Mini Rockets

Student Objective

The student:
- will observe and compare two gas-producing reactions
- will relate chemical concepts to observations of chemical reactions
- will infer a conclusion and evaluate methods

Key Words:
activation energy
Avogadro's Law
exothermic reactions
limiting reagent
molar volume of a gas
propulsion
rocketry
stoichiometry

Materials:
- 1.0 M Hydrochloric Acid (HCl), approx. 50 mL per H2 generator
- 3% Hydrogen Peroxide (H_2O_2), approx. 50 mL per oxygen generator
- mossy zinc
- yeast water or 1.0 M Potassium Iodide (KI) solution
- 10 mL graduated cylinder
- tap water
- piezoelectric sparking unit (1 per group)
- tape measure

For generator unit (2 per group):
- vial with pop-off lid, such as empty film canisters
- nail
- petri dish half
- pipette bulb, calibrated (1 per group)
- hot glue gun and glue (or water-proof adhesive)

Time:
1 class period
Prep time:
60 minutes initial time, 30 minutes with already fabricated sparkers, generators, and calibrated rockets.

Background Information

The space shuttle uses liquid hydrogen and liquid oxygen for its three main engines. The hydrogen is the fuel and the oxygen is the oxidizer. Without either one the shuttle would not make it to outer space. Hydrogen and oxygen are two gases that react with each other in a very quick, exothermic manner. The explosiveness of this reaction is greatest when the hydrogen and oxygen are mixed in just the right proportion. Students will find combustion does not occur with hydrogen or oxygen individually. As well as showing the nature of the fuel used on the space shuttle, the student should also be able to realize the safe nature of hydrogen versus other fuel sources.

Safety

- Safety goggles and apron must be worn throughout this activity.
- Make sure students know the location of the eye wash station and emergency shower and how to use them prior to the experiment.
- Clean all chemical spills promptly. In case of a spill, use dampened paper towels to mop up the spill. Then rinse the towel in running water, wring it out until it is only damp, and put it in the trash.
- Remind students not to aim their rockets at other students.
- Monitor student use of the generators. Both gas-generating reactions release heat, thus building up pressure in the generator. If the pressure is too great, the container could explode. Due to this explosion risk, it is necessary to use containers with lids that can pop off and ensure the reaction rates are not too fast for the size of the container. This would include not adding too much solution to the canister and not adding too much catalyst (or zinc) to the gas-generating vessels.

Disposal

- You may want to have disposal containers for the spent solutions from the generators for use throughout the experiment (if you do this with several classes through the day.)
- The materials used to make oxygen may be washed down the sink, provided the school drains are connected to a sewer system with a treatment plant.
- The materials used to make hydrogen need to be combined. Filter to separate the zinc and rinse the zinc at least three times with water. Collect the acidic washings with the filtrate. After the rinsed zinc is dry, it may be saved for reuse. Neutralize the acid solution before flushing down the sink.
- Any other solutions generated may be flushed down the sink with water.

Procedure--Solution/Material Preparation

1. 3% hydrogen peroxide may be store-bought. It should be fresh.
2. Decide on your catalyst for the oxygen generator.
   - To prepare yeast water, dissolve one tablespoon of dry yeast in 100 mL of water.
   - To prepare 25 mL of 1.0 M KI solution, dissolve 0.42 g of KI in enough water to make 25 mL of solution.
3. To make calibrated pipette bulbs:
   - Cut the pipette near the graduation closest to the bulb trying to keep the cut straight.
   - Fill one bulb completely with water.
   - Once the bulb is filled, empty all the water into a 10 mL graduated cylinder and

record the volume.
- Empty the graduated cylinder and refill the bulb with water.
- Squeeze one-sixth of the volume from the bulb into the graduated cylinder. Using a permanent ink pen, mark the water level on the outside of the bulb.
- Squeeze out another sixth of the volume from the bulb into the graduated cylinder and mark the level again.
- Repeat for the remainder of the water.
- At this point, the calibrated bulb can be used as a guide to mark additional bulbs. Using a wood splint or sheet of paper, line the bulb up with the edge of the paper or splint and mark it off at the same places the bulb is marked. Use this as the template for calibrating the rest of the bulbs. Once calibrated, the bulbs can be reused.

