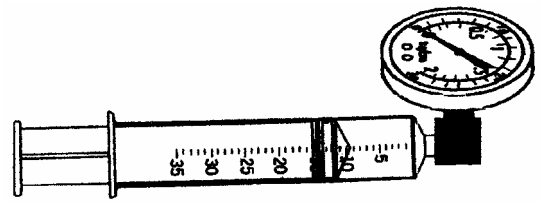
If your morals make you dreary,
depend on it they are wrong.
--Robert Louis Stevenson

The Physical Behavior of Gases

Some of the earliest work leading to formulation of the fundamental laws of *chemical* combination (Law of Multiple Proportions, Law of Definite Composition, Law of Combining Volumes, etc.) was done with gases. In part this happened because the *physical* behavior of gases was already well understood (at least in an empirical way) by the very early 1800s. In fact some of the earliest experiments with gases were quite simple and yet powerful because they inevitably led to an understanding of matter as particulate and linked in its behavior to energy (generally as heat).

The work of Robert Boyle (*Boyle's Law*, 1660) and Jacques Charles (*Charles' Law*, ca. 1800) established the predictable behavior of gases under conditions of (respectively) changing pressure and temperature. Their experiments eventually led to an understanding of the nature of all gases and the development of the concept of "ideal gases".

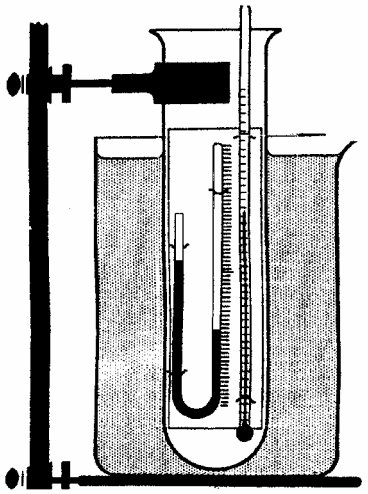
In this activity you will have a chance to see for yourself how gases behave. Boyle's original experiment was done with a "J" shaped tube in which air was trapped by a column of mercury (see Fig. 5.4 on p. 135 in your text). To avoid the problems inherent in the use of toxic mercury, you will use the apparatus pictured below:



The syringe is connected to a pressure gauge and about 30 mL of air has been trapped in the syringe at atmospheric pressure (≈ 1 atmosphere). The gauge reads *additional* pressure and the inside scale is in atmospheres. By changing the volume of the trapped air sample you can determine how the pressure is affected.

Charles Law apparatus adapted from: A Sourcebook for the Physical Sciences, A. Joseph, P. F. Brandwein, E. Morholt, J.F. Castka, *Harcourt, Brace & World*, 1061

The experiment by which Charles deduced the relationship between temperature and volume was also originally done with mercury and a trapped air sample (see Fig. 5.7, p. 138 in your text). In this investigation you will use the apparatus pictured below:



The colored liquid is oil used in vacuum pumps with a dye added to make it more visible. A sample of air is trapped in the long side of the "J" shaped tube. The temperature of the apparatus is controlled by adding ice to the water bath. The entire assembly can be placed on a magnetic stirrer to help maintain an even temperature throughout the beaker. The ruled scale by the side of the J tube is used to measure the relative volume of the air sample (proportional to length since the cross sectional area of the tube is constant).

Preparing to experiment

BE SURE TO BRING YOUR TI-83/84 CALCULATOR TO CLASS FOR THIS EXPERIMENT. YOU WILL ALSO NEED A COPY OF THE HCHEM.83G FILES IN YOUR CALCULATOR MEMORY.

Design an experiment to determine the relationship between pressure and volume for a constant amount of gas and constant temperature (*hint:* take syringe volume readings for each increment on the pressure gauge scale; **DO NOT EXCEED 2 ATMOSPHERES. That means 1.0 on the inside scale!!!!!**).

Design an experiment to determine the relationship between temperature and volume for a constant amount of gas and constant pressure (*hint:* begin at room temperature and add ice gradually, recording the length measurement for every degree, down to about $1^{o}C$ **OR** recording the temperature for each mm change in length--whichever seems more practical).

Analysis

If you do these graphs by hand , the graphs in 1 and 2 may occupy half a page each since you will not be trying to read any information from them. However, the graph for 3 should fill at least 2/3 of the page since you will need to calculate the line equation in order to answer question 4.

1. Plot a graph of pressure vs. volume for your first experiment (remember that the gauge readings are *in addition to* 1 atmosphere).
    a. is the relationship linear?
    b. describe in words the apparent relationship between pressure and volume for a gas

2. Plot a graph of pressure vs. *the reciprocal of the volume* (i.e., calculate 1/V for each reading and plot these on a new graph--using the decimal values for 1/V--as the x-axis.
    a. is the relationship linear?
    b. describe in words the relationship between pressure and the reciprocal of volume for a gas

3. Plot a graph of volume vs. temperature for your second experiment.
    a. is the relationship linear?
    b. describe in words the apparent relationship between temperature and volume for a gas

4. Extrapolate your volume vs. temperature graph to volume = 0. What temperature do you obtain? [if you have done your graph on a computer or calculator, you can use the equation of the line to solve for this answer].

One of the results of Charles' experiment was the determination of what we today call Absolute Zero, or the lowest temperature that can be attained. This establishes the lower limit of the *Kelvin* temperature scale. In degrees Celsius the temperature is $-273^{o}C$. How well does this agree with your result? Suggest some reasons for differences.