Lab #4: The Ideal Gas Law and Air

Objectives: Determine experimentally the relation between the pressure and volume of a gas at constant temperature (Boyle's Law), and the relation between the pressure and temperature for a fixed volume of gas (Charles Law II). In these experiments, your test gas is room air trapped in a container. Check how well air obeys the ideal gas law by comparing its predicted room temperature and actual temperature.

The Ideal Gas Law: (Refer to section T2.2 in the textbook.)

$PV = Nk_BT$ where N = # particles, k_B=1.38 x 10^{-23} J/K

$PV = nRT$ where n = # moles, R = 8.31 J/mole-K.

<u>I. Boyle's Law Procedure:</u>

Your test container is a syringe. A hose attached to the base of the syringe can be connected to a computerized pressure sensor within the *DataStudio* environment.

Measure T(room) = ____________________

Before connecting the hose to the sensor, raise the plunger to about 2/3 the length of the syringe. Connect the hose.

Take data by moving the plunger slowly to approximate a constant temperature gas. The pressure will register on the digital computer meter, and you can measure the volume change using the syringe markings. Be sure to record the total initial volume of your syringe/hose system. You should take readings for both compression and expansion of the volume, for at least 7 pressures. Try to hold the syringe by the plastic tabs, rather than the cylinder (why?). Estimate the uncertainties in your volumes and pressures.

Enter your volume and pressure values into Excel. Think about the ideal gas law given above and how you should plot P and V so that a line results. Make any calculations you need. Put P on the x-axis. Add error bars corresponding to your uncertainties to your plots. (Ask for help if you don't know how to do this.) Use the linear regression tool to fit a line. Write down your slopes and y-intercepts and the error in each. Also fit the data so that the line is forced to go through the origin and write down your slope and error.

<u>II. Charles's Law Procedure</u>

Your container is now a glass flask, sealed by a rubber stopper. A glass tube through the stopper is attached to a hose, which can be connected to the computer sensor.

Measure the volume of the flask and hose (and uncertainty): ________________________

Measure how the gas pressure depends on the temperature by immersing the flask in baths of different temperatures. Ice water is provided, and you can heat water in your steam generator. Mix cold and warm water in different amounts to get different T baths. Measure the pressure for about 7-8 temperatures, over a range of temperatures from 0 – 60 Celsius. *Do not immerse the flask in boiling water*. Measure the temperature of the water using the temperature probe connected to *DataStudio*. Estimate uncertainties in pressure and temperature.

Use Excel to plot the data and find the slope with fitting errors (include a fit which forces the line through the origin.) Put P on the y-axis.

III. <u>How well does your test gas obey the Ideal Gas Law?</u>

You should complete this section during lab, as long as time allows.

To derive the ideal gas law, you would need to combine your relationships from I and II with a relationship between T and V. Instead of doing this, you will test how well room air obeys the ideal gas law by assuming it applies and using it and your measured relationships to make a prediction about the temperature of the room. You will then compare this prediction to your initial measurement of the room temperature.

You have relationships between T and V and P and V, i.e.:

$$P = c_1 / V \quad (1)$$
$$P = c_2 T \quad (2)$$

where you know the values of c_1 and c_2.

Now compare the form of your measured relationships with the ideal gas law. Manipulate equations (1) and (2) so that you set c_1 and c_2 equal to an expression involving only the other constants of the process (e.g., N, k_B, T or V). Subscript the constant T or V for parts 1 and 2 with a 1 and a 2. Obtain an expression for T_1 in terms of quantities you have measured and determine T_1 . Find your uncertainty in the predicted value for T_1. Does the measured temperature fall within this range? If the temperatures are different, calculate a percent difference.

Writeup: Formal report due on Thursday, October 12, 2006. Be sure to address in the discussion section what experimental errors (besides measurement errors) might have affected your results.