Micro Rocket Lab

Hydrogen and Oxygen Mole Ratio

Introduction

"It will free man from the remaining chains, the chains of gravity which still tie him to his planet."
—Wernher von Braun

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
- Combustion
- Stoichiometry
- 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 microscale 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 (Together in class)

1. Write the balanced chemical equation for the single-replacement reaction of zinc and hydrochloric acid to generate hydrogen gas.

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.

Materials

Hydrochloric acid, HCl, 3 M, 15 mL
Hydrogen peroxide, H_2O_2, 3%, 15 mL
Yeast suspension, 2%, 5 mL
Zinc, mossy, Zn, about 5 g
Beaker, 250-mL
Graduated cylinder, 10-mL
Marker (permanent pen)
One-hole rubber stoppers, to fit test tubes, 4
Paper towels
Piezo sparker (optional)
Pipets, Beral-type, graduated, 4
Safety matches
Spatula
Test tube rack
Test tubes, medium, 4
Wood splint

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. Microscale gas generators consist of a small test tube, a rubber stopper, a gas delivery tube, and a gas collection bulb. See Figure 1a.
2. The Beral-type pipets have been cut for you as shown in Figure 1b to obtain the gas-collecting bulbs and gas-delivery tubes. The middle part of the pipet stems was discarded.
3. The gas delivery tubes have been placed into the tops of rubber stoppers as shown in Figure 1a. The narrow end of the gas delivery tube should be above the stopper.

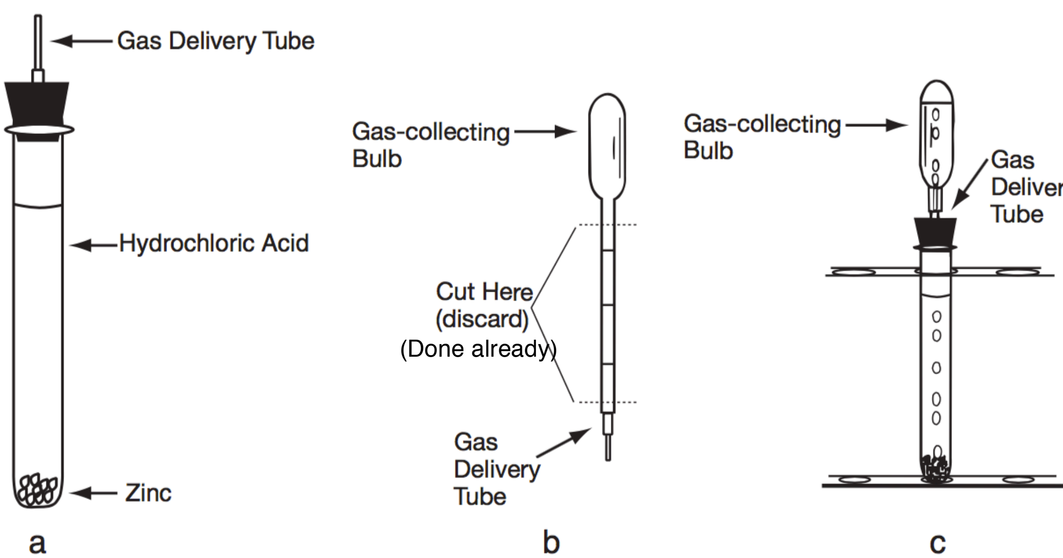

Figure 1. Constructing a Gas Generator

4. Prepare two hydrogen gas generators by placing about four pieces of mossy zinc into the bottom of two small test tubes.
5. Prepare two oxygen gas generators by placing about 2 mL of yeast suspension into the bottom of the other two small test tubes.
6. Set the test tubes in a test tube rack and place the rack into a pan to catch the spillage. Monitor water level in pan and empty as needed.

Collect and Test Hydrogen and Oxygen Gases

7. 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 8. This will allow time for the air to be purged from the test tube. See Figure 1a.
8. Completely fill one pre-calibrated pipet bulb with water and place the bulb over the gas delivery tube to collect hydrogen 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 into the pan. (Figure 1c.)
9. As soon as the bulb is filled with hydrogen, remove it from the gas delivery tube and immediately place a finger over the mouth of the bulb to prevent the collected gas from leaking out.
10. Hold the gas bulb so the opening is pointed upward and have your partner hold a lit splint over the opening of the bulb. After the match is lit, remove finger and squeeze the bulb to let the hydrogen gas escape into the flame. Record the volume of this "pop-test" in the data table.
11. Add 3% hydrogen peroxide to the yeast suspension in one of the oxygen 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 12.
12. Repeat steps 8–10 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

13. Completely fill a marked pipet bulb with water and place it over the oxygen gas generator to collect oxygen.
14. When the bulb is one-sixth full of gas, quickly remove it from the oxygen tube and place it over the hydrogen gas generator.
15. Continue collecting hydrogen until the bulb is filled with gas. This bulb should contain a 1:5 ratio of oxygen and hydrogen.
16. Remove the bulb, cap it with a finger, and determine its relative loudness in the "pop-test," 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.
17. Repeat steps 13–16 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.
18. 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.
19. 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.
20. 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!

1. 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?
2. 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.