Micro Mole Rockets
Hydrogen and Oxygen Mole Ratio
As adapted from Flinn ChemTopic- Labs - Molar Relationships & Stoichiometry

Introduction
The combustion reaction of hydrogen and oxygen is used to produce the explosive energy needed to power the space shuttle. The reaction is also being engineered to serve as a source of continuous energy for fuel cells in electric vehicles. What factors determine the explosiveness of the reaction of hydrogen with oxygen? In this lab, we will generate microscale quantities of hydrogen and oxygen and test their explosive nature, first separately, then in mixtures of various proportions. The goal-to find the most "powerful" gas mixture and use it to launch a rocket across the room!

Concepts
- Mole ratio
- Stoichiometry
- Combustion
- Limiting reactants

Background
Hydrogen, the most abundant element in the universe, is a colorless, odorless gas. It is combustible, which means that it burns quite readily. Hydrogen gas is conveniently generated in the lab by the reaction of zinc metal with hydrochloric acid.

Oxygen, the most abundant element on Earth, is also a colorless, odorless gas. Oxygen gas supports combustion, that is, it must be present for combustible materials to burn. Small scale quantities of oxygen gas are conveniently generated in the lab by the decomposition of hydrogen peroxide. The decomposition reaction of hydrogen peroxide requires a catalyst to initiate the reaction. A variety of different catalysts, including manganese, manganese dioxide, potassium iodide, and even yeast, have been used in this reaction. In this lab, yeast will be used to catalyze the decomposition of hydrogen peroxide and generate oxygen gas.

Experiment Overview
The purpose of this experiment is to generate hydrogen and oxygen and determine the optimum ratio for their combustion reaction to give water. The optimum ratio will be used to calculate the mole ratio for the reaction of hydrogen and oxygen in a balanced chemical equation. The concept of limiting reactants will be used to explain the results obtained with various hydrogen/oxygen gas mixtures.

Pre-Lab Questions
1. Write the balanced chemical equation for the single-replacement reaction of zinc and hydrochloric acid to generate hydrogen gas. What is the total amount of hydrogen gas that could be produced in liters with 5.00 grams of zinc? You can assume you have an unlimited amount of hydrochloric acid?

2. Write the balanced chemical equation for the yeast-catalyzed decomposition of hydrogen peroxide to generate oxygen gas and water. Note: Since a catalyst is not really a -reactant or product, it is usually written over the arrow. What is the total amount of oxygen gas that will be produced in liters if you started with 15 grams of hydrogen peroxide?

Materials

Hydrochloric acid, HCI, 3 M, 15 mL
Hydrogen peroxide, H_20_2, 3%, 15 ml
Yeast suspension, 2%, 5 ml
Zinc, mossy, Zn, about 5 g
Graduated cylinder, 10-ml
Marker (permanent pen)
One-hole rubber stoppers, to fit test tubes, 2
Test tube rack
Test tubes, small, 2
Pipets, Beral-type, graduated, 1
Scoopula

Safety Precautions

Hydrochloric acid is toxic by ingestion and inhalation and is corrosive to skin and eyes. Hydrogen peroxide is a skin and eye irritant. Avoid contact of all chemicals with skin and eyes and notify your teacher immediately in the case of a spill. Wear chemical splash goggles and chemical-resistant gloves and apron. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Construct Gas Generators

1. The gas generators consist of a small test tube, a rubber stopper, a gas delivery tube, and a gas collection bulb. See Figure 1a.

2. Cut four Beral-type pipets as shown in Figure 1b to obtain four gas-collecting bulbs and four gas-delivery tubes. Discard the middle part of the pipet stem. It is important that the pipet bulbs have similar lengths. Trim the lengths so they are equal.

