8D – DETERMINING LIMITING REACTANTS

INQUIRY

How can you produce the greatest amount of products without wasting any material?

MATERIALS

- Device with SPARKvue software
- Pressure sensor with tubing and connectors
- Digital balance (readability: 0.01 g)
- Weigh boats
- 500-mL Erlenmeyer flask (2)
- Rubber stopper, one-hole, to fit flask
- Graduated cylinder
- Spatula, scoopula
- Pipets
- Sodium bicarbonate, $NaHCO_3$
- Citric acid ($C_6H_8O_7$) solid, 2.0 g

BACKGROUND

In order to avoid wasting materials, chemists are often tasked with determining precisely how much of each reactant is necessary for a reaction. Using mole ratios from the balanced chemical equations and a known amount of one reactant, a chemist can calculate the exact amount of a different reactant is required for both reactants to be completely consumed. But what happens to a chemical reaction when the limiting reactant is consumed? This activity explores how you can determine experimentally which of the two reactants, sodium bicarbonate (baking soda) or citric acid, is limiting through several runs of the reaction.

SAFETY

Follow these important safety precautions in addition to your regular classroom procedures.

- Wear safety goggles at all times.
- The gas being generated causes an increase in pressure which may expel the stopper from the bottle. Hold the stopper in place during the experiment but avoid squeezing the body of the sampling bottle/flask.
- Do not point the sampling bottle toward yourself or anyone else.

PROCEDURE

1. **<u>First lab partner begin here</u>:** Using a graduated cylinder, measure 400 mL of water and put it in an Erlenmeyer flask.
2. Use an electronic balance to measure 3.46 g of $NaHCO_3$ and add it to the water in the Erlenmeyer flask. With a stopper on, gently swirl the mixture until it is completely dissolved. You now have 400 mL of a 0.12 M $NaHCO_3$ solution.
3. **<u>Second lab partner begin here</u>:** Open SPARKvue.
4. Open the 08D Determining Limiting Reactants lab file in SPARKvue.
5. Use the Bluetooth icon to connect the Pressure sensor.
6. Make sure that the pressure sensor is correctly assembled as shown here. Check all the attachments to make sure they are snug and secure.

7. **<u>First lab partner</u>:** Pour just under 40 mL of the sodium bicarbonate solution into the graduated cylinder. Use a pipet to make sure you have exactly 40.0 mL. Have the same person read the graduated cylinder each time for precision.

8. Pour the sodium bicarbonate solution you just measured into the new Erlenmeyer flask that you will use for your experiment.

9. **<u>Second lab partner</u>:** Obtain about 2.0 g of citric acid in a weigh boat and take it to your lab station. Use a digital balance to measure about 0.10 g of the citric acid into a separate weight boat. Record the exact mass in Table 1 on your answer sheet.

10. **<u>Both partners together:</u>** Do a "dry run" of steps 11 – 14 below without actually adding chemicals so that you will know exactly what to do and expect.

11. Start collecting data in Sparkvue.

12. <u>It is very important to complete this step as quickly as possible.</u> As soon as one lab partner pours the solid citric acid into the bottle, the other lab partner immediately seals the bottle/flask very tightly with the stopper. Avoid squeezing the sides of the bottle/flask.

13. Hold the stopper <u>very tightly</u> in place and at the same time gently swirl the bottle to help the reactants mix. Continue holding the stopper and swirling at the same speed for the duration of the reaction.

14. Stop collecting data when the reaction is complete and the pressure has leveled off on the graph.

15. Slowly remove the stopper to release the pressure from the bottle.

16. Pour the contents of the bottle/flask into the sink. Thoroughly rinse the bottle/flask with water.

17. Use the graph to find initial pressure, final pressure, and pressure change. Record the values in Table 1.

18. Repeat steps 7 - 14 for 0.20 g, 0.30 g, 0.40 g, and 0.50 g of citric acid. Make sure all runs are visible in SPARKvue as you collect data. Label each run on your graph.

19. One partner start cleaning up while the other partner starts working on your graphs.

<u>Clean Up</u>

20. Return the pressure sensor with tubing and connectors to the front of the room.

21. Make a beaker of soapy water and wash everything that touched chemicals – weigh boats, flasks, stopper, spatula, graduated cylinder, pipets. Rinse well.

22. Dry and return the Erlenmey flasks and extra stopper to the front of the room.

<u>Graphing Your Results</u>

23. On the SPARKvue graph, change the title to your class period and the last names of the lab partners. In your lab report, be sure and insert a correct title for the graph above your pasted in graph.

24. Navigate to Page 2 in SPARKvue. Enter the change in pressure for each run to create a graph of Change in Pressure (kPa) on the y-axis and Exact Mass of Citric Acid (g) on the x-axis.

25. On the SPARKvue graph, change the title to your class period and the last names of the lab partners. In your lab report, be sure and insert a correct title for the graph above your pasted in graph.

26. Scale the graph and then take a screen shot of the graph to include in your lab report

27. Save the screen shot of your graph in your Google Drive. BOTH lab partners will need to do this so that you both can have it for your lab report.

ANALYSIS

Table 1 – Pressure change

Trial #	Approximate Mass of $C_6H_8O_7$ (g)	Exact Mass of $C_6H_8O_7$ (g)	Initial Pressure (kPa)	Final Pressure (kPa)	Change in Pressure (kPa)
1	0.10				
2	0.20				
3	0.30				
4	0.40				
5	0.50				

1. Each 40-mL sample of sodium bicarbonate you measured contained 0.41 g of dissolved sodium bicarbonate. Calculate the number of moles of sodium bicarbonate for each trial. Show one sample calculation and record your answers in Table 2.

2. Calculate the number of moles of citric acid in each trial. Show one sample calculation below and record your answers in Table 2.

Table 2 – Analysis of pressure change

Trial #	Mass of $NaHCO_3$ (g)	Moles of $NaHCO_3$ (mol)	Exact mass of $C_6H_8O_7$ (g)	Moles of $C_6H_8O_7$ (mol)
1				
2				
3				
4				
5				

QUESTIONS

1. Each trial used the same amount of $NaHCO_3$. What happened to the pressure as you added increasing amounts of citric acid? Why did this happen?

2. Based on the graph, what is the ideal amount (in grams) of citric acid required to react with 0.41 g of $NaHCO_3$? Explain how you determined this answer.

3. Based on the graph, which trial is closest to the ideal amounts of reactants? Explain how you chose this trial and eliminated the others.

4. In Table 2, find the moles of each reactant for the ideal trial you identified above. According to the table, what is the ideal $NaHCO_3 : C_6H_8O_7$ mole-to-mole ratio, in simplified whole number coefficients?

5. When citric acid and sodium bicarbonate react, the products are sodium citrate ($Na_3C_6H_5O_7$), water, and carbon dioxide. Write the balanced chemical equation including state-of-matter symbols in your balanced chemical equation. How does the $NaHCO_3 : C_6H_8O_7$ mole ratio in the balanced equation compare to the ratio that you determined in question #4?

6. Which reactant, if any, was a limiting reactant in each trial? Enter your responses in the table. Support your answers with evidence from the lab.

Evidence for the Limiting Reactant

Trial #	Limiting Reactant	Supporting evidence
1		
2		
3		
4		
5		