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Gas Laws in Freshman Chemistry: A Laboratory Experiment

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The study of gaseous state of matter is included in the programs of Freshman Chemistry and in every textbook at this level. Yet, only few laboratory manuals include an experiment describing the apparatus and procedure for studying Boyle's Law. Experiments describing Charles'-Gay Lussac's Law and Combined Gas Laws usually are not included in laboratory manuals, owing to the fact that manufacturers of scientific apparatus do not offer any such apparatus.

In order to eliminate this gap in study of gaseous state, in the laboratory at Upper Iowa College an apparatus is used which enables one to study the relationship of volume, pressure, and temperature in gaseous state and gives the students an opportunity to interpolate the absolute zero. The following is a description of this apparatus and procedures for studying gas laws.

Apparatus

The apparatus shown is a modified Boyle's Law Apparatus (Welch Scientific Co., Chicago) by eliminating the gas thermometer and incorporating the stopcock tube into a water jacket fitted with a drain tube and clamp. The lower end of the stopcock tube below the water jacket is firmly clamped to the rigid support. To contain any possible spillage of mercury, the entire unit is mounted in a plastic dishpan.

The change of volume with changes of pressure and temperature is recorded as a length of trapped air column on the following grounds. The volume of a glass tube is calculated by the formula $V = \pi r^2 L$, where L is the length of the tube. Then $P_1V_1 = P_2V_2$ can be expressed as $P_1\pi r^2L_1 = P_2\pi r^2L_2$ and $P_1/P_2 = \pi r^2L_2/\pi r^2L_1 = L_2/L_1$, and $L_2 = L_1P_1/P_2$. The same simplification takes place also in mathematical expression for Charles' Law. Therefore, since the length of tube is proportional to its volume, the theoretical length of column can be calculated for each pressure or for each temperature, and a graph can be prepared showing absolute zero, interpolated from the data of the experiment.

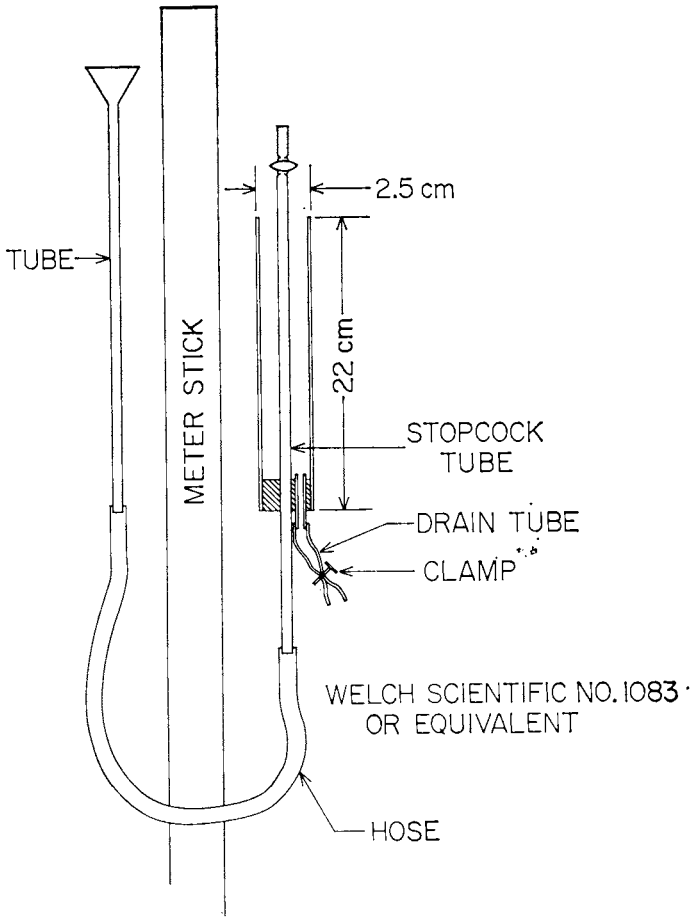

Figure 1. Apparatus

Procedure

A. Boyle's Law

1. Increase in pressure. Adjust the height of the mercury column in the tube with funnel top so that the mercury stands at the same level in both tubes. In this case, the pressure exerted by the trapped gas is equal to the barometric pressure in the laboratory. Record this pressure and the length of air column. First close the stopcock, then raise the tube with funnel top until the mercury level is some 100-150 mm above that of stopcock tube. Record the observed new air column length and the difference in mercury levels in both tubes. This difference will constitute the increase in pressure. Calculate the new pressure (barometric + increased one), and the theoretical air column length. Compare theoretical and observed data and calculate the relative error.

2. Decrease of pressure. Repeat the experiment, lowering the tube with funnel top some 100-150 mm so that the mercury stands below that of stopcock tube. Record the difference in mercury levels, determine the new pressure, and the new gas column length. Calculate the theoretical column length and the relative error.

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B. Charles'-Gay Lussac Law

1. Adjust the tube with funnel top until the mercury level in both tubes is the same. Record the room temperature and length of trapped air column. Fill the water jacket with ice water. Record the temperature of water, the length of air column, and new pressure. From these data calculate the theoretical length of air column (new volume of air), theoretical new pressure ($P_2 = P_1T_2/T_1$) and relative errors.

2. Drain the water jacket and fill it with tap water. Drain this also, allow about 50 ml of warm water to run through, and then fill the jacket with water at approximately 90°C. Record the temperature of water, the length of air column, and the new pressure. Calculate the theoretical values of air column, pressure and error.

C. Combined Gas Laws

1. Immediately after taking the readings of part B,2, raise the tube with funnel top about 120 mm. Record length of air column, new pressure (barometric + the difference in levels of two tubes), and calculate the theoretical value of new air column ($L_2 = L_1P_1T_2/T_1P_2$), and error.

2. Prepare a graph, plotting the length of air columns at temperature of hot water (90°), room temperature and at temperature of ice water on ordinate *VS* temperature plotted on the abscissa. If data of air columns length were determined accurately, the line drawn through the three points will intersect the abscissa approximately at 0°K (- 273.16°-C). An appropriate student's report sheet may be prepared by the instructor.