3. Place the gas delivery tube ends into the tops of rubber stoppers as shown in Figure 1a

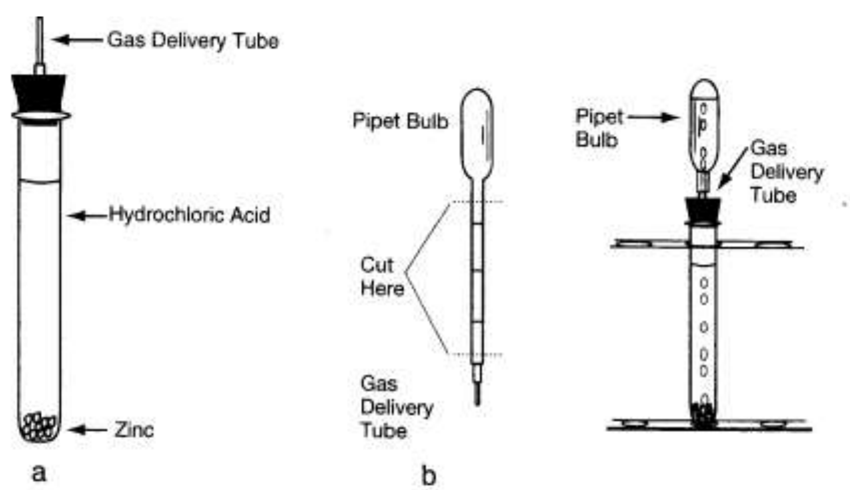

Figure 1. Constructing a Gas Generator

4. Prepare a hydrogen gas generator by placing about four pieces of mossy zinc into the bottom of a small test tube marked “HCl”.

5. Prepare an oxygen gas generator by placing about 2 mL of yeast suspension into the bottom of the other small test tube marked “H_2O_2”.

6. Set the test tubes in a test tube rack.

Calibrate Gas Collection Bulbs

7. Fill a 250-ml, beaker about one-half full with tap water.

8. Immerse one of the cut-off pipet bulbs under water. Fill the bulb completely with water and remove it from the beaker.

9. Squeeze the water out of the pipet bulb into an empty graduated cylinder to measure the total volume (V) of water in the bulb.

10. Divide the pipet bulb into six, equal-volume increments by following steps 11-12.

11, Refill the pipet bulb, then squeeze out one-sixth of the total volume (V/6) into an empty graduated cylinder. Release the squeeze and use a permanent pen to mark the water-level on the side of the bulb.

12. Squeeze out a second V/6 volume, mark the level again, and repeat for the remainder of the water. This should serve to divide the bulb into six, equal-volume increments.

13. Once the first pipet bulb has been calibrated, the rest can be copied to save time. Simply rest a wood splint across the bulb, with the end of the splint flush with the end of the bulb, and mark off the splint at the same places that the bulb is marked. Then use the splint as a template to mark the rest of the bulbs.

Collect and Test Hydrogen and Oxygen Gases

14. Add 3 M hydrochloric acid to the mossy zinc in one of the hydrogen gas generators until the liquid level is about 1 cm below the mouth of the test tube. Cap the tube with the gas delivery stopper. *Note:* Wait about one minute before proceeding to step 15. This will allow time for the air to be purged from the test tube.

15. Completely fill a marked pipet bulb with water and place the bulb over the gas delivery tube to collect the gas by water displacement. As the bubbles enter the pipet bulb, the water will flow out of the bulb and down the sides of the test tube to the paper towels.

16. As soon as the bulb is filled with hydrogen, remove it from the gas delivery tube and place a finger over the mouth of the bulb to prevent the collected gas from leaking out.

17. Hold the gas bulb so the opening is pointed upward and have a classmate quickly strike a match over the opening of the bulb. After the match is lit, let the hydrogen gas escape into the flame. Record the results of this "pop-test" in the data table.

18. Add 3% hydrogen peroxide to the yeast suspension in one of the oxygen gas generators until the liquid level is about I cm below the mouth of the test tube. Cap the tube with the gas delivery stopper. *Note:* Wait about one minute before proceeding to step 19.

19. Repeat steps 15-17 to collect *oxygen gas* and test its properties. Record the results of its "pop-test" in the data table.

Collect and Test Oxygen/Hydrogen Gas Mixtures

20. Completely fill a marked pipet bulb with water and place it over the oxygen gas generator to collect oxygen.

21. When the bulb is one-sixth full of gas, quickly remove it from the oxygen tube and place it over the hydrogen gas generator.

22. Continue collecting hydrogen until the bulb is filled with gas. This bulb should contain a 1:5 ratio of oxygen and hydrogen.

