8.2: Activities

Equipment

- two-liter bottle with sealed-tube connector
- compression arm apparatus
- Pasco box, pressure sensor, and software
- air pump

The General Idea

The constant γ for a gas tells us a lot about that gas. Most notably, it (indirectly) tells us the number of modes available for the equipartition of energy in that gas, which also tells us the heat capacity of that gas under various processes. In this lab, we will use what we know about the composition of air to form an hypothesis of the value of γ for air, then test it with a simple experiment where we force a trapped quantity of air to undergo some well-known processes and measure the values of the pressure at endpoints of these processes. This is a lab where taking the data is the easy part – doing the analysis and accounting for possible sources of error are where the main challenges lie.

Some Things to Think About

This lab is unusual in that the experiment itself is very short. It mostly boils down to "solving the physics problem", which is never an easy task, so you should not expect to cruise through this quickly. Engage your group to figure out the important relevant ideas, and then put them together. Extracting what you are looking for from what is seemingly too little information is always very challenging but is also very satisfying when it is finally accomplished.

Our experimental apparatus is simple in the extreme. We have the ability to compress the gas with the compression arm (though not in a particularly controlled manner), and we can measure the resulting pressure of the gas in real time. What we *cannot* do with this setup is measure either the volume or temperature of the gas. So we need to make the most of what we do have control over. We are looking for γ, and the first thing that comes to mind is the role that this constant plays in the mathematics of the adiabatic process, so it stands to reason that having the trapped air follow an adiabatic process will be useful for our experiment.

- The Pasco application you will be using is called "Gas_Processes."
- You will find that the experiment works a little better if the air in the bottle starts at a pressure a bit higher than atmospheric. Before performing your experiment, run the software to measure the pressure, and if it is below $140 kPa$, use the pump to bring it up to around $145 kPa$. If you run the software for awhile, you may detect a slow leak. As long as it is very slow, it shouldn't be a problem. If it is losing pressure too fast (say faster than $1 kPa$ per 20 seconds), talk to your TA to get help fixing the leak.
- An adiabatic process is one in which no heat it exchanged. How can you change the state of the trapped gas with only the compression arm available, such that no heat is exchanged during that process? Note that you are not able to insulate the bottle of air.
- Assuming you know how to achieve an adiabatic process, what mathematical relationship exists between the pressure and temperature just before the process, to the pressure and temperature after the process? [*If all you know is the relationship between the pressure and volume, then perhaps the ideal gas law can be of assistance.*]
- You will need to do multiple processes to get your final value of γ. Besides the adiabatic process, what other special process(es) (isochoric, isobaric, isothermal) are you able to achieve with this rudimentary setup?
- Using whatever processes you have available, you can measure the beginning and ending pressures of these processes (actually, the pressure sensor will measure several pressures along the way, but these intermediate values are not useful). Using these values, as well as what you know about the processes and the ideal gas law, you should be able to do the math to extract the constant γ.
- Once you have a value for γ, compare it with your hypothesized value, noting in particular whether the experimental value is higher or lower. Discuss in your lab report why this might be the case, based on the following two considerations:
  - The criteria you used to estimate the value of γ for air – what omission(s) might throw-off your result, and in which direction will it be thrown-off?
  - Limitations of the measuring device (other than poor calibration) that might lead to systematic error in one direction. In particular, think about the effect of the *sampling frequency* of the pressure sensor.

Lab Report

Craft a lab report for these activities and analysis, making sure to include every contributing group member's name on the front page. You are ***strongly encouraged*** to refer back to the Read Me as you do this, to make sure that you are not leaving out anything important. You should also feel free to get feedback from your lab TA whenever you find that your group is at an impasse.

Every member of the group must upload a separate digital copy of the report to their lab assignment in Canvas *prior to leaving the lab classroom*. These reports are not to be written outside the lab setting.
