Absolute Zero

Equipment

Included:

1	Absolute Pressure Sensor	PS-2107
1	Quad Temperature Sensor	PS-2143
1	Absolute Zero Apparatus	TD-8595

Not included, but required:

1	850 Universal Interface	UI-5000
3	Plastic Containers (2 liters)	
	Hot Water	
	Room Temperature Water	
	Ice Water	
	Calipers	

Introduction

In this experiment, the value of absolute zero is determined in degrees Celsius by plotting Temperature vs. Absolute Pressure and finding the temperature at which the Absolute Pressure is zero.

Theory

The Ideal Gas Law relates the absolute pressure (P) and volume (V) of a gas to the absolute temperature (T) in degrees Kelvin.

$$PV = nRT \qquad (1)$$

where n is the number of moles of gas, and R is the ideal gas constant.

In 1802, Joseph Gay-Lussac discovered the direct relationship between the pressure and temperature of a gas at constant volume:

$$T = cP \qquad (2)$$

where, c is a constant. Solving Equation (1) for T gives the constant:

$$c = V/nR \qquad (3)$$

According to Equation (2), what is the temperature of a gas when its absolute pressure is zero? We can use the fact that when the absolute pressure of the gas is zero, its temperature is zero. Although it is not possible to reach absolute zero, we can perform an experiment in which we vary the temperature of the gas at constant volume, measure the resulting absolute pressures, and then plot absolute pressure vs. temperature (in ^{o}C). By extrapolating back to zero absolute pressure, we can find the value for absolute zero in degrees Celsius.

Since $T = T_C - T_{Absolute\ Zero}$, Equation (2) becomes

$$T_C = cP + T_{Absolute\ Zero} \qquad (4)$$

At P = 0, the temperature T_C is equal to absolute zero.

Setup

The Absolute Zero Apparatus consists of a hollow sphere that acts as a container of constant volume as the apparatus is placed in different temperature water baths. As shown in Figure 1, plug the mini stereo jack into the temperature port to measure the temperature using the thermistor imbedded in the wall of the sphere. Connect the white plastic pressure coupling to the pressure port to measure the pressure inside the sphere.

Figure 1: Connecting the Sensors

You will need a source of hot water and a source of ice.

<u>Pressure Sensor Calibration</u>:

1. Create two digits displays with the Absolute Pressure on one display. The other digits should be a calculation: Open the Calculator in PASCO Capstone and make this calculation:
   Abs Pressure Calibrated=[Pcal(kPa)]+[Absolute Pressure(kPa)]. Define [Pcal(kPa)] = 0.

2. With the Pressure Sensor disconnected from Absolute Zero sphere, click Monitor and compare the direct reading from the Pressure Sensor and the Calculated Pressure.

3. Subtract the Pressure Sensor Reading from atmospheric pressure (101 kPa or the reading of a barometer, if you have one). Type the result into the calculator for the constant Pcal.

4. If you have entered the correct constant for Pcal, the calculated pressure will read the calibrated pressure value. It may be necessary to calibrate the absolute pressure sensor. The sensor should read 101 kPa (14.7 psi) when you equalize it with atmospheric pressure. Set up a digits display with Absolute Pressure and record some data. If it does not read the correct value, open the Calibration tool at left and calibrate the pressure using "One Standard (1 point offset)".

Temperature Sensor Calibration:

1. Open the Calibration in PASCO Capstone.

2. Follow the calibration procedure, choosing "One Standard (1 point offset)" on calibration step 3.

3. Put the Absolute Zero Apparatus sphere into the ice bath and wait for it to come to equilibrium. See Figure 2. Once the temperature isn't changing anymore, choose to set the current value to the standard value of 0°C in calibration step 4.

