Stoichiometry Balloon Races

Limiting and Excess Reactants

Introduction

If a little is good, more is better, right? Increasing the mass of a reactant in a chemical reaction may not increase the amount of product that can be formed—the yield may be "limited" based on the mole ratio of reactants. Demonstrate the concept of limiting and excess reactants by comparing the amount of carbon dioxide obtained when varying amounts of sodium bicarbonate react with a constant amount of acetic acid. It's off to the races . . .

Concepts

- Stoichiometry
- Limiting reactant
- Mole ratio
- Excess reactant

Materials

Acetic acid solution, CH_3COOH, 2 M, 60 mL
Sodium bicarbonate, $NaHCO_3$, 10.5 g
Balloons, 6
Erlenmeyer flasks, 125-mL, 6
Funnel
Graduated cylinder, 25-mL
Spatula
Weighing dishes, 6

Safety Precautions

Acetic acid is a skin and eye irritant. Avoid contact with skin and eyes. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Label six Erlenmeyer flasks 1–6. Using a graduated cylinder, add 10 mL of 2 M acetic acid to each flask.
2. Obtain six weighing dishes and label them 1–6. Measure the appropriate amount of sodium bicarbonate into each weighing dish, as shown below.

Sample	**1**	**2**	**3**	**4**	**5**	**6**
Mass $NaHCO_3$	0.50 g	1.00 g	1.50 g	2.00 g	2.50 g	3.00 g

3. Obtain six balloons. Stretch the balloons and blow them up at least once. Then let out as much air as possible.
4. Use a powder funnel to add the first sodium bicarbonate sample (#1) to one of the balloons.
5. Flatten out the balloon and then carefully place the neck of the balloon over the mouth of flask #1. Do not allow the solid to drop into the flask at this time.
6. Repeat steps 4 and 5 using the remaining sodium bicarbonate samples in flasks #2–6.

Procedure

1. Line up the flasks on the demonstration table. Ask students to predict what will happen when the sodium bicarbonate is added to the acetic acid in each flask. How will the size of the inflated balloons vary when the reactions are complete?
2. Lift each balloon in turn and shake it to allow the solid to fall into the solution. Make sure the neck of the balloon stays firmly attached to the flask.
3. The reactions will be immediate and vigorous. The white solids will dissolve, the solutions will start to bubble and fizz, and the balloons will become inflated.

Publication No. 10771
061616

4. Allow the reactions to proceed until the bubbling stops. Compare the size of the inflated balloons and whether the solid has dissolved in each case. *(The balloon size should increase fairly uniformly for flasks 1–5, and then stay constant. It may be hard to tell the difference between flasks 4, 5, and 6.)*
5. Discuss the observations and calculate the theoretical number of moles of gas produced in each reaction. Identify the limiting reactant and the excess reactant in each case.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. All of the waste solutions may be disposed of down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tips

- Use new balloons each time the demonstration is performed. Once used, the balloons will become stretched, and their inflated sizes may vary considerably from the expected size.
- Unreacted (solid) sodium bicarbonate will be present in flasks 4–6. Although normally water soluble, sodium bicarbonate does not dissolve in the saturated carbon dioxide solutions.
- Add a few drops of universal indicator to each flask and observe the color changes as the pH of the solution changes during the course of the reaction.

Results and Discussion

The reaction of sodium bicarbonate with acetic acid generates carbon dioxide gas. The reactants combine in a 1:1 mole ratio. The theoretical number of moles of gas for each reaction and the limiting and excess reactants in each case are summarized in the *Results Table*.

$$NaHCO_3(s) + CH_3CO_2H(aq) \rightarrow NaCH_3CO_2(aq) + CO_2(g) + H_2O(l)$$

Results Table

Flask	Acetic Acid		Sodium Bicarbonate		Moles CO_2 (Theoretical)	Limiting Reactant
	Volume	Moles	Mass	Moles		
1	10 mL	0.020	0.50 g	0.0060	0.0060	$NaHCO_3$
2	10 mL	0.020	1.00 g	0.0119	0.0119	$NaHCO_3$
3	10 mL	0.020	1.50 g	0.0179	0.0179	$NaHCO_3$
4	10 mL	0.020	2.00 g	0.0238	0.0200	CH_3CO_2H
5	10 mL	0.020	2.50 g	0.0298	0.0200	CH_3CO_2H
6	10 mL	0.020	3.00 g	0.0357	0.0200	CH_3CO_2H

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Process: Grades K–12
Evidence, models, and exploration
Constancy, change, and measurement
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Reference

This activity was adapted from *Flinn ChemTopic™ Labs;* Volume 7, *Molar Relationships and Stoichiometry;* Cesa, I., Editor; Flinn Scientific: Batavia, IL (2002).

Materials for *Stoichiometry Balloon Races—Limiting and Excess Reactants* are available from Flinn Scientific, Inc. This activity is also available as a Chemical Demonstration Kit that contains all the materials to perform this demonstration seven times.

Catalog No.	Description
A0186	Acetic Acid Solution, 6 M, 500 mL
S0042	Sodium Bicarbonate, Reagent, 500 g
GP3040	Erlenmeyer Flask, 125-mL
AP6444	Stoichiometry Balloon Races—Chemical Demonstration Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.