Experiment 13 – Molar Volume of Carbon Dioxide

Pre-Lab Hints

1. The reaction is similar to that of $CaCO_3$ (equation 13.1).
   Balance reaction with stoichiometric coefficients and include phase subscripts (s. L, g, aq).
2. Calculate mass for V = 100 ml, not 40 ml, and T = 298 K, not 273 K.
   First, use the ideal gas law (n = PV/RT) at 1.00 atm to find the moles of CO_2.
   $CaCO_3$ is 1:1 with CO_2, so multiply moles by molar mass (g/mol) of $CaCO_3$ to get mass (g).
   Write these same calculations at the top of part A on your Report Sheet.
3. See Techniques 1 and 8 in the Laboratory Techniques section at the front of your lab manual.
4. See step C1 in the procedure. Note that the water levels in Fig 13.6 are the same both inside and outside. Also, read the caption to Fig 5.20 in Ebbing and Gammon.
5. See step C2 for 5a and step D1 for 5b. Also, read 6a on the next page in the pre-lab.
6. C6 Refer to Appendix C in the back of your lab manual to find P_{H2O} at 20 ^oC.
   C7 Refer to equation 13.3, which uses Dalton's law.
   D2 Mass difference (A2 − D1) is due to CO_2 only.
   D3 Divide the mass of CO_2 by its molar mass (44.0 g/mol) to find its moles.
   E2 Refer to equation 13.4, which uses the combined gas law.
   Use dry gas pressure in torr and temperature in Kelvins.
   E3 Refer to equation 13.2. Divide V_{CO2} (E2) by n (D3) to get molar volume in L/mole.
   F1 Use coefficients from equation 13.1 to convert moles of CO_2 (D3) into moles of $CaCO_3$.
   F2 Multiply the moles (F1) by the molar mass (100.1 g/mol) to find moles.
   F4 Use equation 13.5 to find the mass % of $CaCO_3$ from F2 and F3.

Procedure Notes

A2: Multiply your mass result from the pre-lab times the factor below for your sample number:
1.24 for sample 1   1.87 for sample 2   3.74 for sample 3
Refer to Figure 13.3 for determining mass of apparatus.
Tare balance with empty beaker before weighing apparatus, so that you weigh gas generator only. Use exact same beaker for part D.
A3: Refer to Figure 13.4. Also, refer to Figures T.8a and T.8b with Technique 8 in the front of your lab manual.
A4: Refer to Figure 13.5.
C1: Refer to Figure 13.6 for equalizing the water levels in the 4000-ml beaker.
Return the gas collection tube to its supply container after the experiment is complete.
Place contents of test tubes in waste container. Pour water into drain.

Calculations

- Please provide all of your Calculations for Pressure, V_{CO2} at STP, Moles of CO_2, Molar Volume (L/mole), and Mass % of $CaCO_3$ on a Separate Sheet of Paper.

Report Sheet

A: Show same calculations from question 2 in the pre-lab. Use V = 100 ml in your equation. Multiply your mass result times the factor for your sample number (see previous page).
A2: Weigh your apparatus as in Figure 13.3, but tare the empty beaker by itself first.
C1 and C2: Skip
C3: Record volume from part C of procedure with water levels equalized as in Figure 13.6.
C6: Find P_{H2O} at the experiment's temperature using Appendix C.
C7: Refer to equation 13.3. Subtract line C6 from line C5.
D2: Subtract final mass (D1) from initial mass (A2) of the generator as in Figure 13.3.
D3: Divide CO_2 mass (D2) by 44.0 g/mol to find moles.
E1: Divide P in torr (C7) by 760 torr/atm to get P in atm.
E2: Refer to combined gas law (equation 13.4).
Use lines C3, C4 (converted to K), and C7 to find V_{CO2} at STP.
E3: Divide V_{CO2} at STP (E2) by moles (D3) to get molar volume in L/mole.
F1: The reaction in equation 13.1 shows a 1:1 mole ratio between CO_2 (D3) and $CaCO_3$.
F2: Multiply $CaCO_3$ moles (F1) times 100.1 g/mol to get mass in grams.
F3: Same as A1.
F4: Divide $CaCO_3$ mass (F2) by initial sample mass (A1) to get %.

Lab Questions

1. Suppose you do not add "Alka-Selzer" to saturate the water in the pan with CO_2. What happens to some of the CO_2 created from your mixture as it travels through the water on the way to the collection tube? Explain how this affects the volume of gas collected and the calculated molar volume.

2. Review part D of the procedure and the section in the Introduction titled "Molar Volume of Carbon Dioxide" Explain how you determine the number of moles of $CaCO_3$ in your sample. How is your calculation affected if some of the CO_2 escapes and is not collected?

3. Review equation 13.1. Suppose your sample absorbed some water vapor before you measured its mass, so that the following reaction occurs:
   $$2CaCO_{3(s)} + 2H_2O_{(g)} \rightarrow Ca(HCO_3)_{2(s)} + Ca(OH)_{2(s)}$$
   Given that each HCO_3^{-1} ion also reacts with acid to create one CO_2 molecule, use stoichiometry to determine the effect on the overall moles of CO_2 created. How is the initial mass measurement of your sample affected by the absorbed water? Explain what happens to your calculation for the $CaCO_3$ mass %.

4. Review Boyle's law. Suppose that when you measure your gas volume, the water level inside the tube is higher than the water level outside of the tube. The extra water in the tube causes the pressure of the gas to be lower than the recorded atmospheric pressure. Explain how this affects the volume of gas collected and the calculated molar volume.

5. Review equations 13.3 and 13.4. Suppose you do not take the vapor pressure of the water into account when calculating the pressure of the CO_2. How does this affect the recorded pressure of dry CO_2? How does this affect the calculated volume of CO_2?