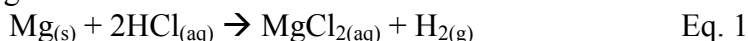


Evaluation of the Gas Law Constant

Purpose: To determine the value of the Gas Law Constant, R, using the Ideal Gas Law, $PV=nRT$

Background: To be able to determine the gas law constant, R, the values of P, V, n, and T must be available. The experiment is based on the reaction between Magnesium metal and hydrochloric acid to produce Hydrogen Gas, Equation 1. The volume, pressure and temperature under which the hydrogen gas is collected will be measured. From the known quantity of Magnesium used and the stoichiometry of the reaction, the number of moles of Hydrogen can be calculated.



Since the hydrogen is collected in an eudiometer tube over an aqueous solution, the gas pressure in the tube after the reaction has ceased is the sum of the hydrogen gas pressure and the vapor pressure of the water. In order to obtain the pressure of the hydrogen gas, the vapor pressure of the water, $P_{\text{H}_2\text{O}}$, at the temperature of the measurement must be subtracted from the atmospheric pressure, P_{atm} Equation 2.

$$P_{\text{H}_2} = P_{\text{atm}} - P_{\text{H}_2\text{O}} \quad \text{Eq. 2}$$

In case the liquid levels (step 3) cannot be equalized after the reaction has ceased, a further correction will be required since the pressure of the gasses in the tube (hydrogen and water vapor) will not then be equal to the atmospheric pressure. If this is the case, the difference in levels must be measured with a meter stick as accurately. This difference, which represents the desired pressure difference, must be converted to mm Hg. This can be accomplished by dividing the measured difference in mm by 13.6 (the ratio of densities of mercury and the aqueous solution $d_1h_1=d_2h_2$). This difference must then be subtracted from the atmospheric pressure. Thus, if the levels cannot be equalized, the pressure of Hydrogen must be obtained from the following expression.

$$P_{\text{H}_2} = P_{\text{atm}} - P_{\text{H}_2\text{O}} - P_{\text{level difference}} \quad \text{Eq. 3}$$

Vapor Pressure (P) of Water at Various Temperatures

T, °C	P, mmHg	T, °C	P, mmHg	T, °C	P, mmHg	T, °C	P, mmHg
13.0	11.2	19.0	16.5	25.0	23.8	31.0	33.7
14.0	12.0	20.0	17.5	26.0	25.2	32.0	35.7
15.0	12.8	21.0	18.7	27.0	26.7	33.0	37.7
16.0	13.6	22.0	19.8	28.0	28.3	34.0	39.9
17.0	14.5	23.0	21.1	29.0	30.0	35.0	42.2
18.0	15.5	24.0	22.4	30.0	31.8	36.0	44.6

If the lab temperature is not on the chart, then the pressure of water vapor must be calculated using the following equation.

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{\text{vap}}}{R} \left(\frac{1}{T_1} - \frac{1}{T_2}\right) \quad \text{Clausius Clapeyron Equation}$$

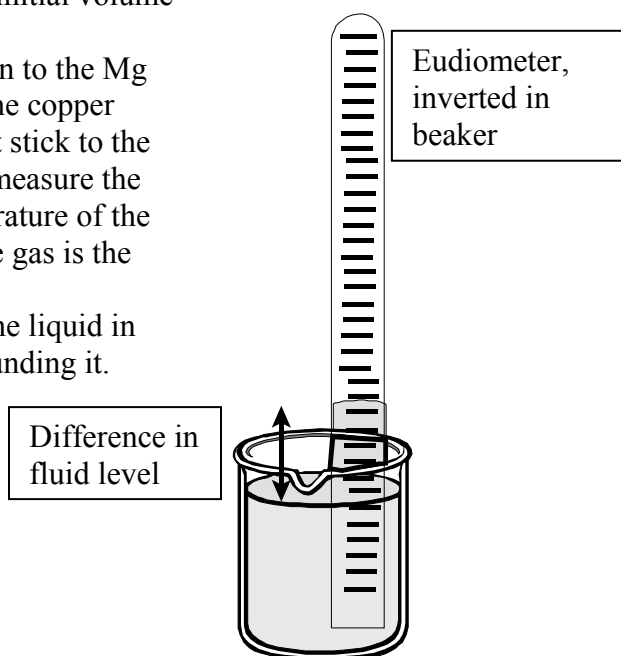
where $R=8.3145 \text{ J/mol K}$ and $\Delta H_{\text{vap}}=44.0 \text{ kJ/mol}$ and Temp is in Kelvin.