4. To make gas generators:
    - Cut the tapered tip off a graduated pipette. This works best if the pipette is cut on the stem portion just above the tapered tip. By cutting in this location, a relatively airtight seal can be made.
    - Punch a hole in the center of a film canister lid.
    - Slip the nozzle into the hole until the flared section wedges into the hole on the inside portion of the lid.
    - Repeat for as many generators as you need. (You will also need one film canister for each generator.)

    *Empty film canisters are recommended because you can effectively punch the holes without any special equipment and the film canisters can be picked up from photo-developing shops. Any plastic container can be used as long as the lid is a snap-on, in case of too much pressure, and it can safely handle the 1.0 M HCl.
5. Decide on a launching area for the rockets and mark it appropriately.

To make your own Piezoelectric sparking units

Materials**:**

- piezoelectric butane charcoal/ fireplace lighter, 1 per sparking unit
- vinyl electric tape
- film canister cap, 1 per sparking unit
- hot glue gun and glue (or water-proof adhesive)
- 24 AWG speaker hook-up wire (solid , not stranded: Radio Shack #278-1509), 10 cm per sparking unit
- wire strippers

Constructing the piezoelectric sparkers:

- Using scissors, split one end of a 10 cm length of speaker wire down the center for a distance of 3-4 cm.
- Strip the last 2 cm of insulation from both sides of the split portion.
- Using a nail, push the nail through the center of the film canister lid. It should not take any special effort to push through the nail.
- Slide the wire through the canister lid so the bottom of the lid will face away from the sparker and the split portion of wire will face towards the sparker. The

canister lid acts as both a splash guard and a launch support pad.

- Secure the lid in place about 4 cm from the unsplit end of the wire with hot glue or other waterproof adhesive.
- Slide one of the stripped portions into the small hole in the nozzle of the lighter until the insulation is against the nozzle. (The Scripto Aim 'n Flame II and the Bic Sure Start were both used successfully. If the Bic Sure Start is used, the tiny spring in the nozzle needs to be removed so the wire will fit.)
- Lay the other stripped portion along the outside of the lighter and secure it in place with a few wrappings of electrical tape.
- Test the hot glue seal and the sparker. The seal needs to be watertight and a "tiny" spark needs to flash across the end of the wire. If you can't see the spark, try to reposition the sparker or try it in the dark. If there is no spark, there could be a short. Check to make sure the only wire touching the metal part of the lighter is the taped portion.

Procedure–during experiment

There are portions of this lab that allow for the student to make decisions. The laboratory manual is written to allow for the choices. You may decide to be more specific; those areas will be included in this section. The more choices the students have the more time the experiment may take due to pre-lab discussion among the groups and/or the difference in the procedures used by the students.

1. The concentrations of the solutions are recommendations. They worked well, but you may decide to change the concentrations depending on your needs.
2. Use 2-3 pieces of mossy zinc in the generator depending on the size of the generator.
3. If yeast water is used as the catalyst, 10-20 drops is sufficient. If KI is used, 2-3 drops are all that is needed.
4. Optimum fill for each generator is about 10 cm from the top of the generator. If there is too much solution added, the generator may explode. If enough solution is not added, the bulb may have more air than hydrogen or oxygen resulting in incorrect data and/or the students might be constantly refilling the generators.
5. Remind students about making and recording observations throughout the experiment.
6. Students could make up their own data table. An example, with sample data, is shown below.

Sample data table:

Parts H_2	0	1	2	3	4	5	6
Parts O_2	6	5	4	3	2	1	0
Relative Loudness	0	2	4	7	10	7	0

Since the bulbs are graduated in sixths, the proportions can be measured using parts of hydrogen to parts of oxygen from zero parts hydrogen to six parts hydrogen. Because these numbers are relative, the data may be scattered. This could be a good place to pool class data and have students plot their data versus the class' data and expound on why there's a difference (or not).

