}(m_1 + m_2)} \times 100$$

15. Answer the questions at the end of the lab. You should type them up in the spread sheet, and then send the spreadsheet for the group in an email.

Questions:

1. How accurate do you think your volume measurements in the experiment were. Can you think of any physical reason why they might be a little too large or small?

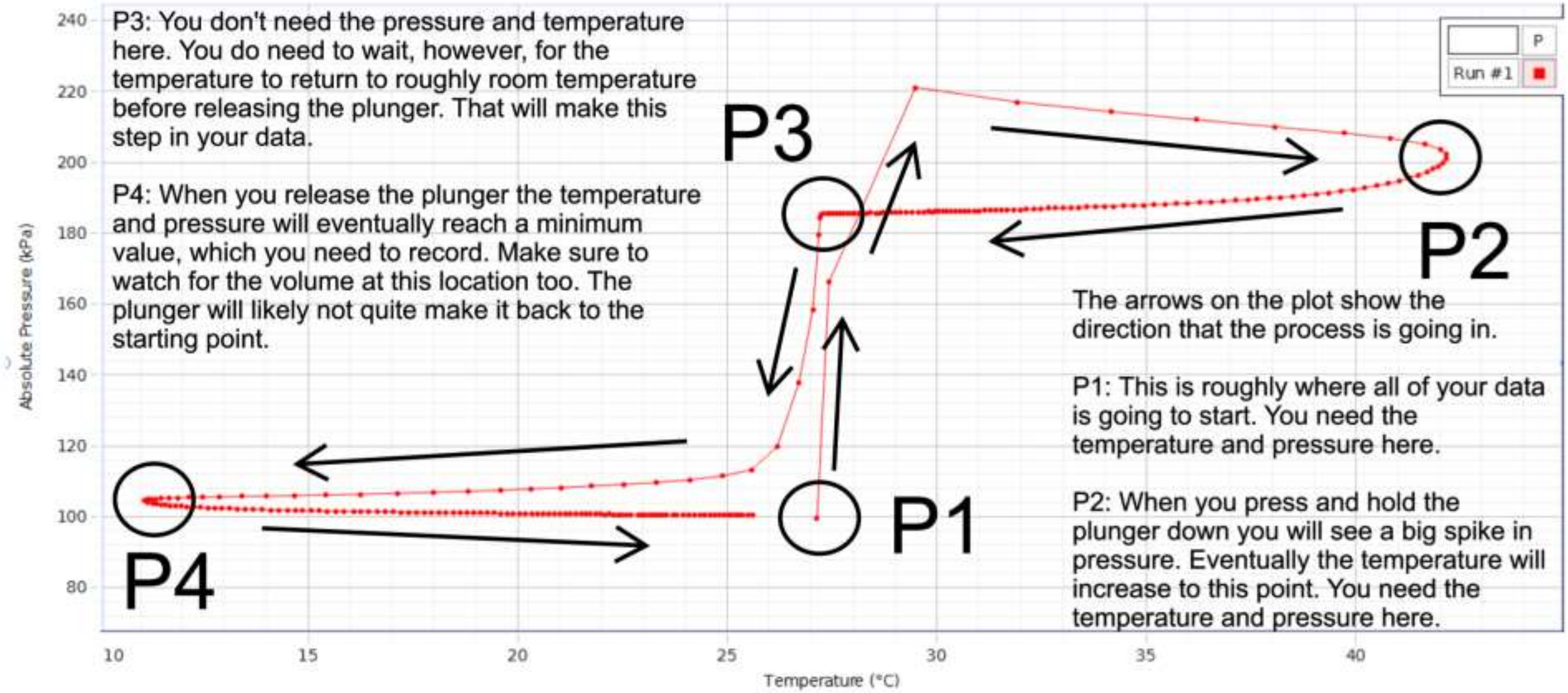
2. What do you think would account for the error in this experiment? Can you think of a way to improve upon the experiment?

3. When you depress the plunger at the beginning of the experiment, the pressure spikes very quickly, but the temperature does not change very much. It takes time for the temperature to increase. Why is this? Can you think of a physical reason? *Hint: When you first depress the plunger, does it actually bottom out, or does it just get close to the bottom?*

4. When you allow the plunger to expand quickly, the temperature drops rapidly. Can you think of a possible application of this effect?

5. Did the % difference in your data change systematically as the starting volume increased? If it did, why?

Sample Data



P3: You don't need the pressure and temperature here. You do need to wait, however, for the temperature to return to roughly room temperature before releasing the plunger. That will make this step in your data.
P4: When you release the plunger the temperature and pressure will eventually reach a minimum value, which you need to record. Make sure to watch for the volume at this location too. The plunger will likely not quite make it back to the starting point.
P3
P2
P1
P4
The arrows on the plot show the direction that the process is going in.
P1: This is roughly where all of your data is going to start. You need the temperature and pressure here.
P2: When you press and hold the plunger down you will see a big spike in pressure. Eventually the temperature will increase to this point. You need the temperature and pressure here.
P
Run #1
Absolute Pressure (kPa)
Temperature (°C)
240
220
200
180
160
140
120
100
80
10
15
20
25
30
35
40