

Experiment 5 - Stoichiometry : Gases

Determining the Ideal Gas Constant

Lab Owl Announcement:

Upon completion of this lab log onto OWL. Your fourth Lab Owl assignment, Lab Owl: Exp 5 should appear there. You have until the next scheduled laboratory to complete this assignment. This is your final assignment. Remember, these Lab Owls are worth 25% of your laboratory grade.

Introduction:

Gases:

When dealing with gases in chemical reactions we cannot weigh them or dispense them as easily as we can with solids and solutions. However there is a relationship between the four quantities needed to describe a gas:

1. Quantity of a gas (moles)
2. Temperature of the gas.
3. Volume occupied by the gas.
4. Pressure exerted by the gas.

that allows us to circumvent this. In this experiment we are going to use these four quantities to determine the Ideal Gas Constant. The reaction of aluminum with a base, aqueous sodium hydroxide, is particularly suited to the experimental procedure adopted in this experiment in that there is a brief period between when the sodium hydroxide comes in contact with the aluminum and when gas evolution starts. This delay gives us the opportunity to take an initial volume reading.



From the Ideal Gas Equation:

$$PV = nRT$$

If one knows the:

1. Pressure of H_2 in atmospheres
2. Volume of H_2 in liters
3. The number of moles of H_2 produced
4. The temperature in K

then one should be able to determine R (The Ideal Gas Constant) and see how accurate this particular procedure is in determining it. The volume is relatively straight forward to determine since it is equal to the volume of water displaced by the gas. The moles of H_2 can be determined from the balanced chemical equation and the amount of aluminum used. Temperature, I think we can do that. The only problem lies in the pressure exerted by H_2 and, as you will see below we have a way to estimate this.

Determining the Ideal Gas Constant:

While this experiment is simple in its design, we do have one problem to address: how to determine the pressure exerted by the $\text{H}_2\text{(g)}$. By adjusting the level of water in the Florence flask to match that in the buret, we are ensuring that the pressure inside the buret is equal to atmospheric pressure. The problem is that $\text{H}_2\text{(g)}$ is not the only gas that has been trapped inside the buret!

In setting up the experiment you have to invert the buret and adjust the level of water so that you may read the volume in the buret! Thus we have air in our system. The H_2 gas is collected over water, and water has a vapor pressure and thus we have some gaseous water in there as well. How do we overcome this? Here is where we turn to Dalton's Law of Partial Pressures, in which the total pressure exerted by a mixture of gases is equal to the sum of the pressures exerted by the individual components.

$P_{\text{total}} = P_A + P_b + P_C + \dots$: which for the reaction of interest becomes:

$P_{\text{total}} = \text{Atmospheric Pressure} = P_{\text{H}_2} + P_{\text{H}_2\text{O}} + P_{\text{air}}$

$P_{\text{total}} =$ This can simply be read from the barometer.

P_{water} This can be determined from the graph of Water Vapor Pressure v Temperature that you did as part of the prelaboratory.

P_{air} We are stuck here and the best that we can do is to trap the minimum amount of air in the buret and treat it as negligible

Thus the P_{H_2} can be approximated by setting it equal to:

$P_{\text{total}} - \text{Vapor Pressure of Water at the temperature at which the experiment was performed.}$

Experimental Procedure

Before coming to the laboratory:

"You are expected to plot a graph of P vs T in order to determine the Vapor Pressure of water at the temperature that you performed the experiment. Even in the unlikely event that that temperature is in fact listed!!

Vapor Pressure of Water as a Function of Temperature

T(°C)	P, (mm Hg)	T(°C)	P, (mm Hg)	T(°C)	P, (mm Hg)	T(°C)	P, (mm Hg)
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

Determining the Ideal Gas Constant.

Before you begin this experiment you may wish to practice inverting a buret full of distilled water into your Florence flask. It would also be worthwhile to get used to taking volume readings with the buret inverted!

1. Cut a piece of aluminum ~0.025g. Weigh and record its exact mass. Try and keep the mass as close to this size as possible.
2. Fill your buret with 1M NaOH almost to the top ignoring the graduations for the moment.
3. Place ~ 3/4" of distilled water into a Florence Flask.
4. Fold the Aluminum loosely so that it fits into the base of the buret. Do not fold it too tightly as this drastically reduces the surface area exposed to the base and will dramatically increase the total reaction time. Insert the foil into the buret.

You have approximately one minute to do step 5.

5. Carefully invert the buret so that the base lies at the bottom of the flask. Use your buret stand to clamp it vertically. If the level of the water is below the first graduation then just record the initial volume. Remember the buret is upside down! If the level of the NaOH inside the buret is above the first graduation, open the stopcock briefly and let the level fall until it is below the graduation.
6. In the first few minutes keep an eye on the gas evolution to make sure that it is not escaping beneath the buret. After a minute or so the Aluminum will float to the top.
7. When gas evolution has ceased, adjust the level of water in the Florence flask so that it is at the same level as the water in the buret. Now record the final volume.



8. Don't forget to record the pressure and temperature. Your TA will record the day's barometric pressure on the board.
9. Determine the number of moles of $\text{H}_2(\text{g})$ produced and the Ideal Gas Constant. How does this value compare with the accepted value of $0.08205 \text{ L}\cdot\text{atm}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$?