Related Research

1. Once the optimum ratio is determined and rockets have been tested, the students may brainstorm ways to make their rockets go farther and then test their methods. The students could then write about what they tried and which methods worked best. This could also be a class competition.
2. Since the best ratio of gases has been found, the angle of the launch, the mass of the rocket, and the shape of the rocket all play a part in determining the distance the rocket will travel. Under ideal, frictionless conditions, an angle of 45^{O} is best, but with the air resistance in the classroom, something less than 45^{O} should be more effective. A rocket with a larger mass will be impacted less by air resistance, but will have a greater amount of inertia to overcome. Streamlining the rocket (nose cone and tail fins) can also increase the flight distance. Leaving some water in the bulb can increase the distance because the water gives the expanding gases something to push against.
3. Launch a commercially made model hydrogen rocket. Discuss the similarities and differences with the mini rockets and the two fuel mixtures.

Internet Sites

http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/et.html

Description of the external tank system for the space shuttle

http://science.howstuffworks.com/space-shuttle2.htm

Description of the space shuttle fuel system

Mini Rockets

			.1	.2	.3	.4	.5	.6	.7	.8
Nature of Matter	Standard 1	SC.A.1.4-				X				
	Standard 2	SC.A.2.4-								
Energy	Standard 1	SC.B.1.4-					X			
	Standard 2	SC.B.2.4-								
The Nature of Science	Standard 1	SC.H.1.4-								
	Standard 2	SC.H.2.4-								
	Standard 3	SC.H.3.4	X	X						
Language Arts benchmarks: LA.B.2.4.1										
Mathematics benchmarks: MA.A.4.4.1, MA.E.1.4.1										

Benchmark SC.A.1.4.4 - The student experiments and determines that the rates of reaction among atoms and molecules depend on the concentration, pressure, and temperature of the reactants and the presence or absence of catalysts.

Benchmark SC.B.1.4.5 - The student knows that each source of energy presents advantages and disadvantages to its use in society.

Benchmark SC.H.3.4.1 - The student knows that performance testing is often conducted using small-scale models, computer simulations, or analogous systems to reduce the chance of system failure.

Benchmark SC.H.3.4.2 - The student knows that technological problems often create a demand for new scientific knowledge and that new technologies make it possible for scientists to extend their research in a way that advances science.

Benchmark LA.B.2.4.1 - The student writes text, notes, outlines, comments, and observations that demonstrate comprehension and synthesis of content, processes, and experiences from a variety of media.

Benchmark MA.A.4.4.1 - The student uses estimation strategies in complex situations to predict results and to check the reasonableness of results.

Benchmark MA.E.1.4.1 - The student interprets data that has been collected, organized, and displayed in charts, tables, and plots.

Mini Rockets

activation energy - the minimum energy required to form the reactants into an activated complex

Avogadro's Law - equal volumes of the gases at the same temperature and pressure contain equal numbers of molecules

exothermic reactions - a chemical reaction or physical change that produces heat

limiting reagent - the reactant that limits the amounts of the other reactants that can combine, and the amount of product that can form, in a chemical reaction

molar volume of gas - the volume occupied by one mole of a gas

propulsion - movement of a body produced by the forward directed forces of the reaction resulting from the rearward discharge of a fluid

rocketry - the branch of engineering science that studies rocket design and operation

stoichiometry - the study of the quantitative, or measurable, relationships that exist in chemical formulas and chemical reactions

Mini Rockets

1. Answers will vary.
2. Answers will vary.
3. Answers will vary but should include the knowledge of the approximate nature of their measuring techniques. Solutions should include ways of making the measuring of the individual gases more accurate, measuring more accurately the level of sound or heat produced, or averaging results together to minimize individual discrepancies.
4. Oxygen generator: $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2\ (g)$
   Hydrogen generator: $2HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$
5. The optimum proportion for maximum loudness is 2 parts O_2 to 4 parts H_2. This is the same as the 1:2 mole ratio in the balanced equation. In the 2:4 mixture, all the reactants are consumed, whereas in all other combinations, one of the reactants is a limiting reactant. $2H_2(g) + O_2(g) \rightarrow 2H_2O(g) + \text{heat}$
6. Oxygen and hydrogen molecules collide as they mix in the bulb but do not have the necessary energy to react (activation energy). The spark supplies that energy.
7. Answers may vary. They may include: filling the bulb entirely with water, mostly filling the generator with solution, allowing the reactions to occur for some amount of time before placing the bulb on the generator nozzle, etc.
8. The 2:4 (1:2) ratio found in this experiment is the mole ratio. Students need to calculate the mass ratio based on this mole ratio. When applied to the 700,000. kg of fuel, the mass of hydrogen should be 78,330 kg and the mass of oxygen should be 621,670 kg.

