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10/30/18

Magnesium and Hydrochloric Acid: Determination of the Ideal Gas Constant

Goals/Objectives:

The goal of this skills challenge is obtain an experimental value for the ideal/universal gas constant, R, using magnesium ribbon and common laboratory materials. Multiple trials must be conducted and a relative standard deviation of <5% must be achieved for the final R value.

Background:

The molecules in gases are far apart and are in constant random motion. Gases are compressible, exert pressure, and disperse rapidly when mixed with other gases. Four properties can be used to describe gases: pressure in atm (P), volume in L (V), temperature in K (T), and the number of moles (n). The relationship between these variables is illustrated by the Ideal Gas Law: PV=nRT. R is the ideal gas constant, which has a value of 0.08206 L*atm/K*mol.[3] In the Ideal Gas Law an ideal gas is a theoretical idea, as it states that there are no attractive forces between the molecules and the molecules take up no space, both of which aren't possible. As long as the pressure is not too high, and the temperature is fairly warm, this law is followed very closely by most gases, including the hydrogen in this lab. In this lab magnesium metal reacts with hydrochloric acid to produce magnesium chloride and hydrogen gas : $Mg (s) + 2HCl (aq) \rightarrow MgCl_2 (aq) + H_2 (g)$. By measuring the mass of the magnesium reactant the number of moles of the hydrogen gas product, thus the value for "n", can be found using stoichiometry. Temperature of the hydrogen can be measured with a thermometer and the volume of hydrogen will be measured from the water level in the burette. The gas in the tube is mostly hydrogen, but there is some water vapor too. The amount of water vapor changes with the temperature of the water and can be found in the following table:

Table 1: Water Vapor and Temperature. Sample table that evaluates correlation between Temperature and Pressure

Temperature (°C)	*Pressure (kPa)*	*Temperature (°C)*	*Pressure (kPa)*
15	1.71	23	2.80
16	1.81	24	2.99
17	1.93	25	3.16
18	2.06	26	3.36
19	2.20	27	3.59
20	2.33	28	3.77
21	2.48	29	4.00
22	2.64	30	4.24

The total pressure in the buret is equal to the room pressure, which can be expressed by $p_{\text{room}} = p_{\text{Hydrogen}} + p_{\text{water vapor.}}$ The room pressure is determined using a barometer, and the pressure of the hydrogen gas can be thus calculated.[1] With these four pieces of information the ideal gas constant, R, can be calculated using PV=nRT. The relative standard deviation of the multiple trials can be calculated and the ideal gas constant values can be compared to the researched R value.

Procedure:

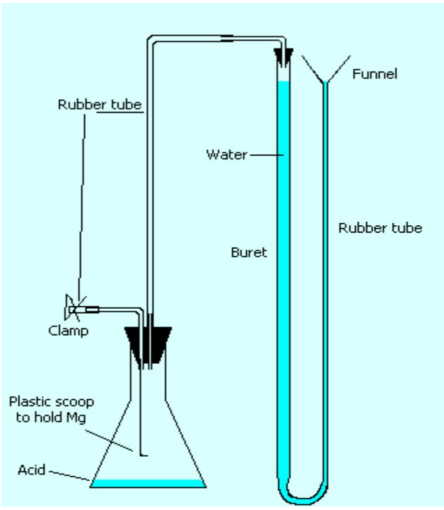

Figure 1: Procedure diagram. Showing the procedure of how the materials are to be set up

Cut a piece of Mg ribbon, making sure the ends are square. Measure the length of the ribbon and cut into three equal pieces, taking the mass of each.[1] Set up the apparatus as shown above, without the stoppers in place. Clamp the burette and funnel near the top of the ring stand.[1] Fill the burette with water until it reaches the 0 mL mark on the burette and the bottom of the funnel, as shown in the diagram. Now insert the stopper into the top of the burette.[1] Add approximately 45 ± 5 mL of HCl into the flask.[1]Roll the length of magnesium ribbon into a tight coil and place on a copper clip above HCl in flask. Ensure that it won't fall into the acid easily, but that it's loose enough to be shaken into the acid when desired later on.[1]Put all of the stoppers in place. With the clamp off the tube, adjust the level of the burette until the water is at the 0 mL mark on the burette. Now close the clamp.[1] Raise the funnel back to the top, and quickly shake the Mg metal into the HCl. It will begin to react quickly and produce H_2 gas.[1]When the reaction is completely finished, wait about five minutes for the apparatus to come to room temperature. Then measure the room temperature at this time.[1] Adjust the height of the funnel so that the level of water in the burette and the funnel are the same. When the heights are the same, the gas pressure inside the tube is the same as the atmospheric pressure in the room. Read the gas volume from the water level in the burette.[1] Repeat roll up the length of magnesium ribbon for the other two ribbons and readjust the funnel to make sure the level of water in the burette and funnel are the same again. The same HCl should be able to be reused for these trials but more can be added to confirm an excess.[1] Measure the atmospheric pressure of the room using a barometer.[1]

Safety Analysis:

Broken glassware must be disposed of properly into a designated bin.

Concentrated hydrochloric acid is dangerous and must be handled with extreme care:

- Wear protective clothing (lab coats, pants, and gloves) to prevent contact with skin. If spilled on skin, use soap and water to wash skin for at least 15 minutes while removing contaminated clothing, as the liquid burns the skin.[4]
- Note that hydrogen gas is flammable, so be sure to have no open flames nearby the experiment.[4]

- Inhalation of fumes results in coughing and choking sensation, and irritation of nose and lungs. If inhaled, remove person to fresh air and get medical attention.[4]
- If ingested, drink water or milk; do not induce vomiting.[4]
- Wear appropriate eye protection (lab goggles/glasses). If contacted with eyes immediately flush with water for at least 15 minutes and get medical attention.[4]
- Magnesium metal is flammable and causes highly exothermic reaction; keep away from exposed heat sources and flames
- Have proper fire prevention and elimination equipment on hand to prevent possible magnesium fires. For small fires, use dry chemical powders. For large fires, use water spray or fog

References:

1) Dice, D. (n.d.). Determining the Value of the Ideal Gas Constant. Retrieved October 30, 2018, from http://www.digipac.ca/chemical/gaslaws/Ideal_Gas_Constant.htm

2) NOAA Office of Response. (n.d.). *Hydrochloric Acid, Solution*. Retrieved October 30, 2018, from https://cameochemicals.noaa.gov/chemical/3598.

3) Santa Monica College. (n.d.). *Experimental Determination of the Gas Constant* [PDF].

4) U.S. Department of Health and Human Services. Hazardous Substances Data Bank (HSDB, online database). National Toxicology Information Program, National Library of Medicine, Bethesda, MD. 1993.