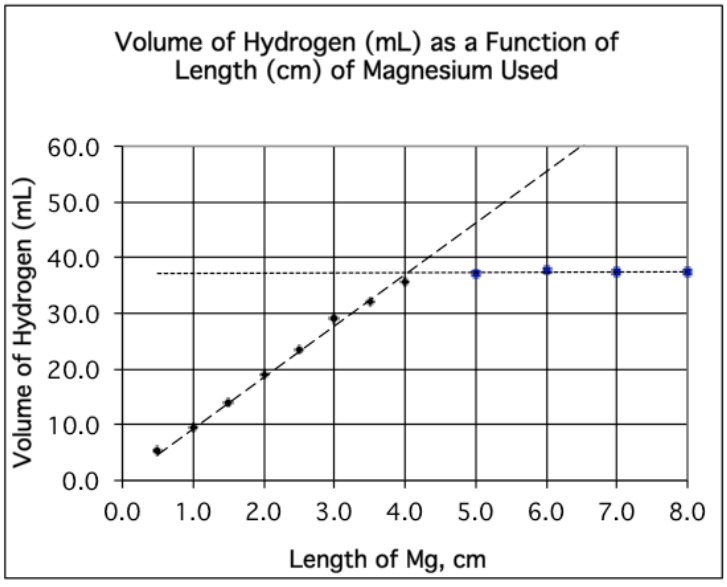
CHAPTER 10 LIMITING REAGENT

THIS CLASSROOM GROUP LABORATORY EXPERIMENT utilizes everyone's data to give an overall group result that demonstrates the concept of limiting reagent. Students prepare hydrogen using a standard quantity (2.5 mmol) of HCl with varying amounts of Mg(s). The reaction is:

$$Mg(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

The amount of HCl used will generate approximately 35 - 38 mL of $H_2(g)$ in reactions with excess Mg. The exact volume depends on the temperature and atmospheric pressure. The amount of Mg used will vary from 0.5 cm (approx. 0.17 mmol) to 8.0 cm (approx. 3.4 mmol). When less than 1.25 mmol Mg is used, Mg is the limiting reagent and the volume of $H_2(g)$ collected will vary in proportion to the amount of Mg used.



Volume of H_2 produced as a function amount of magnesium used.

When the amount of Mg exceeds 1.25 mmol, HCl is the limiting reagent — and because this quantity is held constant, the volume of $H_2(g)$ will not change. Students work in pairs and perform two measurements — one with less than 1.25 mmol of Mg and one with greater than 1.25 mmol Mg. Experimental results will look something like that shown in the figure.

THE LIMITING REAGENT

INFORMATION FOR THE TEACHER

Suitability

For use by high school and university-level chemistry students. This experiment can be conducted at about the time that stoichiometry of chemical reactions and the limiting reagent concept are being introduced.

Background skills required

Students should be able to:

- generate a gas as learned in Chapter 1
- measure quantities of liquid reagents
- use a balance
- use a ruler
- accurately read the volume gradations on the syringe (including estimating between two marks)

Time required

Students should be able to perform this experiment in a single 45 minute laboratory period.

Equipment

Microscale Gas Chemistry Kit (Chapter 1)
ruler to measure Mg
scissors
balance
disposable pipet

Chemicals

HCl (1.7 – 2.0 M)
Mg ribbon

Before students arrive

Determine the mass of 25 cm strip of Mg ribbon (a typical value would be 0.20 g), then convert this to mmol/cm for use by the class. With this value, the students can cut lengths of the Mg ribbon, measure them accurately, and convert to mmol. Prepare a bottle of approximately 1.8 M HCl(aq) by diluting 36.0 mL concentrated HCl into 210.0 mL water to give a total of 240.0 mL. Determine the density (g/mL) of this acid solution by measuring the mass of 100.0 mL. Also, determine which pair of students will perform each experiment. Include the following lengths of Mg ribbon: 0.50 cm, 1.0 cm, 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm, 3.5 cm, 4.0 cm, 5.0 cm, 6.0 cm, 7.0 cm, and 8.0 cm. The first eight of these values ($\leq$ 4 cm) represent quantities in which Mg will be the limiting reagent. For classes with more than 5 pairs of students, other values should be included that fall between those lengths given above.

Website

This chapter is available at our gas website:

http://mattson.creighton.edu/Microscale_Gas_Chemistry.html

Instructions for your students

Content for this chapter first appeared as “Microscale Gas Chemistry, Part 21. The Limiting Reagent. A chemistry laboratory experiment,” Mattson, B., Eskestrand, S., Meyer, A., ***Chem13 News***, **305**, October, 2002.

THE LIMITING REAGENT

INSTRUCTIONS FOR STUDENTS

General Safety Precautions

Always wear safety glasses. Gases in syringes may be under pressure and could spray liquid chemicals. Follow the instructions and only use the quantities suggested.