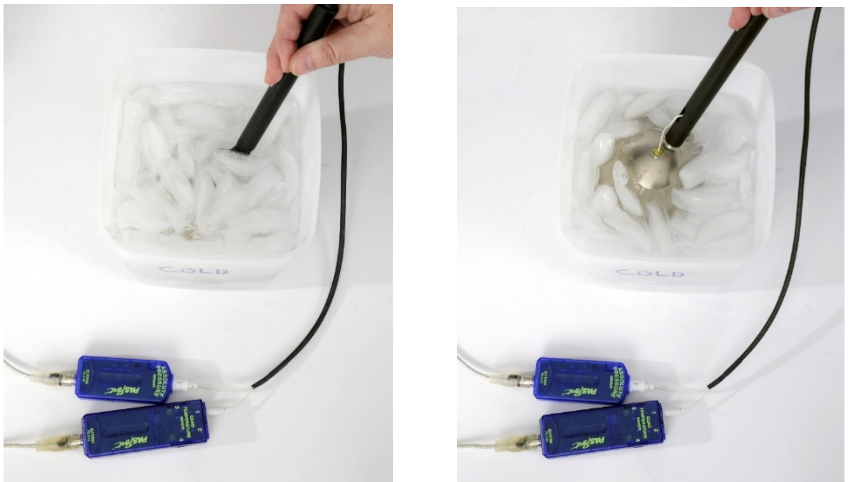

Figure 2: Be sure to completely submerge the sphere into the ice water.

Procedure

1. Set the sample rate at 10 Hz for both sensors. Set up a graph in PASCO Capstone of Temperature in ^{o}C vs. the calculated “Abs Pressure Calibrated”. Create a table with Temperature and “Abs Pressure Calibrated”. Select Manual Sampling from the sampling options in the Setup menu.

2. Fill one of the plastic containers with enough hot water to cover the sphere. Fill the third container with room temperature water, leaving enough room to submerge the sphere. Completely submerge the sphere in the ice water. Make sure the white plastic pressure coupler is connected to the sensor after putting the sphere in the ice water so the number of moles of gas is set while in the ice water.

Figure 3: Three Different Temperature Baths

3. Start data previewing. Completely submerge the sphere and wait for the pressure and temperature to equalize. Click on Keep to save that data pair.

4. Put the sphere into the room temperature water and completely submerge it. Don't disconnect the pressure coupler. Wait for equilibrium and then click on Keep.

5. Put the sphere into the hot water. Stir the water to get an even temperature, submerge the sphere and click on keep when the pressure and temperature equalize.

6. Click on Stop. Rename the run in the table to "Ice First".

7. Start a new run and put the sphere in the hot water and equalize the pressure by disconnecting and then reconnecting the pressure coupler while in the hot water. This makes the sphere have a different amount of gas in it. Once the pressure and temperature have come to equilibrium, press Keep.

8. Put the sphere into the room temperature water and press Keep once it has stabilized.

9. Finally, put the sphere in the ice water, wait for the readings to stabilize, and then press keep. And then press Stop. Rename this run "Hot First".

10. Repeat this procedure, equalizing the pressure in the room temperature bath first, then go to the ice water bath, and then go to a hot water bath. Rename this run "Room First".

Analysis

1. Determining Absolute Zero: By definition, the pressure of a gas is zero at absolute zero temperature. Find the temperature at which P = 0 for each of the three runs. You will need to fit a straight line to each run to do this. Average the results from the three runs and make an estimate of the uncertainty using the standard deviation. Round the average to the appropriate number of digits based on the value of the uncertainty.

2. Use calipers to measure the diameter of the sphere, and calculate its volume. Is this measurement more or less than the actual volume of the sphere? Why?

3. Use the Ideal Gas Law to show that a graph of Temperature vs. Pressure results in a straight line with a slope given by

$$Slope = \frac{V}{nR}$$

4. Determine the slope of this line from the Temperature vs. Pressure graph for one of your runs. Use your values to determine the number of moles (n) of air in the sphere. Pay attention to the units! Which run had the greatest number of moles of gas in the sphere?

Conclusion

Write a summary of your results. What general conclusions can you draw from your results? For instance, how does the pressure of a gas change when the temperature is decreased while the volume is held constant? How does the pressure of a gas change when the number of molecules is decreased while the volume is held constant?

Give the numerical value of Absolute Zero that you measured including the uncertainty, the accepted value, and the percent difference between them. Was the value you found lower or higher than the accepted value? Does the accepted value fall within the uncertainty of your measurement? Why or why not?