EXPERIMENT 13b GASES

Chem 110 Lab

PURPOSE: The purpose of this experiment is to determine the numerical value of the gas constant.

I. INTRODUCTION

According to the Kinetic Molecular Theory of Gases, a sample of matter in the gaseous state is composed of small particles (usually atoms or molecules) that are constantly moving, with high velocities, in straight lines, in all directions; colliding frequently with each other and the walls of the container. Because the average kinetic energy of the particles is so high, the attractive forces between the particles, which would be of different strengths for different substances, have little effect on the behavior of the gas. Therefore, any substance in the gaseous state can be described in terms of four physical measurements: the number of particles in the sample (measured in moles), the pressure, the temperature, and the volume of the container. The relationships among these four variables is constant, and that constant, which has been given the symbol R, is called the Universal Gas Constant.

$$\mathbf{R} = \frac{\mathbf{P} \square \mathbf{V}}{\mathbf{n} \square \mathbf{T}}$$

where **P** = pressure, **V** = volume, **n** = mole, **T** = temperature

When sodium bicarbonate is added to an aqueous solution of hydrochloric acid, they react as follows:

$$NaHCO_3(s) + HCl(aq) \longrightarrow H_2CO_3(aq) + NaCl(aq)$$

Almost immediately the carbonic acid produced in the above reaction decomposes to CO_2 gas and water:

$$H_2CO_3(aq) \longrightarrow CO_2(g) + H_2O(l)$$

In this experiment you will mix sodium bicarbonate with an aqueous hydrochloric acid solution and then collect the CO_2 gas produced in a balloon. You will measure the mass, volume, temperature, and pressure of the gas, and from these data calculate an experimental value for R.

CAUTION

Solutions of acids can harm your eyes, skin, and clothing. Handle with care. Any acid solution spilled on your skin or splashed into your eyes should be rinsed immediately with a large volume of water.

II. EXPERIMENT

A. MASS OF BALLOON AND $NaHCO_3$

1. Obtain an empty balloon from your instructor and weigh it and record its mass on the Report Sheet.

2. Use a utility clamp to securely attach your 8-inch test tube to a ring stand. The bottom of the test tube should be touching the base of the ring stand.

3. Weigh about 1.75 g solid $NaHCO_3$. Do this by turning on the balance, placing a small piece of paper toweling on the balance, pushing the "tare" button so that the balance reads 0.00 g, and then add the $NaHCO_3$ until the balance reads about 1.75 g. Read and record the mass $NaHCO_3$ on the Report Sheet.

4. Carefully transfer the $NaHCO_3$ to the 8-inch test tube.

B. VOLUME HCl SOLUTION

1. From the mass of your $NaHCO_3$ sample, calculate the volume, in mL, of 1.0 M HCl solution that you would need to react all of the $NaHCO_3$ sample. (Molar mass $NaHCO_3$ =84.01 g/mole)
   Show setup of calculation here:

2. Multiply the calculated volume HCl solution by 1.10 to give you a volume of the HCl solution that is 10% higher than what you calculated above. (By using this larger volume of HCl solution we can be sure that there is plenty of HCl to react ALL of the $NaHCO_3$, thus, $NaHCO_3$ will be the limiting reactant in the reaction.)
   Show setup of calculation here:

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   Instructor's initials

3. After you have gotten your instructor's approval of your calculations, take a clean, dry beaker to the reagent bench and get approximately the volume of 1.0 M HCl solution that you calculated in step 2, above.

4. At your bench, accurately measure the calculated volume of 1.0 M HCl solution.

C. REACTION OF HCl & $NaHCO_3$

1. Carefully add the 1.0 M HCl solution to the $NaHCO_3$ in the test tube, and then quickly attach the balloon to the top of the test tube and hold it there to prevent leakage of the gas, which starts to form immediately. At the same time, gently wiggle the reaction mixture in the test tube. Record your observations on the Report Sheet

2. When the reaction is complete (no more CO_2 bubbles being produced), pinch off the opening of the balloon and remove it from the test tube, being careful not to allow any gas to escape from the balloon. Tie off the balloon.

3. Weigh the balloon with CO_2 and read and record the mass on the Report Sheet.

4. Take the balloon to the sink. Near the sink is a bucket of water and a 1 liter beaker. Fill the beaker with water and place it upside down in the bucket of water. Put the balloon up inside the inverted beaker. There should only be water and the balloon in the inverted beaker. There should be no air in the beaker. Pop the balloon.

5. Without lifting the inverted beaker out of the water, raise it enough so that the level of water inside the beaker is even with the level of water outside the beaker. Read the volume of gas in the beaker and record it on your Report Sheet.

6. Use your thermometer to measure the temperature of the water in the bucket. This is the same as the temperature of the gas. Record the gas temperature on your Report Sheet.

7. Read the pressure from the barometer and record it on your Report Sheet.

D. CALCULATIONS

Give complete setups of all calculations on your Report Sheet.

1. Calculate the mole CO_2 produced in the reaction from the mass of the limiting reactant, $NaHCO_3$, used in the reaction. (Molar masses: $NaHCO_3$ = 84.01 g/mole; CO_2 = 44.01 g/mole)

2. Convert the barometric pressure from *inches of mercury* (in. Hg) to *millimeters of mercury* (mm Hg). 1 inch is equal to exactly 2.54 cm.

3. Convert the pressure from *millimeters of mercury* to *atmospheres* (atm). 1 atm is equal to exactly 760 mm Hg.

4. Convert the temperature in °C to Kelvin.

5. Convert the volume of the gas from mL to L:

6. Calculate the experimental Universal Gas Constant using the equation:

$$\mathbf{R} = \frac{\mathbf{P} \cdot \mathbf{V}}{\mathbf{n} \cdot \mathbf{T}}$$

where **P** = pressure, **n** = moles, **V** = volume, **T** = temperature

Be sure to include all units in the setup and the answer.

Report Experiment 13 GASES
Chem 110

Name ______________________________ ______________________________ Date ________________
(last) (first)

Instructor's Initials________________

A. DATA

1	Mass Empty Balloon	
2	Mass $NaHCO_3$	
3	Mass Balloon with CO_2	
4	Volume CO_2 (mL)	
5	Temperature CO_2 (°C)	
6	Pressure CO_2 (in. Hg)	

Observations of reaction of HCl and $NaHCO_3$ ____

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B. CALCULATIONS

1. Mole CO_2

2. Conversion of Pressure from in. Hg to mm Hg.

3. Conversion of Pressure from mm Hg to atm.

4. Conversion of Temperature from °C to Kelvin.

5. Conversion of Volume from mL to L.

5. Calculation of Experimental Value of R

6. Accepted (theoretical) Value of R (from instructor) 0.08205746 L atm $K^{-1}mol^{-1}$

7. Calculation of % Error

C. QUESTIONS

1. Is your experimental value of R higher or lower than the accepted value of R? ______________

2. Give two possible reasons why your experimental value of R was different from the theoretical value of R. Be sure the reasons you cite are those over which you had no control or which you could not avoid. (For example, spilling is something that could be controlled and is considered a mistake and not an experimental error.)

   a. ____

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   b. ____

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