

This sheet is the lab document your TA will use to score your lab. It is to be turned in at the end of lab. To receive full credit you must use complete sentences and explain your reasoning clearly.

**HC-1 The Ideal Gas Law and Absolute Zero:**

In this lab you will do Experiments I and II. In Experiment I you will explore the different behaviors between an isothermal and an adiabatic process. In Experiment II you will find absolute zero. In both experiments you will be verifying the ideal gas law, checking that there is a linear relation between P and V (Experiment I) and P and T (Experiment II) when the remaining quantities in the ideal gas law are kept fixed. The procedure for determining the “best fit” line that relates the dependent variable to the independent variable is called a linear regression, or least-squares fit to a line. It comes directly from the maximum likelihood analysis we discussed in Lecture 10. The details are a bit tedious so we won’t go into it here; instead, you will use a linear regression tool (in Excel) to do the job to find the “best fit” line from your data. If you want to know more, there’s a really good book about how this works: “Data reduction and error analysis for the physical sciences” by Philip R. Bevington and D. Keith Robinson, McGraw-Hill, 2003.

Note there is a Data Studios file called HC-1.ds that will help with parts I and II. You can download it from the Laboratory page on the course website (same place this document is found) to the lab PC.

**Experiment I:**

In this experiment you will compress 60 cm<sup>3</sup> (cc) of air to about 20 cm<sup>3</sup> and observe quantitatively how the pressure varies. The computer only reads the pressure (relative to a vacuum) and volume data is entered manually with the  Keep button. Each time you click the  Keep button you will be asked to enter the volume in cm<sup>3</sup>. The computer will build a table and graph the results as a PV diagram. You will also construct a graph of P vs. 1/V for use answering the questions.

Procedure:

- 1) Follow the instructions in part 1 and 2 of the lab manual taking some time to familiarize yourselves with the data collection procedure.
- 2) Before taking a data set disconnect the coupling, set the syringe to 60 cm<sup>3</sup>, reconnect the coupler, click  Start, then  Keep, and enter 60 in the pop-up box. This ensures that you always start with the same volume and pressure.
- 3) Compress the gas in the syringe as slowly as possible clicking  Keep at 5 cm<sup>3</sup> intervals and recording the volume. You can continue to slowly compress the gas while the volume is being recorded. To reach 20 cm<sup>3</sup> requires substantial force and it

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may be difficult to maintain but go as slowly as is practical and as close to  $20 \text{ cm}^3$  as you can.

- 4) Now take another data set starting with the instructions in 2) above but compressing the gas as quickly as possible to the same volume you reached in part 3). Click  Keep as soon as you reach minimum volume.
- 5) Plot the data collected in part 3) in two ways; P vs. V and P vs.  $1/V$ . Do this in Excel or in any other way you choose. One graph should be a straight line and do a linear regression on that one to find the best-fit value for the y-intercept. Print both and include them in your write up. You do not need to plot the data from part 4).

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Questions:

1) The slow compression is an attempt to create an isothermal process. Using the data in the table compare the product of  $P \times V$  at the endpoints and explain your conclusions about how close this process is to an ideal isothermal process.

2) Look at this question another way with the linear plot of this data.

If the process is isothermal, what should the y-intercept be? Explain your reasoning.

What is the y-intercept (0, >0, or <0)?

Are the pressures recorded those expected for an isothermal process? Explain your reasoning.

3) During this slow process you were doing Work on the gas. How come this Work does not raise the temperature? Hint: Why did we compress the gas slowly?

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4) Now compare the product of  $P \times V$  at the endpoints of the fast compression and explain the differences from the slow process in the questions below.

a) Which process had the greatest change in internal energy? How can you tell?

b) Was the same amount of Work done in both cases? How can you tell?

5) Consider  $Q$  for the slow case.

a) What other thermodynamic quantity does it equal? Explain your reasoning.

b) Does this  $Q$  flow out of or into the gas? Explain your reasoning.

6) Consider  $Q$  for the fast case.

a) What does  $Q$  equal? Explain your reasoning.

b) What do we call this process?

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## Experiment II:

In this experiment you will change the temperature of a fixed volume (and fixed  $n$ ) of air and observe quantitatively how the pressure varies. Use the same computer experiment as before and record pressure and temperature data in the table below. You do not need to do data entry in the computer, otherwise follow the directions in your lab manual. You will need to plot  $P$  vs.  $T$ , do a linear regression, and find the  $x$ -intercept (just like figure 16.2 in Knight). While you are waiting for thermal equilibrium at the various temperatures, answer the question below.

Question:

- 1) Why should there be a limit to how cold something can be? Hint: What is the meaning of  $P = 0$ ?

Procedure:

- 1) Collect the four data points as instructed in your lab manual and record them in the table below.

	Liquid N <sub>2</sub>	Ice Water	Room Temp.	Boiling Water
Temperature				
Pressure				

- 2) Create a plot of  $P$  vs.  $T$ , do a linear regression, and find the  $y$ -intercept. Print your plot and include it in your write up.

***\*\*\*Never put liquid nitrogen in a sealed container! This may seem obvious, but last year a student did this and created an explosion in the lab.\*\*\****

Questions:

- 1) What is the percent difference between your value and the accepted value for absolute zero? Show your calculation.