PHYSICS 133 EXPERIMENT NO. 9
GAS THERMOMETRY, OR THE QUEST FOR THE ABSOLUTE ZERO

Introduction

The kinetic theory of gases states that an ideal gas will obey the relation

$$pV = nRT \tag{1}$$

where, in SI units, p is the pressure in Pascals, V is the volume in m^3, n is the number of moles of gas, R is the gas constant (8.31 J/mol K), and T is the absolute temperature in K. When V and n are kept constant, we see that equation (1) gives a linear relationship between p and T. Using the pressure and temperature characteristics of air, we will estimate the absolute zero of temperature on the Celsius scale.

Equipment

- Hot plate,
- beaker,
- aluminum gas cell,
- large graduated cylinder with reservoir,
- pressure transducer,
- power supply,
- digital voltmeter,
- ice water.

Method

The pressure transducer employed in this experiment is a device that uses piezoelectric crystals. Piezoelectric crystals produce an electric voltage across their faces when squeezed or stretched. By orienting a number of them cleverly inside the transducer, one can measure the applied gas pressure from the produced output voltage. Briefly stated, the pressure transducer outputs an electric voltage proportional to the applied pressure. The transducers are calibrated so that they will output about 0 volts at 1 atm pressure. The linearity of the transducers will be checked over a small range by changing the height of a column of water pressing on the air inside a plastic tube connected to the transducer.

Next, the tube will be evacuated by attaching it to a vacuum pump (effectively reducing the pressure almost to zero), and the change in output voltage output will be noted. Finally, the pressure of the gas in the aluminum gas cell will be measured after placing the aluminum gas cell into boiling water and ice water, at temperatures of 100^{o}C and 0^{o}C, respectively.

Procedure

I. Linearity of pressure transducer
Attach the pressure transducer to the T-connector at the bottom of the large graduated cylinder and open the clamp leading to the pressure transducer. Notice that there is another tube leading to a metal can on the supporting rod. By moving the can up and down, you can change the level of the water in the graduated cylinder. Explain how this apparatus works.

Measure the voltage output from the pressure transducer at 5 different water levels. Using the relation that 1 atm corresponds to 1033 cm of water, calculate the pressure in the transducer for these different heights in atms. Graph the change in voltage vs. the change in water pressure that caused the voltage change.

> Q1. Is the graph linear? Calculate the slope of the graph.
> Q2. What can you say about the linearity of the transducer?

II. Zero pressure
To ensure that no water has entered the transducer, **we will use a second transducer for the remainder of the experiment. (Do not use the same transducer you used in Part I above.)** Attach another transducer to the vacuum pump, open the valve, and record the voltage after several minutes, once the value has become stable. The lowest pressure that the mechanical pump can reach is approximately 0.0001 atm, which is small enough to be considered zero for our purposes. Find a linear equation relating pressure and voltage which includes the voltage at 1atm. and the voltage at 0 atm. Compare the slope with that obtained in part 1.

III. Pressure thermometry
The pressure inside the aluminum gas cell will now be measured at 0^{o}C and 100^{o}C. Immerse the gas cell in the boiling water. **<u>CAUTION!:</u> boiling water is as dangerous in the physics lab as it is in the kitchen. <u>Proceed with care!</u>** Avoid making any sudden or impulsive moves that might knock over the apparatus. **Be careful not to touch hot objects.**

After waiting a few minutes for the gas to reach the temperature of the water, attach the **same pressure transducer (i.e., the one that you just used in Part 2 above)** to the gas cell and record the voltage reading. You might measure the temperature of the water with a thermometer, but they are only accurate to 1^{o}C. Next, put the gas cell (**with the transducer still attached**) into the bucket of ice water and wait for it to come to equilibrium. Record the voltage. From the equation that you determined for voltage vs. pressure in part 2, calculate the pressure at both temperatures. Graph the pressure versus temperature with these two points and extend the line to $p = 0$.

> Q3. At what temperature (in ^{o}C) would the pressure go to zero?
> Q4. How does this compare to the expected value of absolute zero?