Toxicity

Hydrogen is relatively non-toxic; however, it is a simple asphyxiant if inhaled in very large quantities. We will not be generating large quantities of hydrogen.

Instructions

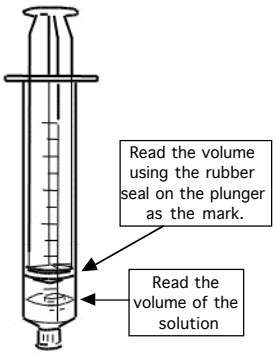
1. Measure out the two lengths of Mg that were assigned to you and your lab partner. Use a scissors to cut the Mg. Record the exact length of each on your Report Sheet. Perform the experiment on one piece of Mg at a time.

2. Fold the Mg back and forth so that it fits inside the little cap. Maintain maximum exposed surface area. Lower the cap containing the Mg into the syringe by flotation.

3. Measure out exactly 1.50 g of the HCl(aq) into a weighing dish.

4. Draw up all of the acid into the syringe. Add three drops water to the weighing dish to dissolve any remaining acid. Draw these drops into the syringe and cap the syringe.

5. Read the initial volume of the syringe using the bottom of the rubber seal as the mark. Also read the level of the acid solution — should be close to 0 mL. The difference between these two readings is the volume of air in the syringe. Record your data.



6. Perform the reaction by shaking the syringe. Although the reaction is fast when Mg is the limiting reagent (the short piece), it is slow when the concentration of acid is small (such as when HCl is in small excess). If you are using a longer piece of magnesium, continue to shake the reaction syringe for 8 - 10 minutes; not all of the magnesium will react. Assist the plunger from time to time by pulling it outward by a few mL.

7. Oftentimes during the reaction the plunger does not move as freely as it should and erroneous final volume readings could result. In order to eliminate this problem, draw the plunger outward to create a reduced pressure and then remove the syringe cap under water, using a large container such as an ice cream pail in order to

accommodate your hands and the syringe. Recap the syringe. The gas pressure inside the syringe is now very close to the atmospheric pressure outside the syringe. Be careful to not move the plunger inward or outward. Take the final volume readings for both gas and solution as previously done in Step 5. The difference in volumes this time is the volume of hydrogen + air initially present. The volume of hydrogen only is obtained by subtracting the volume of air (Step 5) from the volume of hydrogen + air just determined. (Note: We have included a QuickTime movie of this step at the website version of this article.[1])

8. Repeat the experiment with the other piece of Mg.

9. Complete the lab report sheet. Your instructor will provide you with (a) the conversion factor so that length of Mg (cm) can be converted into mmol Mg and (b) the density and molarity of the HCl solution so that 1.50 g HCl(aq) can be converted into mmol HCl.

Disposal of hydrogen samples

Unwanted hydrogen samples can be safely discharged into the room.

Clean-up and storage

At the end of the experiments, clean all syringe parts (including the diaphragm), caps and tubing with soap and water. Rinse all parts with water. Be careful with the small parts because they can easily be lost down the drain. Store plunger out of barrel.

Laboratory Report

Trial I

Length of Mg ribbon used:

Mass of acid used:

Volume of hydrogen calculation:

Initial syringe readings:

Rubber seal (mL): Solution (mL): Volume air (mL):

Final syringe readings:

Rubber seal (mL): Solution (mL): Volume air (mL):

Volume of hydrogen collected (mL):

Trial II (identical to Trial I)

[1] http://mattson.creighton.edu/LR/index.html

Questions

1. Add your data points to the graph being prepared on the chalkboard (or follow the data collection procedures given by your teacher). Do your results seam reasonable? If not, check your calculations carefully.
2. Determine the number of mmoles of HCl used each time.
3. Convert your lengths of Mg into moles and mmoles of Mg.
4. Considering the reaction stoichiometry, how many mmoles of Mg are needed to react with the HCl used?
5. Use the answer to Question 4 to determine what length of Mg represents exactly the stoichiometric amount.
6. Inspect the class graph to determine if the value determined in Question 5 seems reasonable.

SUMMARY OF MATERIALS AND CHEMICALS NEEDED FOR CHAPTER 10. THE LIMITING REAGENT.

Equipment required

Item	For 5 pairs	For 10 pairs
Microscale Gas Chemistry Kit (Chapter 1)	5	10
balance	2 - 3	3 - 5
disposable pipet	5	10

Materials required

Item	For 5 pairs	For 10 pairs
ruler to measure Mg	5	10
scissors	5	10

Chemicals required

Item	For 5 pairs	For 10 pairs
Mg ribbon	40 cm	80 cm
2 M HCl(aq)	25 mL	50 mL

