LAB 2
Air: An Ideal Gas?

OBJECTIVES
1. Experimentally verify the Ideal Gas Law.
2. Determine Absolute Zero and the Universal Gas Constant.
3. Determine the fastest way to cool a cup of hot water using only a spoon.

EQUIPMENT
CapStone, absolute pressure sensor, temperature sensor, syringe, tubing, quick-release coupling, metal canister with stopper, and tubing-to-stopper connector.

THEORY
Solid, liquid and gas are the most common states of matter found on this planet. The only difference among all these states is the amount of movement of the particles that make up the substance. The Ideal Gas Model allows one to make the following statement: gases exert force on the walls of their containers by means of the continual collisions of the gas molecules with the surface. The force per unit area is termed pressure. Pressure depends on three parameters according to the kinetic model of ideal gases: volume, temperature, and the number of moles.

From the ideal gas law \( pV = nRT \), the absolute pressure is directly proportional to the temperature of the gas: \( p = \frac{(nR/V) T}{V} \). Note that this is of the form of the equation for a straight line, \( y = mx + b \). If we plot pressure versus temperature, it should be a straight line whose slope is equal to \( (nR/V) \). We can also get absolute zero from this line by solving for the temperature at which the pressure becomes zero.

PROCEDURE

Part 1: Ideal Gas Law — Pressure vs. Volume

The goal of Part 1 is to verify the ideal gas dependence of the pressure on the volume.

(a) Use a syringe, tubing and a Capstone absolute pressure sensor to measure the pressure of air inside the syringe. Set the pressure to be atmospheric pressure when the syringe volume is 20 mL. Use the ideal gas model to predict the pressures at 5 points below 20 mL of your choosing.

(b) Compress the syringe and measure the pressures at your points. Use a percent difference to compare your calculated values to your measured values.

- Identify the sources of error in this experiment that may contribute significantly to the percent error.

(c) Choose a method to plot pressure vs. volume to determine whether your data supports the ideal gas model. Interpret your plotted data; does the data agree with the Ideal Gas Model?
Part 2: Ideal Gas Law — Pressure vs. Temperature

The goal of Part 2 is to determine the ideal gas constant and the temperature of absolute zero (in Celsius) using the ideal gas model. Also, you’ll get enough data to verify the ideal gas pressure-temperature relationship.

(a) Use a canister of air, a water bath and two sensors (absolute pressure and temperature) to plot the pressure (Pa) vs. temperature (°C) of air for different temperatures. Make sure that you have at least 10 data points that span a temperature ranges of ~30 °C.

(b) Apply a linear fit to your p-T data and record the equation of the fitted line.

(c) From the slope of the fitted line, calculate the value of the ideal gas constant.

(\textbf{Hint:} You do not need to calculate the number of moles or the volume of the air. You can calculate the number of moles per cubic meter n/V from the density of air and the molar mass of air.)

(d) From the equation that fit your p-T data, calculate absolute zero, the temperature at which the pressure goes to zero.

(e) Use a percent difference to compare your experimental values for the ideal gas constant and for absolute zero to their theoretical values.

- \textit{What are the most significant sources of error in this experiment and how do you expect them to affect your results?}

- \textit{Would the slope have been any different if you plotted pressure versus temperature in Kelvin rather than Celsius? Explain.}

Part 3: What is the fastest method to cool a cup of hot water, if your only available instrument is a spoon?

(a) The only available equipment is a metal spoon, ice bath, insulated cup, Capstone thermometer, and access to boiling water.
(b) Design four different experiments and rank them in terms of which method of cooling will be the slowest or fastest. Explain your reasoning!
(c) To use the spoon, first dip the spoon into the ice bath and then into the hot water in the insulated cup.
(d) Do the experiments by measuring the temperature every 30 seconds for 10 minutes for each prediction. Plot all data on a single plot and interpret your results.
Cooling water rules:
1. No other equipment other than what is listed may be used.
2. No pouring the water out of the cup.
3. No adding ice to the water.
4. Cup must stay flat on table at all times.
5. The only thing you can put in the water is the spoon (and the temperature sensor).
6. Goal: what is the largest $\Delta T$ in 8 minutes?