23. Remove the bulb, cap it with a finger, and determine its relative loudness in the "poptest," as described above for hydrogen and oxygen. Develop a scale to describe how loud this mixture is compared to pure hydrogen and pure oxygen. Record the result in the data table.

24. Repeat steps 20-23 to collect and test other volume ratios (2:4, 3:3, 4:2, 5:1) of oxygen and hydrogen (see the data table). Always collect oxygen first, followed by hydrogen. Record all results in the data table.

25. Rank the gas mixtures on a scale from zero to 10 to describe their relative loudness in the "pop-test." Let the most "explosive" mixture be a 10, the least reactive gas a zero.

26. Collect various gas mixtures as many times as necessary to determine the optimum ratio of oxygen and hydrogen for combustion. *Note:* The pop-test is obviously subjective, but by repeating it several times with each possible mixture, it should be possible to determine the most explosive (loudest) gas mixture.

27. When the reaction in one of the gas generators slows down so much that it is no longer useful, fill the second gas generating tube with liquid (either HCl or H_2O_2, as appropriate) and use it instead.

Rocket Launches!

28. Collect the optimum (loudest) gas mixture one more time, and bring it to the instructor. Your instructor will place the bulb on a rocket launch pad and ignite it with a piezo sparker. How far does the micro mole rocket travel?

29. Collect the optimum mixture again, but this time leave about 1 ml, of water in the bulb. With your instructor's consent, launch the micro mole rocket.

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Period ____ Date ___/___/___

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M I C R O   M O L E   R O C K E T S

Data Table

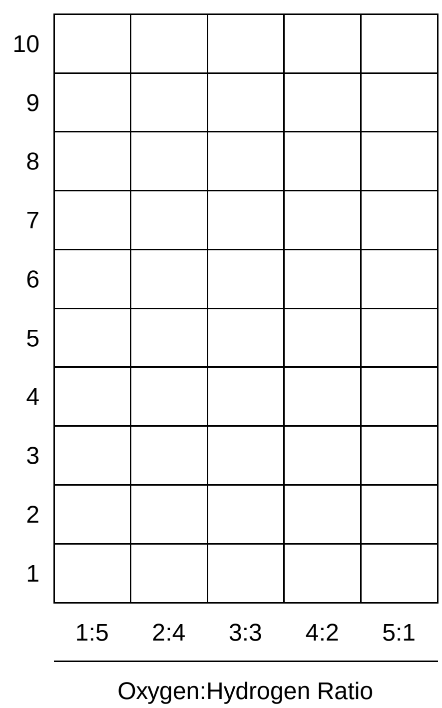
"Pop-test" Properties of H_2 gas alone	
"Pop-test" Properties of O_2 gas alone	

Pop-test Properties of O_2:H_2 Gas Mixtures

Oxygen:Hydrogen Mole Ratio	Pop Test Results
1:5	
2:4	
3:3	
4:2	
5:1	

Post-Lab Questions

1. In the space provided construct a bar graph to illustrate the pop test results with the various oxygen/hydrogen gas mixtures.



2. Explain the relative loudness of pure oxygen and pure hydrogen in the pop-test.

3. Write a balanced chemical equation for the combustion reaction of hydrogen and oxygen to give water.

When the reactants in a mixture are present in the exact mole ratio given by the balanced chemical equation, all of the reactants should be used up when the reaction is over. There will be no "leftover" reactants. However, if one of the reactants is present in an amount greater than its mole ratio, then that reactant cannot react completely, and some of it will be left over at the end of the reaction.

4. Use the mole ratio of hydrogen to oxygen to determine what happens when various hydrogen/oxygen gas mixtures are allowed to burn. Complete the following table to indicate which reactant (H_2 or O_2) is present in excess, and how much of it will be left over after the combustion reaction is complete. *Note:* The second one has been completed as an example.

Parts H_2	6	5	4	3	2	1	0
Parts O_2	0	1	2	3	4	5	6
Which reactant is present in excess?		**H_2**					
How much of that reactant is left over?		3					

5. a) Which oxygen/hydrogen gas mixture produced the most explosive mixture?
Provide evidence to support your claim.

b) Explain why this mixture was most explosive.

6. Why do the hydrogen and oxygen gas mixtures in the collection bulb not react as soon as they are collected? Note: Consider the role of the match and the properties of gas molecules at room temperature.