Evaluating the Gas Law Constant

Procedure:

You will perform four determinations of R. For each trial:

1. Calculate the mass of magnesium necessary to evolve 80 mL of H₂ at STP. Then mass approximately this quantity of Mg Ribbon on the top-loading balance to the precision of the equipment.
2. Add approximately 8 mL of concentrated HCl to the eudiometer tube. With your wash bottle, wash down into the tube any acid that might have adhered to the eudiometer walls. Coil the massed strip of Mg into the eudiometer tube, approximately 5-10 cm from the open end. (Use copper wire around the ribbon to keep it in place.) Fill the tube with water and invert into a beaker filled halfway with water. See the figure below. The eudiometer volume should read zero if the tube is filled completely with water. Record the initial volume if it is not.
3. The concentrated HCl will gradually diffuse down to the Mg and react with it. The Mg may break free from the copper wire. Tilt the tube to ensure that the Mg does not stick to the sides of the tube. After the reaction has ceased, measure the volume of hydrogen gas produced and the temperature of the gas. (We are assuming that the temperature of the gas is the same as the water through which it passed.)
4. Measure the difference in water levels between the liquid in the eudiometer and the water in the beaker surrounding it.
5. Record the barometric pressure for the day.
6. Dispose of your waste in the container in the hood. Rinse the copper wire, dry it, and return it to your workstation.



Processing your data:

1. Determine the moles of Mg
2. Determine the moles of Hydrogen gas
3. Determine the vapor pressure of water at the temperature under which the experiment was performed.
4. Convert the water level difference to the height that a column of mercury would support under the same pressure. $P = gdh$, where P is pressure, g is the gravitational acceleration constant, d is the density of the liquid and h is the height. For two liquids at the same pressure, $gd_1h_1 = gd_2h_2$. If the liquids are in the same location, g will cancel. Hence, $d_1h_1 = d_2h_2$. The density of water is 1.00g/mL and that of mercury is 13.59 g/mL at 25 degrees Celsius. So the height of mercury can be calculated as:
$$h_{\text{Hg}} = (d_{\text{water}}/d_{\text{Hg}}) * h_{\text{water column}}$$
. Make certain that your water height is expressed in mm before you convert to the height of Hg.
5. Calculate the corrected pressure (accounting for the level difference and the vapor pressure). Convert to atm.
6. Using the ideal gas law, $PV = nRT$, solve for R for each trial and average them.
7. Since the accepted value of R is known, determine the % error.

Evaluating the Gas Law Constant

Pre-lab questions:

1. What properties of hydrogen make it possible to collect it by displacement of water?
2. Find the vapor pressure of water at 29.6°C.
3. Calculate the mass of Mg needed to produce 80 mL of Hydrogen gas.
4. Why must the difference in fluid levels be measured?
5. What safety hazards are associated with hydrogen gas?
6. Why is it necessary to use concentrated HCl rather than a more dilute solution?

Post Lab Questions:

What would be the effect on your calculated value of R (increase, decrease or remain constant) for the following. In each case, explain your reasoning.

1. Some of the hydrogen gas escaped
2. The vapor pressure of water is neglected
3. Some of the Mg ribbon broke loose but eventually all reacted.

Why was it unnecessary to record the volume of concentrated HCl used?

Were your results more accurate or precise? Explain, providing appropriate calculations.