Mini Rockets

Hydrogen and oxygen are two gases that react with each other in a very quick, exothermic manner. The explosiveness of this reaction is greatest when the hydrogen and oxygen are mixed in just the right proportion. In this lab, you are generating hydrogen and oxygen and testing their explosive nature. Your goal is to find the best mixture.

Safety

- Safety goggles and apron must be worn throughout this activity.
- Notify your teacher if there is a chemical spill. Spills should be cleaned up promptly according to your teacher's instructions.
- Do not touch any chemicals. Do not taste any chemicals. Never return any chemicals to their original containers.
- Know the location of the emergency shower and eyewash station and the procedure for using them. If you get any chemicals in your eyes, immediately begin flushing your eyes while calling to your teacher.

Cleanup and Disposal

- Follow your teacher's instructions regarding cleanup of your station and disposal of any chemicals.
- Wash your hands thoroughly with soap and water after all your work is finished.

Procedure

1. Get two micro-generators. Make sure they are labeled, one for oxygen and one for hydrogen. Check to make sure both generator's caps have nozzles and the nozzles are not plugged in any way.
2. Fill one petri dish with water. This serves as a recycling water supply during the experiment.
3. Fill the calibrated pipette bulb entirely with water from the petri dish. You may want to practice this before you begin the rest of the experiment. One way to do this is to squeeze the bulb tightly, invert it into the petri dish, and draw up as much water as possible. Then hold the bulb mouth upward and squeeze out the remaining air. Without letting go of the bulb, invert it again and draw up more water. Continue squeezing out the remaining air and filling with water until there isn't any air left in the bulb.
4. In the hydrogen generator, place 2-3 pieces of mossy zinc. Carefully add 1.0 M HCl. Replace the lid and place in the petri dish. Optimum fill for each generator is about 10 cm from the top of the generator.

5. In the oxygen generator, add 3% H_2O_2. Add the catalyst provided by your teacher. Replace the lid and place in the petri dish.
6. To collect a sample of gas by water displacement, fill the bulb completely with water from the petri dish, and place it mouth downward over the nozzle of a generator. You want the fit to be loose between the bulb and the nozzle so water can leak out as gas is being generated.
7. As soon as the bulb is filled with gas, remove it from the nozzle and place a finger over the mouth of the bulb to prevent the gas from escaping.
8. Test the gas by inserting the wire tip of the piezoelectric sparker into the bulb and pulling the trigger. **Make sure you hold the bulb securely when testing–do not let it fly**.
9. Refill the bulb with water and collect another bulb of gas trying different proportions of oxygen and hydrogen. To do this, first fill the bulb to a specific proportion with one gas, and then transfer to the other generator for the remaining amount. Since the bulbs are graduated in sixths, the proportions can be measured using parts of hydrogen to parts of oxygen from zero parts hydrogen to six parts hydrogen.

   Note: If either generator reaction slows down so that it takes more than one minute to fill the bulb with gas, lift off the bulb, remove the lid, decant off the remaining liquid into the appropriate waste container, place fresh solution (and catalyst for the oxygen generator) from the appropriate container, replace the lid, and resume collecting gas.
10. Determine the optimum combination of hydrogen and oxygen. Record your observations below:

11. Once you have determined the optimum mixture of the two gases, collect it again. Take the bulb to the launch area. Use the piezoelectric sparking unit to launch your bulb. This time do not hold onto the bulb. Make sure nobody is in the line of fire.

Mini Rockets

1. How did you test for the optimum mixture of the two gases? How did you show your data?

2. How did you decide how much solution to place in each generator?

3. How could you increase the accuracy of your data?

4. Write balanced equations for the reactions taking place in each gas generator.

5. What was the optimum proportion of the two gases? Why? (include a balanced equation for the reaction)

6. Why don't oxygen and hydrogen react as soon as they mix in the pipette bulb?

7. What lab techniques were used to ensure the gas collecting bulb only contained the desired gas?

8. The space shuttle carries 700,000. kg of fuel for its three main engines. These engines use liquid hydrogen and liquid oxygen. Based on your results from this experiment, what should be the mass of liquid hydrogen? How much liquid oxygen would be necessary?