6.1 Balloon Stoichiometry

Subjects: Stoichiometry, kinetics, limiting reactant

Description: Different stoichiometric ratios of solid sodium bicarbonate are added to flasks containing 1M HCl. Balloons attached to the flask will collect the CO_2 gas evolved. The rate of inflation and the volume of inflation are determined by the initial amounts of the materials used.

Materials:
3 Stretched balloons
2.94 g Sodium bicarbonate – split into 1.68 g, 0.84 g, and 0.42 g amounts ‡
3 250 mL flasks
300 mL 0.1M HCl‡
100 mL graduated cylinder
Spatula
3 Clamps for the flasks
3 ring stands*
Universal indicator ‡
Plastic funnel
Weigh boats (next to balance)

*Shared items. Ring stands are located above the bench on the shelf.
‡Hydrochloric acid is located in the cabinet under the hood. Universal indicator is located in the flammables cabinet. Sodium bicarbonate is located on the general chemical storage shelf.

Pre-class Preparation:
Note: It may be useful to secure the flasks using clamps and ring stands to prevent tipping.
1. Pre-stretch the balloons and label with 1.68g, 0.84g, and 0.42g.
2. Weigh the sodium bicarbonate and place it into each balloon using the funnel.
3. Add 100 mL 0.1M HCl to each flask. Add several drops of universal indicator.
4. Stretch the mouths of the balloons over the flasks. Be careful not to let the solid fall into the flasks until ready.

Procedure:
1. Shake the sodium bicarbonate from the balloons simultaneously into the acids.
2. Observe the rate and volume of inflation.

Discussion:
The reaction between acid and sodium bicarbonate is given below:

$$HCl(aq) + NaHCO_3(aq) \rightarrow CO_2(g) + H_2O(l) + NaCl(aq)$$

Net ionic equation:

$2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$

The number of mols in 100 mL of 0.1M HCl is given by:
0.1 L HCl * 0.1mol/L = 0.01 mol HCl

The stoichiometric ratio of HCl to $NaHCO_3$ is 1:1 and therefore 0.01 mol of sodium bicarbonate reacts with 0.01 mol of HCl.

0.01mol sodium bicarbonate * 84.01 g/mol = 0.84 gram sodium bicarbonate.

The balloon with 1.68 grams of sodium bicarbonate contains twice the stoichiometric amount and is in excess. The HCl is the limiting reagent and will be used up. Some sodium bicarbonate will be left over and the indicator will indicate that the solution is weakly basic.

The balloon with 0.84 gram sodium bicarbonate is stoichiometrically equivalent to the HCl and thus both the sodium bicarbonate and HCl are used up. As the reaction goes to completion, the reaction slows down and may take longer to reach the same volume as the first balloon.

The balloon with 0.42 gram of sodium bicarbonate contains half the stoichiometric equivalent and will not inflate to the same extent as the other two balloons. The solution will stay acidic due to leftover acid and the indicator will remain red.

Safety: Use caution when working with hydrochloric acid. Use gloves and safety glasses when preparing and performing this experiment.

Disposal: Solutions can be flushed down the drain with water. Balloons can be thrown in the trashed or reused.

References:
1. L. Summerlin, C. Borgford, J. Ealy. *Chemical Demonstrations: A Sourcebook for Teachers*; Volume 2; 1987; p. 141-142
2. University of Oregon, Department of Chemistry, *ChemDemos* website: http://chemdemos.uoregon.edu/pages/detail.php?s=balloon&page=1&id=058ded8f63bab0cee94d2b4c4cc184d1