Combustion of Hydrogen

Properties of Hydrogen

Introduction

Demonstrate the properties of hydrogen gas by collecting the gas in a test tube or graduated cylinder and testing its combustion under different conditions. Is hydrogen more or less dense than air? How does the rate of mixing of hydrogen with air affect the rate of combustion? What are the products of combustion?

Concepts

- Properties of gases
- Density of gases
- Hydrogen
- Combustion

Materials

Candles, tealight, 4
Graduated cylinder, borosilicate glass, 1-L
Hydrogen gas generator or lecture bottle
Test tubes, Pyrex®, 20 mm × 150 mm, 6

Safety Precautions

Hydrogen gas is flammable and forms explosive mixtures with air. Follow all safety precautions discussed in the presentation, especially the need to make sure the test tubes or graduated cylinder are completely full of hydrogen gas. Use only Pyrex® or borosilicate-glass glassware and check for cracks or chips before use. Wear chemical splash goggles and chemical-resistant gloves or apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Invert two test tubes and fill them with hydrogen gas by downward displacement of air. Keep each test tube inverted (open end down) until it is time to use the tubes.
2. Ignite one of the tubes of gas over a candle flame and use this tube to ignite the second tube filled with hydrogen:
   - Hold the first test tube mouth down over the candle flame.
   - Immediately move away from the candle flame.
   - Hold the second test tube, mouth up, under the first test tube so that the two tubes are in a straight line, but at an angle of 60° with the floor.
3. Observe that the gas in the second tube is ignited. The "pop" in the first tube is very quiet, and in the second tube is considerably louder. Repeat this part of the experiment once or twice in order for the students to clearly observe the difference in the two reactions.
4. Refill the test tubes with hydrogen gas and repeat the process, but this time hold the first test tube mouth up for a few seconds before igniting the gas. In this case the gas in the first tube pops loudly, and the gas in the second tube does not ignite at all.
5. Ignite the remaining gas in the second tube over the candle flame so that the students will see that there is still a combustible gas in the tube.
6. Collect a large test tube or cylinder of hydrogen gas. *Caution: Hold the graduated cylinder upside down and fill the cylinder by the downward displacement of air. Make sure that the cylinder is completely full of the hydrogen gas.* Keep the cylinder inverted until ready to ignite. Do not allow air to enter the cylinder before igniting the hydrogen.
7. Ask the students to predict whether the gas will burn quietly or with a loud report. Students are usually certain that the report will be loud, and surprised that anyone would even attempt to do this demonstration!
8. Turn the room lights off, ignite the gas by holding the cylinder (open end down) over a candle flame. Immediately invert the cylinder (with the burning gas) and hold the cylinder upright as if holding a torch. Pure hydrogen gas burns

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slowly and quietly.

9. The effect is interesting and useful. When the room lights are turned back on, observe a trail of liquid (clear and colorless) flowing down into the cylinder.
10. Discuss the identity of the liquid and why the hydrogen gas did not explode. What is the liquid? How can it be identified? Why did the gas not explode?

Discussion

Hydrogen gas was first studied in 1766 by Henry Cavendish, who isolated the "inflammable air" produced in the reaction of metals with acids. The true chemical nature of this gas was not understood until about 20 years later, when Lavoisier correctly explained the reaction that occurs when hydrogen combines with oxygen to make water. Lavoisier named the gas hydrogen from the Greek words meaning "water-former." Hydrogen is the most abundant element in the universe—it is the "fuel" that makes our sun and stars burn brightly. Hydrogen is also a major component of the Earth's crust and the environment. Despite its abundance, however, very little hydrogen is found on Earth in the free state as hydrogen gas. This is because hydrogen is easily oxidized and combines readily with many other elements, including carbon, oxygen, and nitrogen. Most of the hydrogen on Earth is found in water and in petroleum-based products such as oil and gas.

Hydrogen is a flammable gas that is less dense than air and has very low solubility in water. The combustion reaction of hydrogen and oxygen to make water is highly exothermic, and hydrogen gas forms an explosive 2:1 mixture with oxygen. In the absence of mixing with air, however, hydrogen produces only a very faint pop sound when it is ignited. This is the sound heard when the hydrogen in the first inverted test tube is placed over the candle flame—there is very little air surrounding the hydrogen inside the tube. The second test tube gives a much louder reaction as the less dense hydrogen gas mixes with air and is then ignited.

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
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, interactions of energy and matter
Content Standard G: History and Nature of Science, nature of scientific knowledge

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Combustion of Hydrogen* activity, presented by Irwin Talesnick, is available in *Properties of Hydrogen*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Combustion of Hydrogen* are available from Flinn Scientific, Inc.

Catalog No.	Description
LB1015	Hydrogen Gas, Lecture Bottle
LB1051	Lecture Bottle Control Valve, Brass
GP9090	Graduated Cylinder, Borosilicate Glass, 100 mL
GP6068	Test Tubes, Without Rims, Borosilicate Glass, 20 × 50 mm
C0192	Candles, Plumber's Candles, Pkg/14

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