Summary of the Boyle's Law Experiment

This document is a summary of the Boyle's Law experiment. The full description of the experiment is http://www.upscale.utoronto.ca/IYearLab/Intros/BoylesLaw/BoylesLaw.html.

Boyle's Law

Boyle's Law states that the pressure **p** and volume **V** of a fixed quantity of gas at constant temperature are related by:

$$\mathbf{p\ V} = \text{constant}$$

Thus, a fit of **pV** versus 1/**V** should be a straight line with zero slope. If the slope is not zero, it is likely that a *systematic error* has occurred in estimating the effective top of the closed tube. This error, if present, is negligible for infinite volumes, which corresponds to a zero value of 1/**V**. Thus the intercept of the fit should be the true value of **pV**, which will allow a correction to be applied to the values of the volume.

Data Collection and Analysis

Atmospheric pressure $\mathbf{P_a}$ and room temperature should be measured before and immediately after taking data.

If the difference in Mercury levels in the open and closed portions of the glass tube is **h**, then the pressure of the sample of gas is:

$$\mathbf{p} = \mathbf{P_a} \pm \mathbf{h}$$

You should collect data over as wide a range of pressure and volume as possible.

Do not move the reservoir up or down too quickly. This can cause the mercury to overshoot and cause a spill. After moving the reservoir you should wait a few seconds before taking readings.

Converting to SI Units

For verifying Boyle's Law, measuring pressure in *mm of Mercury* (*Torr*) and volume in units of the length of the closed end of the tube is convenient.

You will convert your final value of **pV** to the SI unit of *newton-meters* = *joules*. To do the conversion you will need to know that:

- The cross-sectional area of the tube is $0.1225 \pm 0.0005\ \text{cm}^2$.
- The density of Mercury at 0 C is $13.5951\ \text{gm/cm}^3$ with negligible error.

- The volume of a quantity of Mercury increases as its temperature increases. Thus its density decreases with increasing temperature.
- The volume increase is Δ**V** =**V**$_0$ α **t** where:
    - $\alpha = 0.181 \times 10^{-3}$ deg^{-1} with negligible error.
    - **V**$_0$ is the volume of the Mercury when the temperature is 0 C.

Calculate the value and error of 3/2 **pV** in joules. Theoretical physics predicts that this is the total kinetic energy of the air molecules in your small sample of gas.

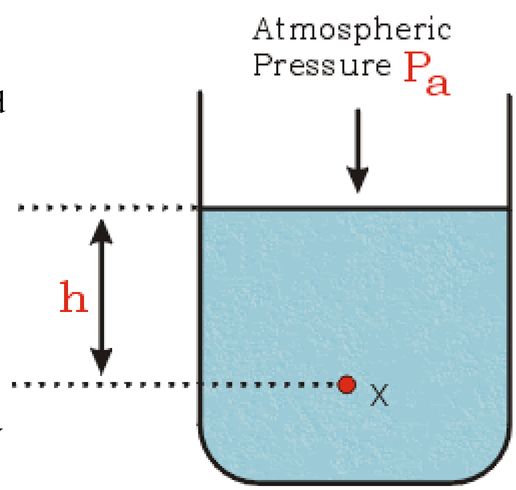
Compare this energy to the amount of energy necessary to boil a gram of water from room temperature.

Preparatory Questions

These questions should be answered and turned in to your Demonstrator *before* beginning the experiment.

Note: These questions are intended to guide you in your preparation for the experiment. They do not have any "tricks."

1. In the full experiment description you looked at an animation showing the effect of changing the height of the mercury reservoir on the heights of the mercury in the tubes. The distance between the heights of the mercury in the two tubes was shown with an arrow. The arrow changed color and intensity as the animation progressed. The color and intensity of the arrow is related to the pressure of the gas in the closed end of the tube with respect to atmospheric pressure. How does the color and intensity of the arrow represent this pressure?
2. This question refers to the figure to the right. Write down the equation for the pressure **p** at the point **X** situated a distance **h** below the surface of the liquid. Assume the density of the liquid is ρ . Hint: consider the force that a column of liquid of cross sectional area **A** exerts at the point **X**. Then divide by **A** to get the pressure.



3. Write down two physical properties of *real* gases that might cause their behavior to deviate from Boyle's Law.
4. Given a fixed quantity of gas, will these deviations of the "ideal" behavior of Boyle' s Law be smallest at large or small volumes?
5. The error in the pressure **p** is Δ**p**, and the error in the volume **V** is Δ **V**.
    - What is the error in **1/p**?
    - What is the error in **1/V**?
6. The error in the pressure **p** is Δ**p**, and the error in the volume **V** is Δ**V**. What is the error in the product **p** × **V**?